Color Atlas of Dental Medicine

Editors:
Klaus H. Rateitschak
Herbert F. Wolf

Aesthetic Dentistry

Josef Schmidseder

Thiem

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Preface

At a recent meeting of the American Academy of Esthetic Dentistry a survey questioned whether aesthetic treatment methods were ethical. The situation typical for that time was used as basis for the survey: "Let's assume that the patient is completely healthy and there are no biological or physical reasons for a therapeutic intervention. Do you, given such circumstances, consider treatments like ceramic veneers, changing tooth color and tooth shape through bonding procedures, bleaching, orthognatic surgery, plastic surgery of the nose, or orthodontic treatments in adults ethical, and would you offer your patients such treatments?"

The answers to the questionnaire were rated on a scale of 1 to 100 with "1" being an unethical treatment and °100" an ethical treatment. The result was quite remarkable because it showed a high acceptance of all but two aesthetic measures (substitution of direct or indirect composites for amalgam restoration):

Closing a diastema using bonding	100
Changing tooth color and shape using bonding	95
Ceramic veneers	91
Office bleaching	94
Home bleaching	85
Orthodontic treatment in adults	97
Replacing amalgam restorations using direct composites	52
Replacing amalgam restorations using composite inlays	58
Replacing amalgam restorations using ceramic inlays	70
Gingivoplasty entirely for aesthetic reasons	94
Surgical correction of the chin	97
Orthognatic surgery	90
Surgical correction of the nose	77
Face lifting	86

In view of these results, one is tempted to raise the counter question: Is aesthetic dentistry still considered a medical discipline? Are we moving too far away from the core objectives of dentistry when we apply novel treatment options? Maybe we are slowly reverting toward the status of being barbers? It is well known that the former barbers turned toward cosmetics after they had abandoned dealing with dental problems.

Of course, a treatment that primarily creates an aesthetic improvement is not essential. By the same token, are flowers in an apartment, pictures on the walls, or new clothes essential? Obviously not! However, if you are surrounded by pleasant things or you are fulfilling a wish or a dream, this makes you feel good. Well-being is a crucial part of being healthy. From this point of view, the opinion of many is that aesthetic dentistry is essential!

Health, arguably, is mankind's most precious gift. However, when we are healthy we like to rate our looks very highly. Only, beauty is a phenomenon that cannot be measured. The following example needs no further explanation: In 1996, the people in Germany spent approximately 10 billion dollars on cosmetics. This is roughly equivalent to the amount of money the German dental insurance system paid for dental services. For this reason-and based on my own experience-I do not believe what I am frequently told by my colleagues, which is: "My patients are not willing to spend money to make their teeth more beautiful!"

In my humble opinion, the real reason for the skeptical attitude resides mainly in dental education. In many countries, dental education still focuses on teaching students how to relieve patients from pain, how to replace lost tooth structure, and how to stop further tooth destruction. Furthermore, students must fabricate a full denture during their initial preclinical studies. In my opinion, this is comparable to having a medical student attend a funeral as the initial requirement of their education! There is no doubt that such a therapy-oriented training significantly affects practical thinking.

It is no surprise that in many of my seminars colleagues frequently complain that they are unhappy in their job. Those dentists who only treat caries and practice at the level of their dental education must feel bored by their job!

Please, reassess your personal situation and take a more progressive stance! The history of aesthetic dentistry is very young. It is only since the introduction of the new adhesive techniques a few decades ago that anterior and lateral teeth could be restored successfully with thin ceramic veneers, and that tooth-colored composite fillings could be placed. Today, any restorations can be bonded with almost insoluble cements (resin-reinforced glass ionomer cements and composite cements).

This atlas shows the possibilities of aesthetic dentistry. As already mentioned, many of the methods presented here are not performed for the treatment or prevention of disease. This atlas deals exclusively with dental aesthetics and the positive effects resulting from its application, which contributes decisively to the well-being of the patient. Today's patients not only expect us to provide them with healthy teeth, a healthy periodontium, and an undisturbed neuromuscular function; many also desire beautiful teeth.

Fortunately, there will always be a sufficient number of dentists who will provide basic therapeutic services. Therefore, I would recommend all readers of this atlas to free time in your schedule that will allow you to offer dental services that are truly desirable.

However, the services must be offered in a novel way and must be actively sold. A dynamic internal and external marketing concept is part of this new dentistry. We don't need product marketing, but we do need promotion of services.

In short, we, the dentists, also sell beauty as a service. Beauty is essential for the general well-being and it boosts self esteem. Beauty can enhance the professional career of the patient. A beautiful smile may be a decisive factor during the critical moments of a first meeting. The dental product-a crown or a veneer-is nothing but a stepping-stone to success. Our marketing effort must show the patients that we are concerned about their needs and have superb techniques available with which we can help them achieve their goals.

In a modern dental practice, the patient no longer is just a petitioner who seeks relief from pain-the patient is your client. The patient selects the treatment modality, and we, the dentists, deliver the service as requested. The patient can decide freely between amalgam, gold, composite, or ceramics as the material of choice for a posterior tooth restoration, and between several processing methods for its fabrication. The patient can choose between a clasp-retained denture and a fixed prosthesis supported by implants. Last but not least, the patient can request having something done that will improve their looks.

I hope you will enjoy reading this book and that you will come up with many new ideas whilst doing so.

JosefSchmidseder

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Aesthetic dentistry looks at conventional dentistry from many different angles. Since it was not possible for me to cover all aspects and include all sub-disciplines by myself, I would like to acknowledge the following authors who have contributed to this work.

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Evolution of Artificial Tooth Replacements From an Aesthetic Point of View

Even though people have been engaged in replacing missing teeth since a relatively early stage in history, the use of artificial teeth to make people more beautiful and for chewing food was for a long time a neglected and unsuccessful undertaking. We know from Etruscan grave findings in the region of modern-day Tuscany that tooth replacements were worn as early as 700 BC. The Greeks and Phoenicians fastened loose and artificial teeth to neighboring teeth by means of gold wire (Woodforde 1869).

However, it was only in the 20th century that the development of artificial tooth replacement reached such a stage of perfection that permitted the user to openly laugh and to chew food without any problems. Approximately 100 years ago, artificial teeth were still so unreliable that they generally had to be taken out before meals. Unlike today, it was considered inappropriate in those days to talk about dental problems.

1 **Ladies with fans**
In his painting *Ladies with fans* Edgar Degas (1834-1917) illustrated the typical gestures of noble ladies, with which they tried elegantly to conceal their dental problems. Missing teeth were frequently hidden behind a fan, not only when smiling. Furthermore, a lady never ate in company, resulting in a saying that she lived only on love and air. In reality, the reason was missing teeth.

The Long Road to Individual, Functional Tooth Replacements

Today we can barely imagine the pain our ancestors must have suffered or how suffering from toothache must have influenced decision-making by leading historical figures. In those days, teeth were lost at a young age. Today, attempts are made to restore damaged teeth for as long as possible, while in the past dental treatment consisted of pulling the damaged, painful tooth. Since very few academically trained dentists were available, barbers (hairdressers) carried out *tooth extractions* as a side line. The average citizen was not aware of tooth replacements. However, certain possibilities for substituting teeth were available to the prosperous. The aesthetic value of *tooth replacements* was more important than was the value of improving the ability to bite and chew food .

Up until the mid-18th century, the material used for artificial teeth and the base plate to which they were attached consisted of cattle bone, horse teeth, and walrus teeth, or ivory. Extracted human teeth were used in the fabrication of expensive artificial dentures. The teeth were cut off at the neck and fixed in prepared holes on the base plate (Woodforde 1869). Such teeth often came from poor people, who sold their own healthy teeth for money, or from dead people found on battlefields, in graveyards, or at execution sites.

These dentures did not always improve the face aesthetically, as is best illustrated in the case of George Washington's portrait on the one-dollar bill. His face is clearly disfigured by the lower denture made of hippopotamus bone, onto which eight human teeth were attached, making him appear to have a dumpling in his mouth. However, this aesthetic disadvantage had to be accepted at the time because a toothless mouth would have appeared even more disfiguring. Washington's denture was not suitable for biting and chewing.

Fortunately, over the course of time, advances were also made in artificial tooth replacement. After porcelain was invented in 1710 by Bottgers in Saxony, the material was offered to the manufacturers of artificial tooth replacement. Porcelain was white, resistant to wear, and, in an unsintered state, could easily be molded into teeth.

In 1774, the two Frenchmen Duchateau and de Chemant were the first to use ceramic masses to manufacture a tooth replacement. This first attempt heralded continuous developments in artificial teeth. Over the subsequent decades, the initial uniform blocks of teeth evolved into transparent, tooth-colored single teeth with a functional shape and

2 **Tooth extractors in history**
Left: Wilhelm Busch's (1832-1908) idea of a tooth being extracted.

Right: This painting by Francisco de Goya (1746-1828) shows a young woman pulling teeth from a hanged delinquent in order to sell them for money, a procedure then considered as the customary practice to replace extracted teeth.

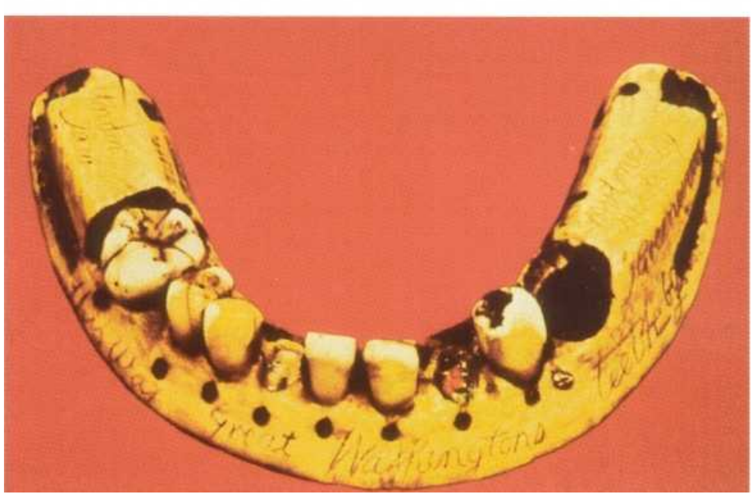
equipped with retentive pins made of noble metal that had been fused with porcelain on the back of the tooth. Consequently, the *porcelain tooth* can be seen as the beginning of the development of ceramic dental reconstructions (Krumbholz 1992).

The industrial production of porcelain teeth began around 1900. In 1893, the Wienand tooth factory was built in Germany; this was followed by the Hoddes factory (Bad Nauheim) in 1900, the Hutschenreuther factory in 1921, and Dr. Hildebrandt's tooth factory in 1922. Hildebrandt developed the first porcelain tooth based on dentin enamel layering principles. He also set another milestone in successfully reinforcing the artificial tooth structure by building it around a hard kernel. This approach led to ceramic teeth attaining their functional ability. A significant aesthetic improvement occurred when Gatzka introduced vacuum firing in 1949 (Claus 1980). This approach meant that the pore volume of the teeth decreased from 5.0% to 0.5%, resulting in superior translucency.

Today, industrially produced nonmetallic, inorganic teeth are *mineral,* or *feldspathic teeth.* Apart from the few chemicals added to the ceramic mass to influence expansion, fracture strength, transparency, and color, the most important raw material is feldspar. The most frequently used feldspars are potassium feldspar orthoclase ($K_2O \cdot Al_2O_3 \cdot 6\,SiO_2$), sodium feldspar albite ($Na_2O \cdot Al_2O_3 \cdot 6\,SiO_2$), and nepheline syenite ($K_2O \cdot Na_2O \cdot 4Al_2O_3 \cdot SiO_2$). These crystalline feldspars are mixed with another raw material, crystalline quartz (SiO_2), and made into a frit by melting the mixture. This destroys the crystal structure and a largely amorphous, glassy material (Claus 1985; Claus 1990) is obtained.

Since the beginning of World War 11, artificial teeth have also been produced from *plastics.* The original qualitative deficiencies have been overcome, and today they have replaced porcelain teeth because they are lighter in weight.

3 Portrait of George Washington on a one-dollar bill
It is clear to what extent the lower denture disfigured the face of the President of the United States of America. He looks as if he has a dumpling in his mouth.



4 George Washington's lower denture
The denture, fabricated in 1789, is carved from hippopotamus tusk and originally contained eight human teeth.

Courtesy of *The Academy of Medicine, New York*

Individual Tooth Replacements

Metal Crowns

Up until the 1960s, no dental ceramic system was available that could be generally accepted for individual tooth reconstructions. The capping of prepared abutments with gray or gold-colored metal crowns, which had begun after the turn of the last century, was a first step toward individual tooth restoration. Repeated attempts were thus made to cover the metal with a tooth-colored glaze similar to enamel.

Metal-Ceramics

Glazing was also explored for dental reconstructions by melting several layers of glaze on top of each other to cover the metal surface. It was believed that with this system the superior tensile strength of the metal could be combined with the advantages of nonmetal, inorganic materials, such as tooth-like color, hardness, chemical resistance, and biocompatability.

After the successful production of a metal alloy with low melting point and increased hardness, the era of metal-ceramics began in the United States after World War II with the Permadent method (Weinstein, New York). In Europe, this method was not successful because of the high production and license costs (Claus 1980). Here, the first ceramics fused to metal alloy system became generally accepted during the early 1960s, as a result of a cooperation between the two corporations Degussa and Vita. The past 30 years have seen dramatic developments in metal-ceramics. The technique was applied to produce a lasting, aesthetic crown which could be used to restore teeth and to bridge gaps produced by missing teeth (Caesar and Hermann 1986; Caesar and Steger 1986).

Today, a large number of different metal-ceramic materials are available to the dental technician. The materials include metal-ceramics that melt at a relatively low temperature (800'C). These ceramics enable the development of further alloys with advantages for aesthetics and biocompatibility.

Since titanium has served as a framework material, dental ceramic masses to cover this metal have also been available. The advantages of titanium include its good biocompatibility and light weight.

5 Portraits by old masters
Our ancestors had themselves portrayed in dignified pose exhibiting a stern face. The lips always remained shut. One reason for this was that a session with the portraitist lasted many hours and it would have been too exhausting to keep smiling during this time; a further reason, however, was that the subject often had missing teeth!

6 Modern portraits
In contrast, cover pages of present-day magazines show beautiful people with smiling faces. In private we also usually smile at the camera. The reason for this is that, for the first time in history, both young and elderly people have teeth that can be displayed because both groups have no teeth missing.

Biocompatibility and Aesthetics

The advantages of dental ceramics as coatings of metal-ceramic frameworks prevail, but problems due to biocompatibility and aesthetics cannot always be avoided. The *weak point* in the system is the *metal alloy.* With more than 1000 metal alloys available, more and more complaints are being voiced about their bioincompatibility. Patients are becoming increasingly more critical of this problem (Gall 1983; Hermann 1985). An aesthetic disadvantage of metal-ceramic restorations is that they are *not translucent* because of the metal layer. In contrast to natural teeth, light cannot penetrate the metal-ceramic interface. Metal edges may be visible through the ceramic and gray areas may appear. There is an increasing desire for metal-free tooth replacements. The development of transparent dental ceramic shoulder masses enables aesthetic improvements in the neck area of the tooth.

Today's informed patients request improved biocompatibility and aesthetics. The prerequisites for an alternative non-metallic, inorganic material are increased strength and hardness as well as optimized chemical stability and resistance to corrosion.

All Ceramic

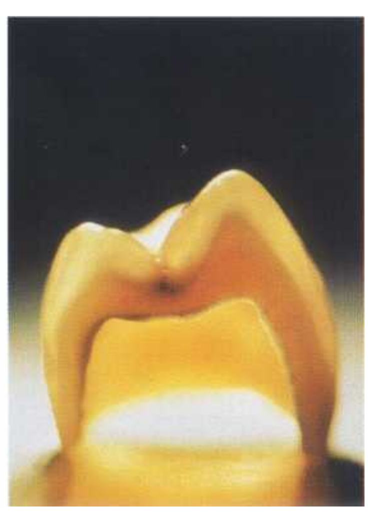
The goal of research has always been to develop a suitable all-ceramic tooth substitute. This goal was never achieved because of the brittleness of the material. This is the "Achilles heel" of all nonmetallic, inorganic materials. In contrast to metals, ceramic materials are flexible and elastic, which means that their application has mainly been restricted to single crowns, inlays, and veneers.

It was the American Land who, in 1896, developed a procedure for fabricating the metal-free *jacket crown.* He fired the ceramic on shaped platinum foil. The shaped platinum cap was coated with the porcelain mass and then fired. Later, the porcelain masses were replaced with kaolin-free feldspar frit. In 1925, Brill improved the procedure, resulting in a breakthrough for the jacket crown in Germany (Krumbholz 1992; Strub 1992).

McLean and Huges achieved the crucial breakthrough in 1965. Further cooperation with McLean and the company Vita resulted in the development of the Vitadur (1968) and Vitadur N system (1976), which came to dominate the aesthetic treatment of front teeth.

7 VMK-68 **crown**
One of the central incisors was restored using a VMK-68 crown.

Courtesy of 8. *Scherer*



8 **Posterior crowns**
Left: Section of an opaque metal-ceramic posterior crown.

Right. Section of a transparent all-ceramic posterior crown.

Additional All Ceramic Systems

The desire for more biocompatible and aesthetic materials, combined with the rise in the price of gold, necessitated the development of usable, all-ceramic systems. These began to appear during the early 1980s when European dentists enthusiastically adopted the Cerestore and Dicor systems developed in the United States. As a result, other systems, such as Hi-Ceram, Optec HSP, Mirage II, Empress, and In-Ceram, were developed (Strub 1992; Pobster 1993). Most systems use completely different processes. Layering, casting, infiltration, and press techniques are used as well as different glass ceramic systems (Bolten and Monkmeyer 1987; Bolz 1987; Geller et al. 1987). Crystals or other stable particles were incorporated as strengthening units.

Unfortunately, because of the rather low fracture resistance of most systems, the failure rate was high, particularly in the posterior tooth regions. Systems such as Empress and In-Ceram became generally accepted. While Empress, inferior in strength, has mainly been used for inlays, onlays, veneers, and anterior crowns, In-Ceram, far superior in strength, has also been used successfully for premolars and molars and for smaller anterior bridges.

Conclusion and Outlook

Functioning artificial tooth constructions that are also aesthetically acceptable are nowadays taken for granted. In the past 30 years, a revolution has taken place in artificial tooth reconstruction, the end of which is not yet foreseeable. Dentists are increasingly interested in all-ceramic systems with improved aesthetics and biocompatibility; inlay, onlay, and veneer processing methods with all-ceramic systems such as Cerec and Celay are increasingly being taken into consideration.

In the future, new methods will evolve and it is also to be expected that crowns and bridges will be computer-processed or mechanically produced. Indications for using all-ceramic will continue to increase. It will be used in the front tooth area with even better aesthetic results. McLean (1993) and Lauer (1996), for example, have clearly shown that it is possible to improve the strength of all-ceramic systems by observing basic laws of structure and design.

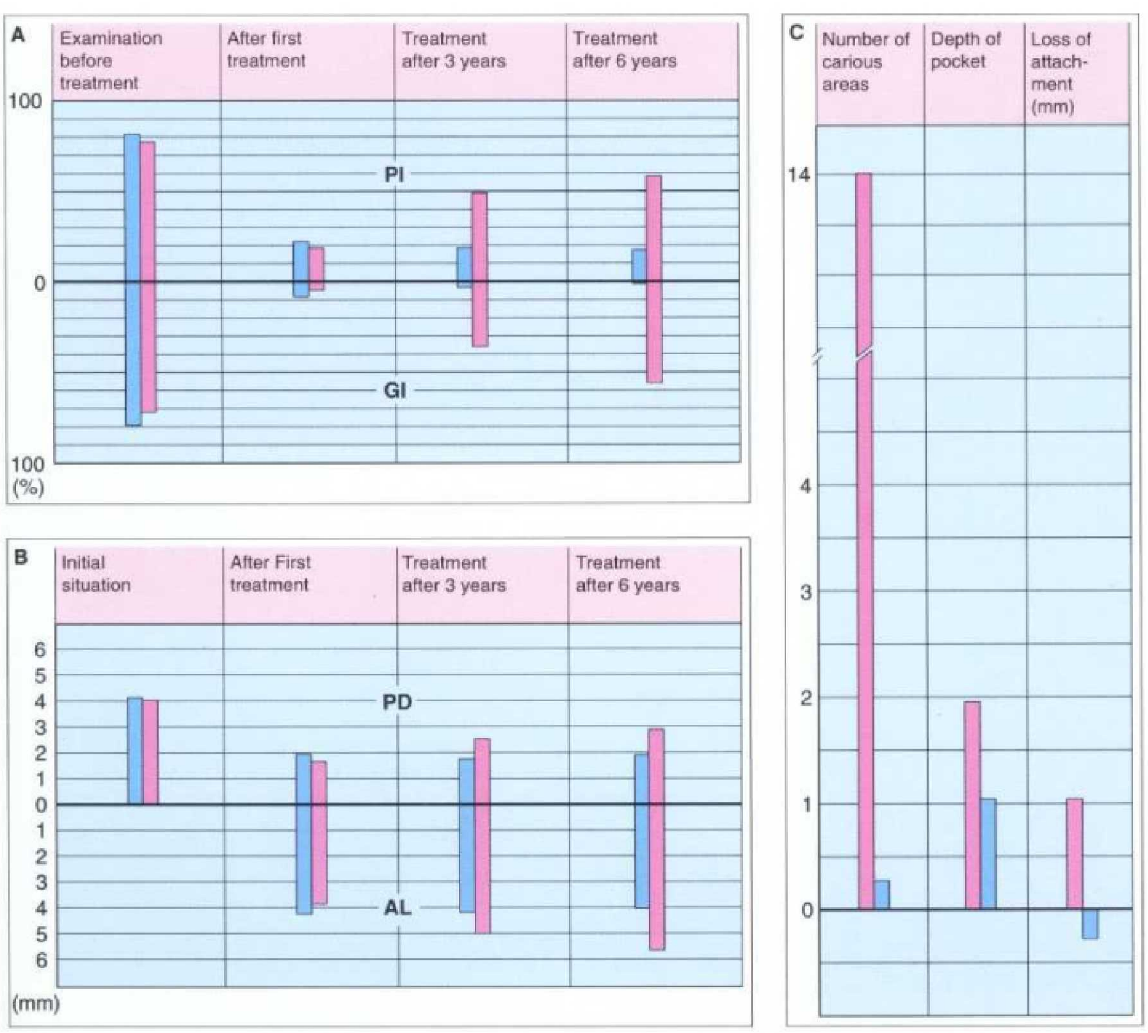
It is to be expected, however, that in the future metal-ceramics will continue to cover a large part of the prosthetic field, since all-ceramic reconstructions will be overtaxed due to clinical realities. For this reason, it makes sense to continue the development of metal-ceramic systems with improved biocompatibility and aesthetics, and based on gold-colored alloys.

9 All-ceramic systems for crowns and partly for bridges (Products marked with * are, to our knowledge, no longer available on the market).

System	Material	Method	Aesthetics	Manufacturer
Vitadur	Alumina	Sintering	Layers	Vita Zahnfabrik
Dicor	Glass ceramics	Casting/Ceraming	Staining	DeTrey/Densply
Dicor Plus	Glass ceramics	Casting/Ceraming	Layers	DeTrey/Densply
Olympia	Glass ceramics	Casting/Ceraming	Staining	Olympia
Willis Glass	Glass ceramics	Casting/Ceraming	Layers	W. Geller
Cerestore*	Alumina	Pressing/Sintering	Layers	Johnson & Johnson
AllCeram	Alumina	Pressing/Sintering	Layers	Innotek
Hi-Ceram	Alumina	Sintering	Layers	Vita Zahnfabrik
Mirage	Glass ceramics	Sintering	Layers	Concorde
Cerapearl*	Apatite	Casting/Ceraming	Staining	Kyocera
Optec	Glass ceramics	Sintering	Layers	Jeneric
In-Ceram	Alumina	Sintering/Infiltrating	Layers	Vita Zahnfabrik
Empress	Glass ceramics	Pressing	Staining/Layers	Ivoclar
Cerapress	Any	Pressing	Staining/Layers	Cerapress

Basic Principles of Aesthetic Dentistry

Aesthetic dentistry is a treatment concept that, in addition to the practical treatment of the defective tissue, includes recognizing the cause of disease needs and suitable treatment alternatives. The Swedish dentist Per Axelsson (1978) raised the following question: is there a difference in oral health between patients who visit the dentist twice a year and those who only visit the dentist when they experience pain? The result was astonishing: actually, it did not matter whether or not patients visited the dentist regularly because both patient groups lost their teeth. However, in the years following this study, Axelsson (1981) was able to show a crucial difference: patients who visit a dental practice with an established maintenance system can go through life with healthy teeth as long as they are willing to make regular follow-up visits after completing full-mouth rehabilitation.



10 **Importance of recalls**
A Percentage of tooth surfaces covered with plaque (plaque index PI, upper half) and percentage of gingival units with inflammation (gingival index GI, lower half).

B Probing depth (PD) and attachment loss (AL).

C Carious surfaces, pocket depth, and attachment loss after 6 years.

Recall group

Control group (not recalled)

Caries as an Infectious Disease and How It Can Be Prevented

It is not enough to simply restore an existing cavity. Caries is an infectious disease. If the infectious disease is not treated causally, there will be no lasting treatment success. This is especially important with tooth-colored restorations, restorations in the posterior teeth, and cemented restorations. Most resin cements, composite resin cements, and resin-modified glass ionomers have a relatively low filler content. Because of this they show somewhat inferior physical properties and with time the cement is washed away at the marginal area. As a result, the risk of caries will increase at this location.

The *individual risk of caries and periodontitis* of each patient should be established at the beginning of the treatment. Expensive, cemented, tooth-colored restorations should not be started until the initial therapy has been completed. In addition, it should be ensured before the treatment begins that the patient will regularly attend follow-up appointments.

In a dental practice, aesthetic dental medicine should be offered only in connection with a preventive dental concept based on the following four levels:

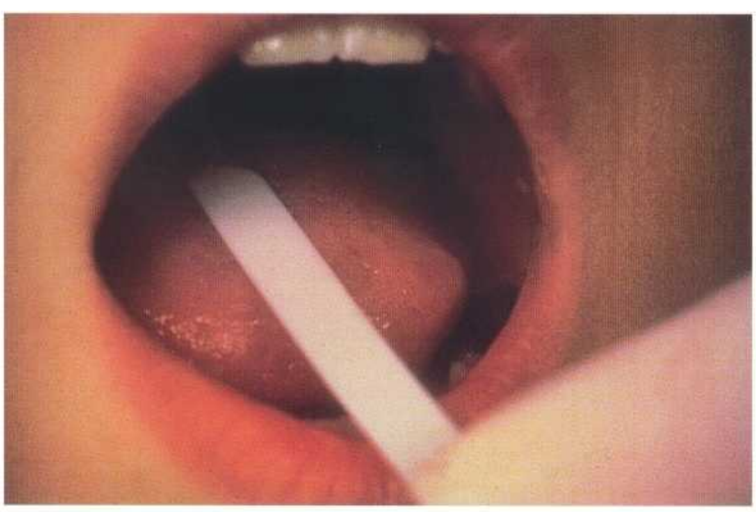
- prenatal prevention
- primary prevention
- secondary prevention
- tertiary prevention

The goal of *primary* prevention is to secure healthy teeth and healthy periodontal tissues. *Secondary* prevention should prevent the recurrence of dental disease following therapy. The goal of *tertiary* prevention is to ensure that restorations and their restorative materials have preventive qualities. Therefore, cements that release fluoride and exhibit low solubility, such as glass ionomers, should be given preference to classic zinc phosphate cements.

11 Summary
Before initiating aesthetic treatment, it is important to determine a patient's caries and periodontitis risks. The factors listed on the right should be taken into consideration.

Individual Risk of Caries and Periodontitis

- Patients with low risk of caries and periodontitis (approx. 80 %)
- Patients with high risk of caries (approx. 10 %), more than one new filling per year, more than 250 000 Streptococcus mutans/mL saliva
- Caries alba
- Lactobacilli ≥ 100 000 CFU/mL saliva
- Frequent sweet snacks
- Plaque formation index (PFR-I) ≥ III
- Patients with high risk of periodontitis (approx. 5 %)
- Loss of attachment exceeding 1 mm/5 years
- Patients with very high risk of caries and periodontitis (approx. 5 %)



12 Microbiological examination of the oral cavity
To determine caries activity, the quantity of *Lactobacillus* or *Streptococcus mutans* can be readily determined using commercially available microbiological kits.

Right: Level 1 = low Lactobacillus activity; Level 4 = high caries risk due to high bacterial activity.

Left: Caries risk can easily be determined using a saliva sample.

Goals of Prevention

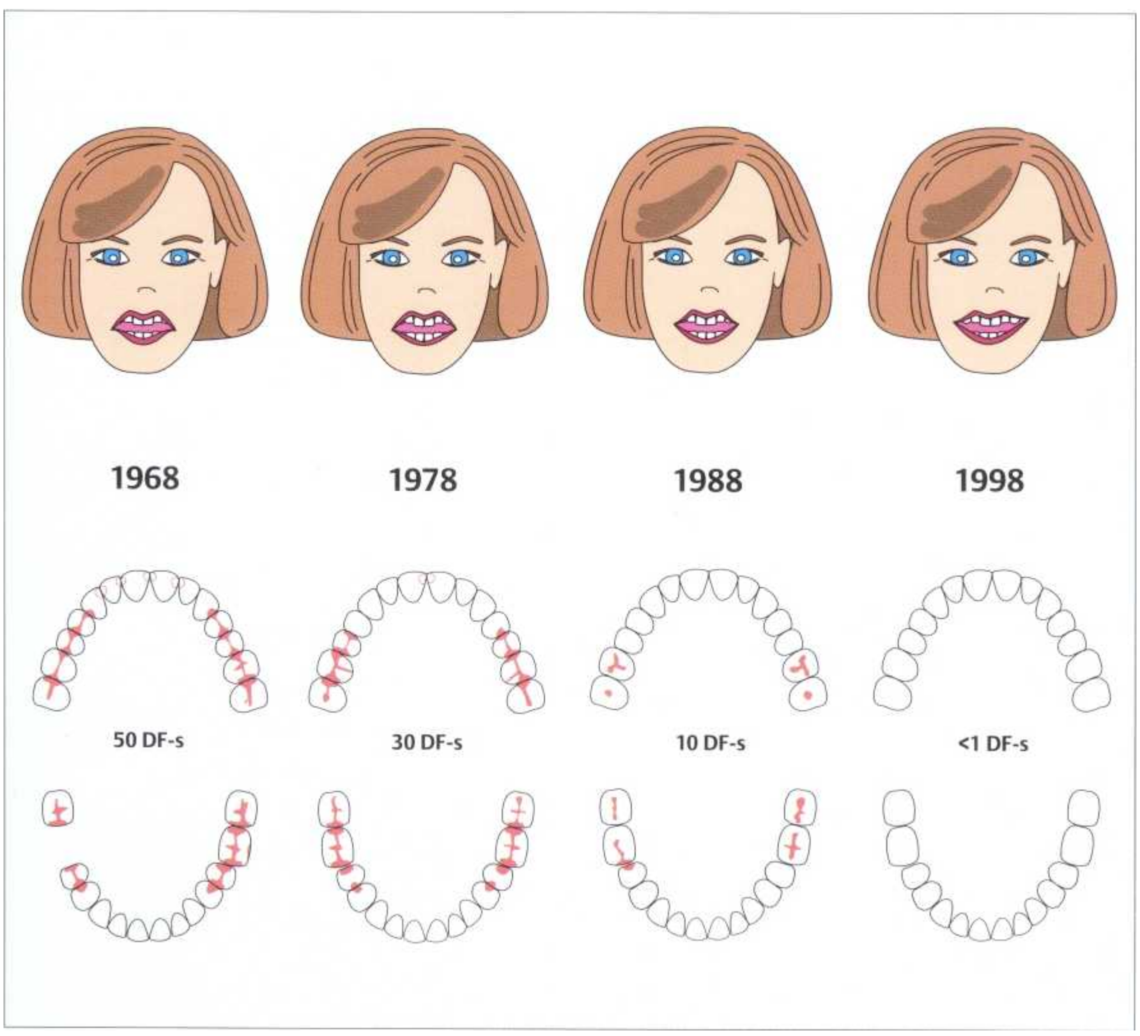
Two goals can be achieved with a well-designed preventive program:

1. In the age group below 19 years, interproximal restorations are not needed. In this age group, the use of sealants should have a high priority. If a posterior tooth requires a large restoration, the best possible material is selected after input from the patient. A small, initial carious lesion can be restored with a direct composite restoration, while a larger defect on a permanent molar can be restored with a gold restoration, based on longevity data available for these restorations. However, if instead the patient prefers a tooth-colored restoration (ceramic inlay/onlay or composite), those involved should be made aware of the increased risk of fracture and the related possibility of having to replace the restoration in the future.

   Age groups with increased caries risk include 3, 7, and 8-year-olds and 13 to 15-year-olds. All teenagers undergoing orthodontic therapy belong to a very high risk group.

2. In the 20 to 50 year age group, the majority of patients should not develop any new carious lesions. Most restorations in this age group are replacements of existing fillings and crown restorations. The best possible restorative material should be selected in this case, too. It is important to select the best material to fit an existing defect rather than design a preparation to match a particular material. Ceramic restorations, particularly those fabricated using CAD/CAM technology (e.g., Cerec), force the preparation technique to be suited to the material, making the treatment less conservative. If it is a relatively small defect, the preferred materials include direct composites, gold alloys, or composite rather than ceramics.

   The goal should be to save healthy tooth substance rather than to remove it for a particular restorative procedure.



13 Reduction in caries lesions among adolescents in Karlstad, Sweden, over the past 30 years Today, the majority of children will reach adulthood without suffering from caries. Incipient carious lesions can be treated with adhesive restorative materials.

Aesthetic Dentistry-A Treatment Concept

Aesthetic treatment, like any other dental treatment, consists of four phases:

Phase 1: Systemic Phase
This phase starts before the treatment begins. Its purpose is to protect both the therapist as well as the patient. Risk patients, for example patients with diabetes mellitus and cardiovascular or blood diseases, are identified before the actual treatment starts. This step includes consultations with the physician treating the patient.

Phase 2: Hygiene Phase
The goal of this phase is to establish a clean oral cavity to secure a healthy basis for the subsequent phase.

Phase 3: Corrective Phase
Dental and aesthetic corrections are carried out during this phase.

Phase 4: Maintenance Phase
During this phase, the finished reconstructions are checked as well as the overall health of the oral cavity.

The Necessity of Caring for Aesthetic Restorations

The longevity of many tooth-colored restorations can be as good as that of metal restorations. Prerequisites for success is careful planning of the treatment, skillful use of the materials, and a maintenance phase that is adapted to the individual restoration. To ensure success, the patient, the dentist, and the dental hygienist must be aware of the specific demands of a particular treatment or material.

Most aesthetic restorations consist of resins, ceramics, glasses, or a combination of these materials. Materials rich in resins (composites, resin cements, resin-reinforced glass ionomers and compomers) have a higher rate of wear and are subject to chemical degradation. Ceramics have a greater risk of fracturing and may be etched by some oral hygiene articles. Before beginning any treatment, the dentist and the patient should discuss the advantages and disadvantages of the different restorative materials and coordinate professional and home-care oral hygiene procedures accordingly.

14 **Systematic treatment planning**
Aesthetic treatment should only be carried out upon completion of the hygiene phase. Its actual long-term success is ensured by the maintenance phase (see also Figs. 10 and 11).

Hygiene Phase	Corrective Phase	Maintenance Phase
• Initial basic tartar removal	• Continuation of plaque control	• Checking work performed
• Caries treatment: temporary restorations, endodontics	• Orthodontic pretreatment	• Maintenance of oral health; prevention of new defects
• Oral hygiene instruction	• Functional pretreatment with splints	• Individual recall system based on the state of the patient's teeth and oral hygiene
• Extraction of hopeless teeth	• Periodontal surgery, aesthetic periodontal surgery	
• Temporary splint	• Placement of implants	
• Temporary reconstructions	• Restorative therapy: inlays, veneers, partial crowns, bridges, crowns, dentures	
• Professional tooth cleaning: thorough supragingival and subgingival cleaning, including scaling and root planing	• Reassessment of therapy	
• First adjustment of the occlusion; removal of severe preliminary contacts	• Refining the therapy, removing possible overhangs	
• Plaque control		
• Evaluation of oral hygiene		
• Reevaluation of treatment plan		

Professional Tooth Cleaning in Patients with Aesthetic Restorations

It is very important that the dental hygienist and the entire dental practice team use established methods when performing professional tooth cleaning, scaling, root planing, polishing, and different fluoride applications that are needed for existing restorations. Removal of plaque, tartar, and bacterial toxins from root surfaces can be carried out manually or mechanically.

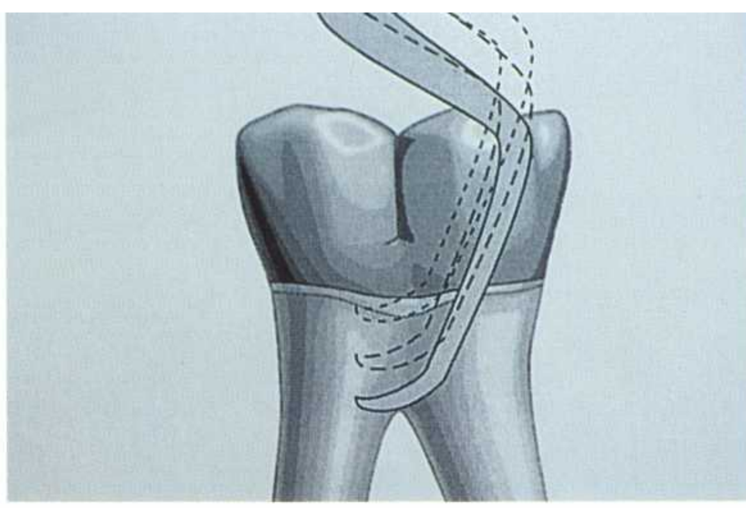
After the first examination, which is executed by the dentist in collaboration with the dental hygenist, an individual treatment plan is drawn up. The plan is developed for the patient, based on the seriousness and type of the patient's disease.

Manual Scaling

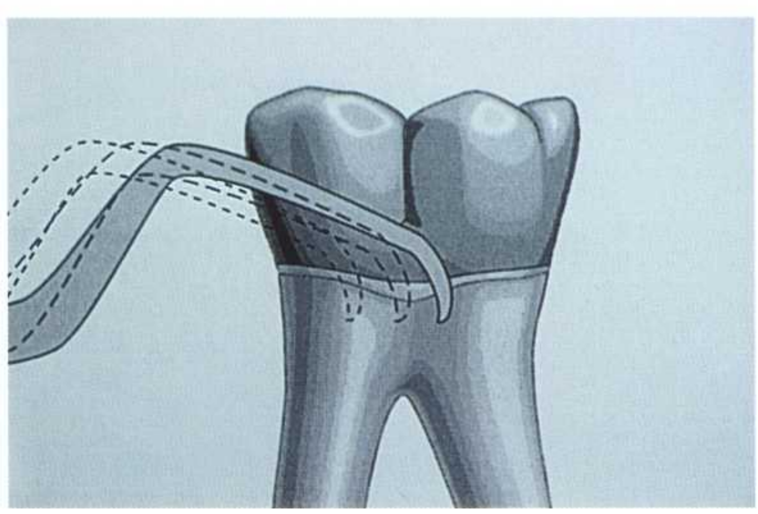
Manual scaling performed using metal curets does not damage a bonded restoration to the same extent as ultrasonic scales, assuming that the therapist takes certain precautions. These precautions include first identifying the margins of the restoration. Dentists and the dental hygienists have learned to carry out scaling and root planing with the cutting edge of the curet in the periodontal pocket and in firm contact with the tooth surface, moving the curet in a coronal direction. Such a technique causes the curet to slide over the margins of the restoration and could result in parts of the restoration being torn off and the restoration, with its resin-filled marginal gap, loosening and eroding.

A simple modification of this scaling technique is to move the scaler along and parallel to the restoration margin. By doing so, less damage is caused in the marginal area. Scaling and root planing at the margin of bonded restorations must be performed carefully and very consciously.

-Recommended curets: Gracey curets
-Working direction: horizontal
-Avoid scalers because they generate poor tactile feeling.



15 Using curets on nonrestored teeth
The usual curet technique involves the curet being inserted into the sulcus and pulled in a coronal direction, with the cutting edge along the tooth surface. The tooth surface can thus be scaled and planed. This action can only be recommended for nonrestored teeth, as otherwise there is a danger of restoration margins being damaged.



16 Using curets on restored teeth
The curet should not be moved along the root in a coronal direction, but in a direction parallel to the restoration margin. This prevents damage to the margins of the restorations.

Scaling using Powered Instruments

Scaling is also performed with sonic and ultrasonic devices. Many dentists and dental hygienists use such scalers, since they can remove calculus more quickly. At the same time, therapeutic irrigation of the sulcus can be performed with the spray of the scaler.

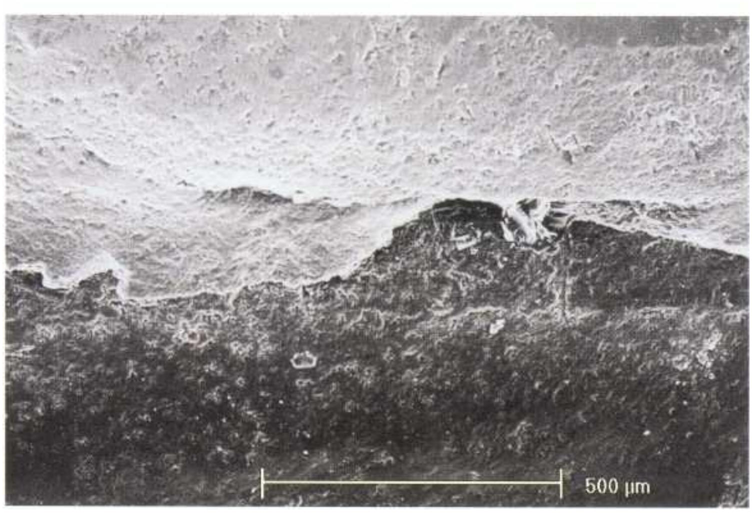
If handled improperly, ultrasonic devices can damage all types of restorations. They can chip ceramics, cause abrasion of composites, increase the surface roughness of all restorations, and destroy the adhesive joint between tooth and restoration. Because of these drawbacks, sonic and ultrasonic instruments should be avoided in patients who have several bonded restorations. If necessary, however, the appliances should be used with great caution, and margins of tooth-colored restorations should not be touched.

Consequently, it is necessary to inform patients with aesthetic restorations that they should have their teeth cleaned professionally more frequently to avoid a large accumulation of plaque, calculus, and stain and it does not become necessary to use larger equipment to remove these mechanically. If the patient visits the practice at shorter recall intervals, less tartar will accumulate and, consequently, less aggressive methods are needed to remove it. Thus, manual scaling becomes simpler and less time-consuming. The risk of injuring a restoration margin decreases. At the same time, it is possible to check and detect secondary caries lesions at an early stage .

Air Polishing Devices

Discolorations are usually removed by polishing, conducted with rotating instruments, brushes, and rubber cups. Additionally, air-powered abrasive devices are also available. The air polishing abrasive appliances (CaviJet, ProphyJet, Air-Flow, and AirScaler) are very efficient at eliminating dark stains in concave tooth surfaces and in areas that are difficult to access. However, their abrasive power prohibits them from being used near restorations of any types. Their use should be exclusively restricted to natural, unfilled tooth surfaces.

17 Ultrasonic devices and composites
This composite surface has been destroyed by an ultrasonic device. The result is discoloration and accelerated degradation of the restoration.



18 Ultrasonic devices and ceramics
Ultrasonic scalers can damage all-ceramic crowns, veneers, and inlay margins.

Polishing Teeth

The best method of polishing tooth surfaces is with rotating instruments and prophylactic pastes. It should be noted that the prophylactic pastes to be used should have low abrasivity. Any rubber cups that are used should be made of a very soft, low abrasive material. Many of the relatively hard rubber cups and most commercial prophylactic pastes are too abrasive for composite surfaces and resin cement margins.

Avoid using ultrasonic devices for removing calculus and also air polishing units. Finishing strips and disks must also be used with great caution.

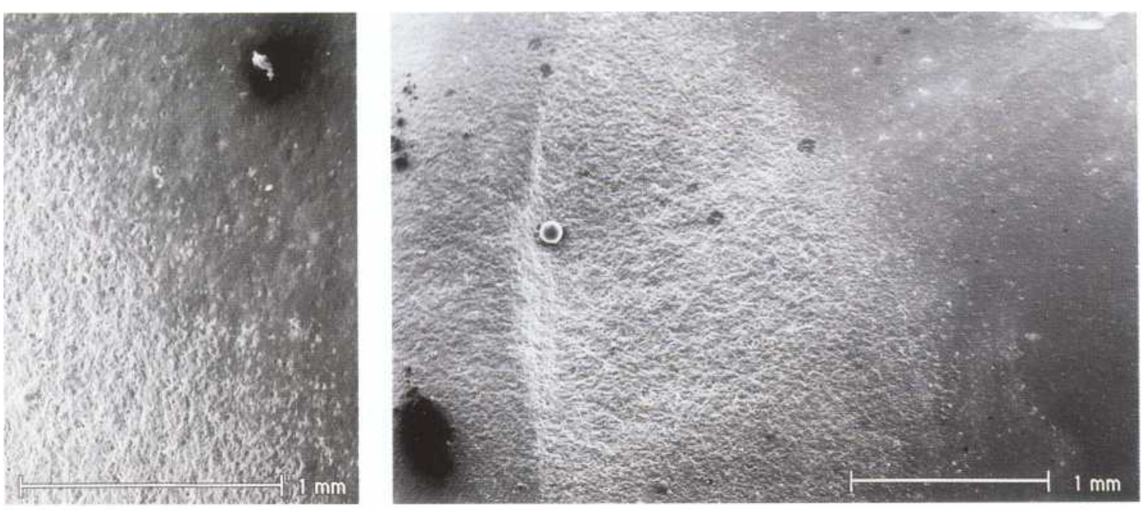
Since, ideally, a good composite restoration is invisible, the margins of the restoration should be marked on the treatment card.

Recommended polishing pastes:
-Proxyt
-CCS Prophylaxepaste; RDA 40

Fluoride Treatments

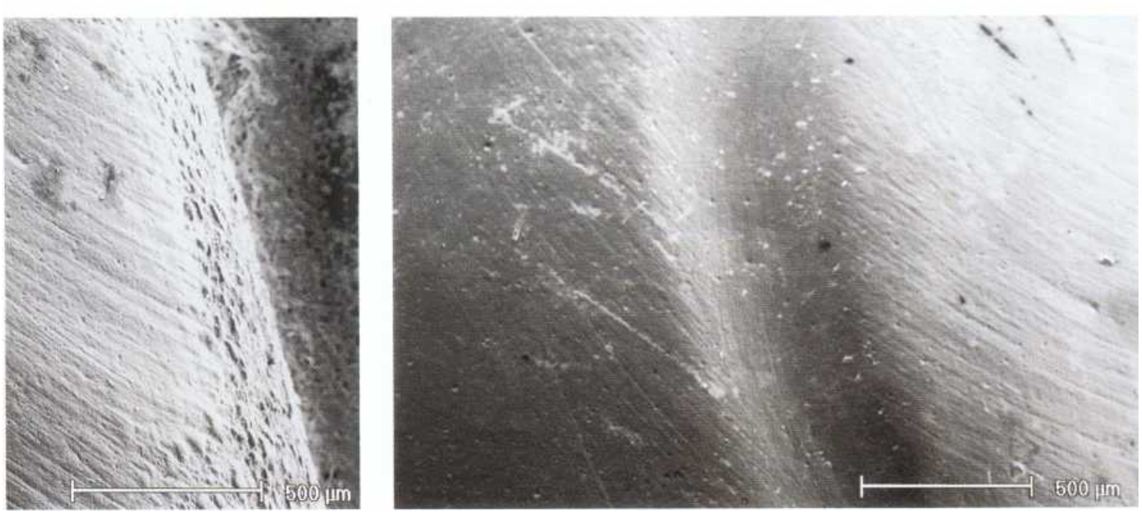
At each recall, the patient's teeth should be fluoride treated. For this purpose the dental hygienist uses stannous, and sodium fluorides. Stannous fluorides should not be used with tooth-colored restorations because they can etch their surfaces. The problem with such etching is especially pronounced with ceramic surfaces. If an IPS Empress veneer whose surface is painted a great deal is exposed too frequently to an acidic stannous fluoride, the ceramic surface can gradually be attacked and the surface color can be dissolved. Therefore, as a general rule, neutral sodium fluorides should be used in the practice.

Recommended fluorides:
-Blend-A-Med fluoride gel
-Oral-B Neutra-Foam
-ACT dental rinse



19 **Effect of air abrasives on restorations**
The surface of this composite restoration (hybrid) has been damaged by the use of air abrasive equipment.

Left: Abrasion of the ceramic surface using air abrasive equipment.



20 **Influence of various polishing techniques on restorations**
A deep groove has been polished into this composite surface by using a prophylactic rubber cup and an abrasive polishing paste.

Left: Abrasion of a microfilled composite surface with a Prophy-Jet.

Home Care-Patients with Aesthetic Restorations

A patient with tooth-colored restorations should be given clear instructions by the dentist or dental hygienist on how to perform oral hygiene at home. Given the quantity of products offered in drug stores, it may be difficult for patients to select the right toothpaste and toothbrush for their home care.

Toothbrushes

Patients with many tooth-colored restorations must use very soft toothbrushes. The toothbrush can easily abrade composite restorations in particular.

Some patients have difficulties with plaque control and therefore need to be recalled more frequently.

If patients have problems with their oral hygiene, it may be helpful to recommend an electric toothbrush. Electric toothbrushes with rotating soft bristles are reliable and effective.

Toothpastes

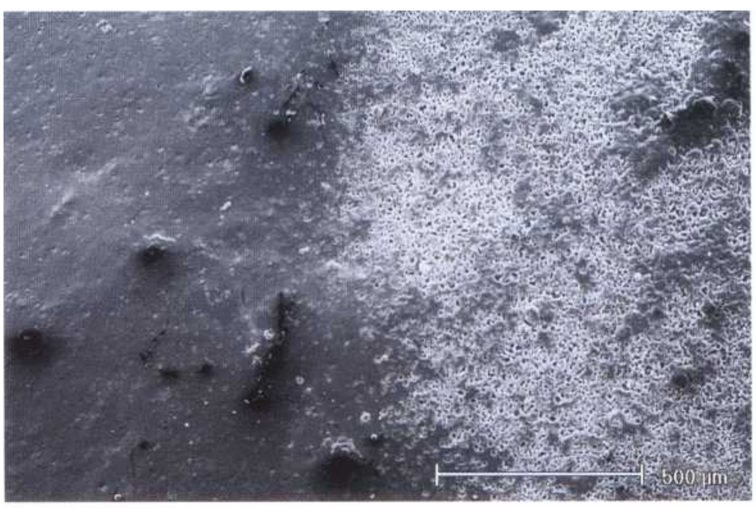
A large number of different products are available, including toothpastes that specifically remove tartar, those that are good for the gingiva, and those that whiten the teeth. Toothpastes are available as pastes or gels. Most toothpastes contain fluoride, while some also contain baking soda and peroxides. Patients should be informed that gel toothpastes are less abrasive than pastes. A toothpaste with low abrasivity should be used. Often, pastes that make teeth white are more abrasive and should therefore be avoided. Toothpastes containing stannous fluoride can lead to discoloration of composite surfaces. Colgate Gel is an example of a gel toothpaste that has a low abrasivity and contains sodium fluoride.

Mouthwashes

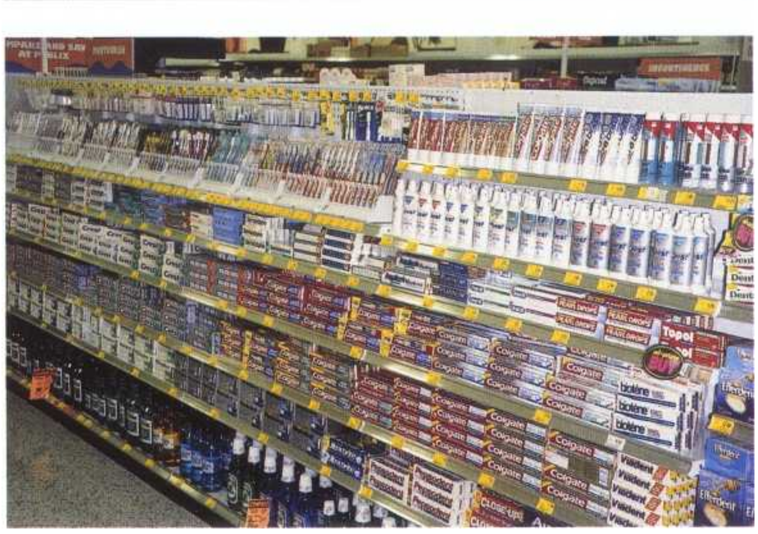
Many mouthwashes have a very high alcohol content. The alcohol can soften resins and after some time they can cause the resin surface to dissolve. Therefore, nonalcoholic products should be used.

Generally, two groups of mouthwash are recommended:

-mouthwashes with fluoride
-mouthwashes with an antiplaque additive



21 **Etched ceramic surface**
This ceramic surface was treated with an amine fluoride gel. Amine fluoride and stanuous fluoride with a very low pH value are present in many toothpastes and prophylactic pastes. A sodium fluoride toothpaste with neutral pH value should preferably be used on ceramic restorations.



22 **Samples of oral hygiene products**
A large variety of oral hygiene articles are available in supermarkets. The dentist or dental practice staff must give clear advice to patients with aesthetic restorations on how to choose suitable oral hygiene products.

Mouthwashes containing chlorhexidine are not recommended. Chlorhexidine causes discoloration of the tooth surface. This discoloration increasingly appears at the bonded sites and on resin surfaces and is very difficult to remove. If mouth rinses containing chlorhexidine must be used, local application of a gel is recommended to minimize the discoloration.

Additional Aids

Many patients use dental floss, proxabrushes, and toothpicks. The use of dental floss is usually completely harmless if the patient has been taught a proper technique by the dental hygienist. The use of toothpicks is not recommended. An oral irrigator is quite safe, as long as no chemicals are used that discolor or dissolve resin surfaces.

Diet

The patient should receive nutritional advice including a list of foods that often cause tooth surface discolorations or dissolve ceramic surfaces. Patients will only rarely change their diet. They should, nevertheless, know which nutritional parameters may change the color of tooth surfaces, particularly resin surfaces or cement joints.

Smokers

Cigarette smoke leads to a pronounced discoloration of the tooth surface, particularly of resin surfaces. Smokers should be recalled frequently.

Oral Habits

Bruxism, chewing of ice cubes, and chronic biting on objects such as toothpicks, fountain pens, etc. lead to the loss of tooth substance. The patient must be made aware of this.

If the patient cannot break these habits, damage can occur not only to natural dentition, but also to any restorations. The patient should be informed, verbally and then in writing, of the necessity of attending recall sessions at the practice at shorter intervals due to particular life-style factors (smoking, oral habits, dietary factors, etc.).

Toothbrushes (soft bristles)	• Manual e. g., Sensodyne-Soft, Colgate Plus soft, Colgate Precision, Colgate total soft, Blend-A-Med Professional, Blend-A-Med Medic Plus 3, Aronal Öko-Dent, Elmex Sensitive, Butler Protect • Electric e. g., Blend-A-Med Medic-Control (soft), Brown-Plak-Control, Interplak, sonicare
Toothpastes	• Containing sodium fluoride, pH-neutral/basic low-abrasive/abrasive-free e. g., Blend-A-Med Gel, Colgate Gel, Perio-Gard Gel • My First Colgate Children's Gel, RDA value 29, pH value 6.7 • Elmex-Sensitive, RDA value 30, pH value 6.1
Fluorides	• pH-value slightly acidic to avoid etching the restoration and adhesive joint • e. g., Blend-A-Med fluoride gel, Oral-B FLUORINSE, Johnson & Johnson ACT; pH value 4.5, nonalcoholic
Plaque inhibitors	• No tooth staining (chlorhexidine digluconate-free, stannous fluoride-free) • e. g., Perio-Guard mouth wash (Sanguinara), Odol-Med-3 Junior, pH neutral, nonalcoholic

23 **Recommended oral hygiene aids for patients with all-ceramic restorations**
In principle, patients should use as soft a toothbrush as possible. Many patients with high aesthetic claims show pronounced abrasive defects. A suitable power toothbrush can prevent further progression of such abrasive defects. Additionally, a low abrasive toothpaste with neutral pH value containing sodium fluoride should preferably be used. Mouthwashes containing chlorhexidine should be avoided because of their strong tendency to stain the teeth.

Checklist—Dentist

Professional Oral Hygiene for Patients with Aesthetic Reconstructions

Control of Restoration Margins

- Roughness
- Discolorations
- Marginal gaps (due to erosion)

Plaque Index

- Disclosing with fluorescein
- Plaque-disclosing agents can stain restoration margins

Scaling

- Gracey curettes
  To avoid damaging the margins, work in a horizontal direction
- Scalers are not suitable
- Ultrasonic devices
  —destroy the surface of composites
  —loosen the ceramic-resin tooth system
  —could result in ceramic fractures
- Intraoral air polishing devices (e. g., ProphyJet)
  —act as a cauterant on composites
  —destroy the ceramic glaze

Removal of Discoloration from Proximal Surfaces

- Use fine finishing strips, but do not damage the contact point
- Afterwards, use polishing paste and dental floss for final finish

Polish

- Sodium fluoride containing, pH-neutral and low-abrasive polishing pastes, e. g., Paradontax professional
- Polishing pastes containing stannous fluoride are acidic
  —they act as a cauterant on the ceramic surface
  —during polishing the uppermost layer can be etched and removed
  —this can result in the loss of the glazed surface
- Abrasive polishing pastes
  —can remove the glaze and the uppermost layer of color
- Diamond polishing pastes
  —for ceramic restorations
  —not to be used on restorations with visible resin gaps and composites
- Alumina polishing paste
  —for composites and ceramic restorations

Cleaning Interproximal Surfaces

- pH-neutral, low abrasive polishing pastes and dental floss

Fluoridation

- Fluorsilan (Fluorprotector)
- Fluoride gel with low acidity (Blend-A-Med fluoride gel)

Plaque Disclosing

- No discoloring side effect

With Available Abrasives

- Michigan tray therapy for patients with bruxism
  —grinding can cause ceramic fractures
  —antagonist can be unduly abraded

Checklist—Patient

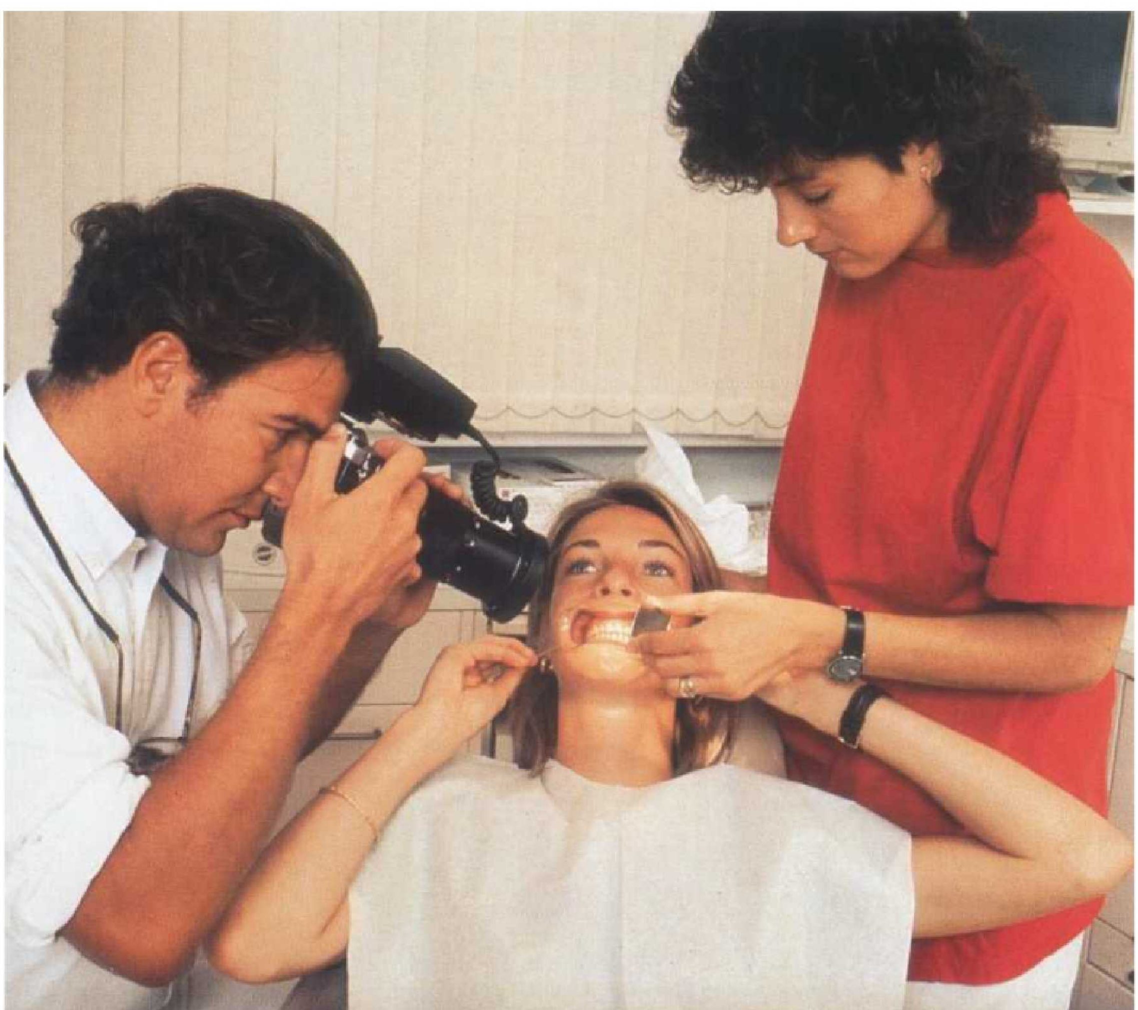
Home Care by Patients with Aesthetic Reconstructions

- Composites accumulate plaque faster than other restorative materials
- Composite and ceramic restorations change color more quickly
- Use soft toothbrushes to avoid abrasion
- Use abrasive-free/low-abrasive toothpastes or gels that have a neutral/basic pH value and contain fluoride—acidic and abrasive toothpastes can destroy the surface of the restoration and the bond
- Do not use mouthwashes containing chlorhexidine or toothpastes containing tin difluoride to reduce plaque—these agents can discolor the restoration margins
- Do not use acidic mouth irrigations containing alcohol—these can dissolve restorations
- For fluoridation, do not use products containing fluoride with a low pH value (often products containing stannous fluoride)—these can damage the restoration and its adhesive bond
- Avoid foods and medications containing an excessive amount of acid that remain in the oral cavity for a long time—the acid can harm the restoration
- Avoid excessive alcohol consumption and discoloring foods and sweets—these can dissolve and discolor the restorations
- Avoid oral habits (chewing on nails and/or pens)
- Patients with bruxism teeth should use nightguards to prevent ceramic fractures or excessive wear of the antagonists

Photography

Photography is just as indispensable for aesthetic dentistry as radiography is for traditional restorative dentistry. Today, in a modern dental office, photography is routinely used for documentation, for marketing, and as a communication tool to explain different procedures to patients. If one has access to the right equipment and follows some general rules, the use of photography in dentistry is simpler now than ever before.

The first system cameras that made it possible to take intraoral photographs were introduced during the early 1960s. Until recently only the conventional single-lens reflex (SLR) cameras were available to dentists. However, today's computer technology has also penetrated into the dentist's treatment room: new digital camera systems. Today patients can be shown the state of their oral health directly on screen during treatment. In addition, the treatment goal can immediately be shown with the help of computer simulations and printouts.



24 **Producing a photographic status report**
In aesthetic dentistry, case documentation is very important (both before and after treatment) for patient information, communication with the laboratory, and also for general quality control.

Why take Photos?

There are various reasons for taking photos in the dental office:

-Having photographic documentation of the initial condition, the individual treatment steps, and the final result is very important.

-Dentists document their work and monitor their skills. Good recording is a part of the *quality control system* and offers dentists a wealth of information from, for example, the gingival condition of the patient to color differences of veneer.

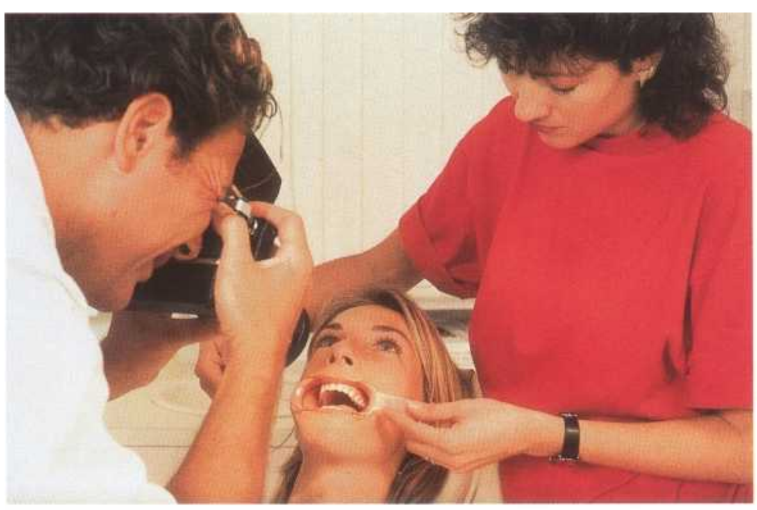
-Photographs simplify *communication* between the dentist and the dental laboratory. Accompanying photographs greatly facilitate the work of the dental technician. The needs of both dentist and patient can be better presented and consequently the result is more satisfactory. There is hardly a bigger challenge for a dental technician than fabricating a single anterior veneer or crown. A good illustration of the situation helps the technician to succeed.

-Photographs are very helpful when used for both *patient motivation* and *education.* Photographs document what can be achieved with modern dentistry.

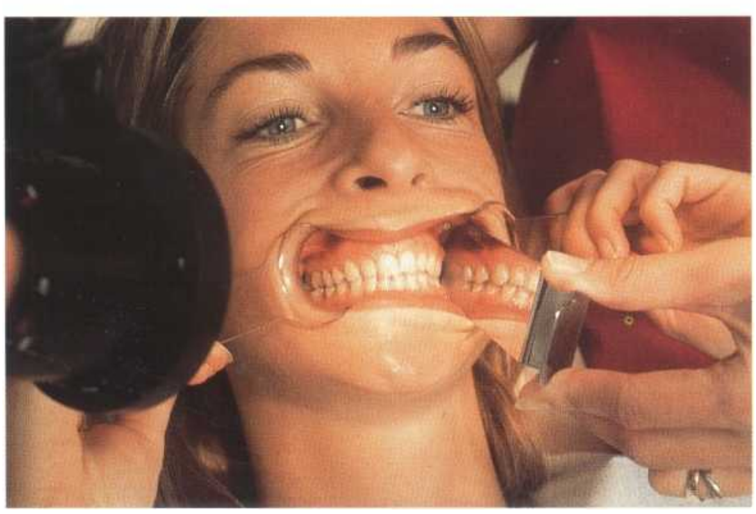
-"Before and after" recordings can be used as an excellent *marketing tool.* They make it possiblbe to demonstrate a planned treatment to the patient. It is particularly convincing when dentists presents *their own treatment cases* during these sessions ("1 did that, and I can do that for you too! ").

-After treatment is completed, give patients "before and after" photographs that are mounted in a little album and which they can take home. A satisfied patient will recruit *new patients.* Excellence is and will remain the best advertisement for your practice. What, after all, is marketing? The answer is: perform well and make sure others talk about it.

-Photographs are also helpful in communicating with *health providers* and *insurance companies.* But it can also be extremely helpful to have good photographs in cases involving *legal disputes.*



25 **Photograph of the anterior teeth**
When a frontal shot of the anterior teeth is taken, the patient's lips are retracted with two cheek retractors. The photographer stands in front of the patient.



26 **Photograph of posterior teeth with occluded tooth arches**
The lips are here also retracted with cheek retractors. A long, slightly conical mirror makes it possible to photograph the posterior teeth with occluded mandibular and maxillary teeth.

Basics of Photography

Modern 35-mm cameras are constructed so that very limited technical knowledge is needed for their use. Most of these cameras have automatic film-speed detection, autofocus, automatic exposure control with a synchronized flash which senses poor light conditions, and automatic film rewinding. Nevertheless, some basic photographic knowledge is indispensable.

Exposure Time and Aperture

Exposure time and aperture size restrict the amount of light to which the film is exposed. The photographer should set the size of the aperture. A small aperture (large f-number) enables a large *depth of field.* Therefore, the aperture should be as small as possible in macro photography. However, this necessitates a sufficiently strong light source. As long as one works within a reasonable range of magnification (1:2 to 1:1), the amount of light is usually sufficient.

Resolution

The dentist chooses the desired magnification (for example 1:2 or 1:1) and then moves the camera slowly toward the object until position and sharpness are correct. The photograph is then taken.

Lenses

For intraoral photography the dentist uses a macro lens with a focal length of 90-120 mm. Such lenses produce a 1:1 image.

Type of Film

One can select between slide or negative films. Slides can be used for lectures; prints are suitable for patient education and communicating with laboratories.

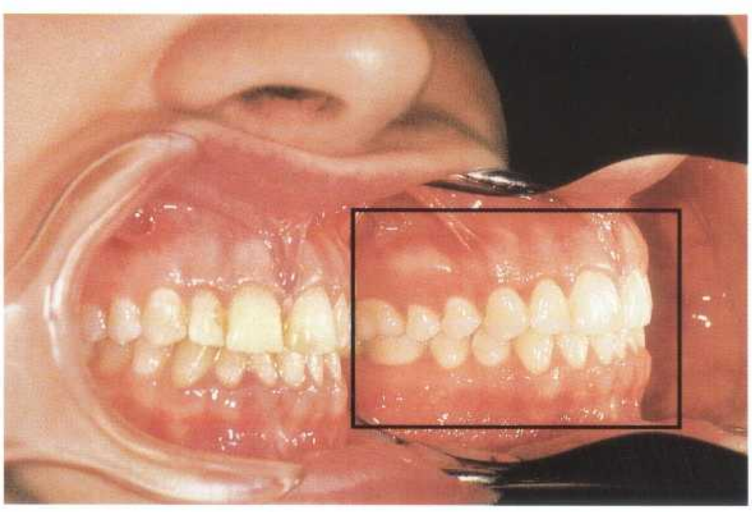
Film Speed

The film speed is given in ASA, ISO, or DIN. The recommended film speed for the case under discussion is 100 ASA.

Light Sources

Ring flashes are commonly used in intraoral photography.

27 Frontal view
When only teeth are being photographed, a magnification of 1:2 to 1:1 is suitable.



28 Lateral view using a mirror
A magnification of 1:2 (35-mm format) should be chosen.

Camera Systems

In principle, the dentist must choose between two camera systems: conventional film systems or digital storage media. Digital cameras are discussed on page 22. In the case of conventional film systems, the choice is between:
- Instant cameras (Polaroid System)
- Conventional camera systems (35-mm film), and
- APS system cameras (Advanced Photo System)

Instant Camera (Polaroid System)

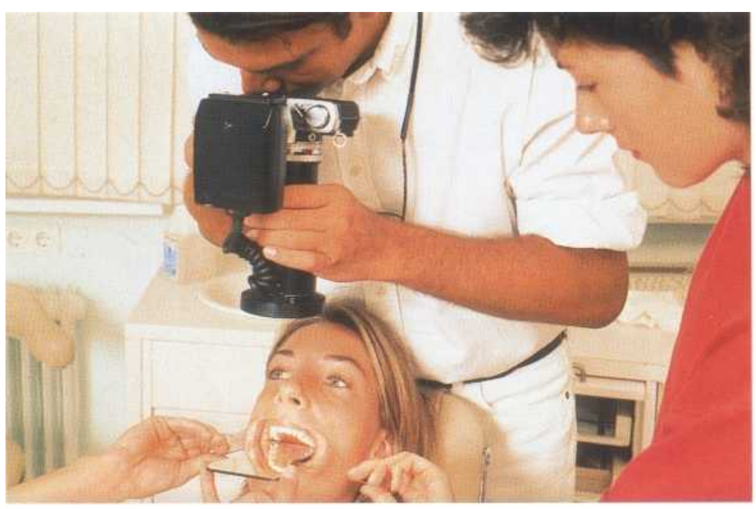
In certain situation, instant cameras have their advantages, for example, if neither an intraoral camera nor a digital photo system is available and a quick photograph is needed to show a new patient the poor condition of their old restorations. If the dentist now takes a Polaroid photograph, the patient can immediately be shown the importance of the proposed treatment and the method of procedure can be explained. Polaroid pictures are also useful as a fast marketing instrument. The patient can receive "before and after" treatment photographs, which can be shown to family, friends, and colleagues. Consequently, Polaroid pictures are useful in the fast and powerful marketing of oral care.

35-mm Photo Systems and APS System

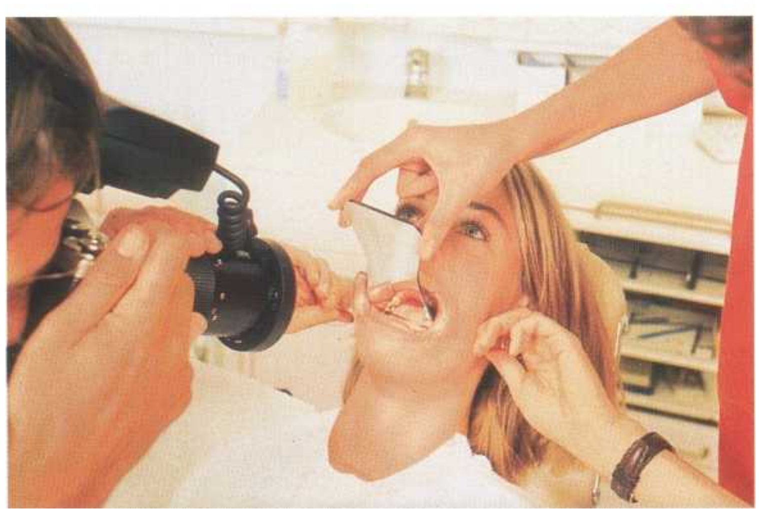
For intraoral photography-macrophotography-SLR cameras with corresponding accessories (macrolens, flash) are indispensible for both the conventional 35-mm film format and the newer APS system.

The APS system uses a new, smaller film format (negative film) that stores all camera settings on magnetic strips. The APS film is exposed conventionally and then developed. The laboratory can later produce identical color prints by using the stored data. Furthermore, the APS system allows photos with classic, wide, and panoramic picture formats.

Because of its highly developed periphery, it is possible to transfer the pictures stored on photographic film via a video signal to a conventional TV screen for viewing. The picture can also be transferred via a digital connection to an APS player, processed by the computer, and be printed out. This could affect the dentist's decision in favor of the APS when deciding which new camera equipment to buy.



29 **Photographing the upper jaw**
Retractors keep away the lips. A mirror of optimal size is placed against the lower tooth arch. The photographer stands behind the **patient and photographs** the patient's maxillary teeth using the mirror.



30 **Photographing the lower jaw**
Retractors keep the lips apart when the mandible is being photographed, too. The mirror used for photographing the upper jaw is also used here and is placed against the upper tooth arch. The photographer stands in front of the patient and indirectly photographs the tooth arch of the lowerjaw using the mirror.

Camera Equipment

-SLR camera (APS or 35-mm film),
-Macrolens (90-120 mm focal length) that allows for a 1:1 magnification,
-Matching (TTL-attached) flash, usually ring or multiple side-flash version,
-Photographic film, for example, with standard 100 ASA speed,
-Cheek retractors and intraoral mirrors.

For intraoral photography it is important to use a camera system that allows for the use of a small aperture (usually f-32) in order to obtain maximum,depth of field with the macrolens.

Examples of Conventional 35-mm Camera Systems

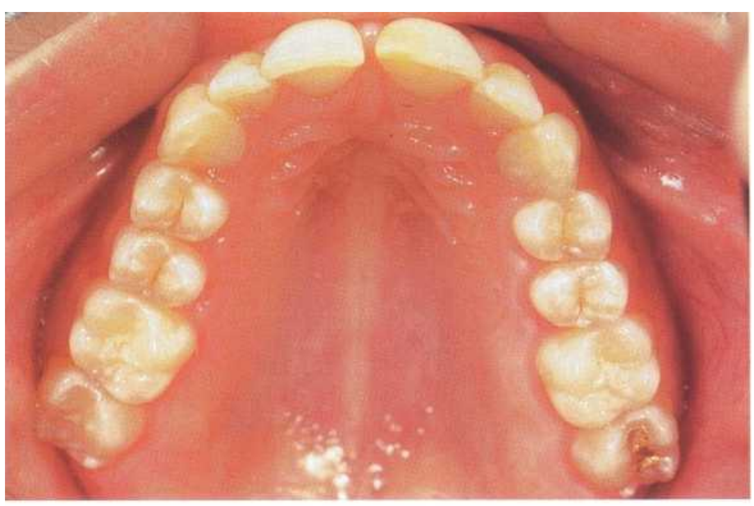
Two dedicated systems are especially suitable for dental close-up photography:
-Nikon Medical Nikkor (120 mm)
-Yashica Dental Eye II

Moreover, it is possible to put together a close-up system from the existing range of all major brands.
-Nikon F-601 AF or F50 with Nikon AF Micro-Nikkor 2.8/105 mm
-Minolta Dyuar 600 si classic or 500 si super with Minolta A-F Macro 2.8/100 mm
-Canon EOS 500 N or EOS 50 E with Canon EF 2.8/100 mm Macro
-Pentax MZ-5/10 or Z-70 with Pentax SMC-FA 2.8/100 mm Macro
-Sigma SA-300N/SA-5 with Sigma AF 2.8/90 mm Macro

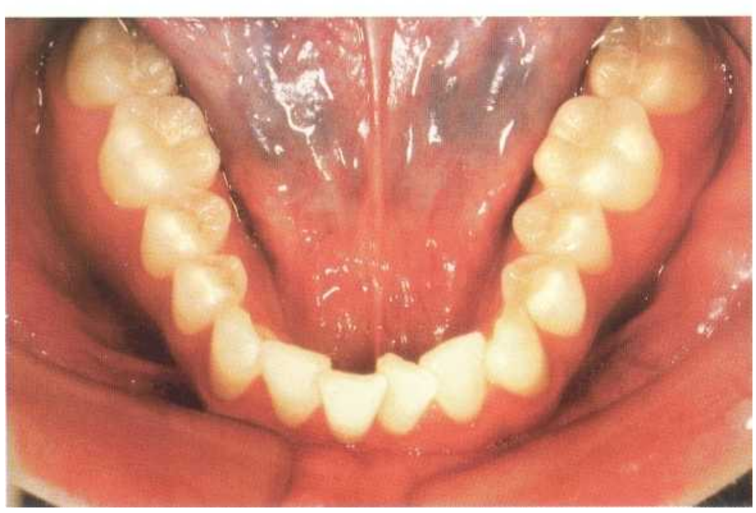
The above-mentioned macrolenses are all original parts. For each brand, matching lenses (macrolenses at focal lengths of 90-120 mm) by companies such as Sigma, Tamron, Toni-ka etc. are also available that often cost half the price of the original brand names. It is difficult to decide which is the best system. It is probably still the best photographer who takes the best photographs, regardless of the system!

APS Camera Systems

The major camera manufacturers have recently introduced APS-SLR camera casings to which special APS lenses, con-ventional 35-mm lenses, or TTL-controlled external flashes (e.g., ring flashes) can be attached. APS systems suitable for dental close-up photography include:
-Canon EOS IX
-Nikon Pronea 6001
-Minolta Vectis S-1



31 Photograph of the upper tooth arch
A magnification of 1:3 to 1:4 is recommended.



32 Photograph of the lower tooth arch
A magnification of 1:3 to 1:4 is necessary.

Digital Camera Systems-Criteria for Selection

A new camera generation no longer records the pictures on a film but on an electronic memory chip. These pictures can be processed further on personal computers or shown on the monitor. Using a color printer such digitally recorded pictures can also be printed immediately.

Digital cameras contain a photosensitive chip (CCD sensor). This converts the picture into electric impulses (digital data). The image is stored in the memory chip, even when the camera is turned off. The image can be downloaded from the camera to the computer via a direct connection between camera and PC. Using a driver and image processing software, usually included in the purchase of such a camera, the photograph can be downloaded from the camera memory and transferred to the screen of a PC or a Macintosh, where it then can be processed. The quality of the picture depends on the pixel density of the chip, which determines whether the digitized picture is in focus or true color.

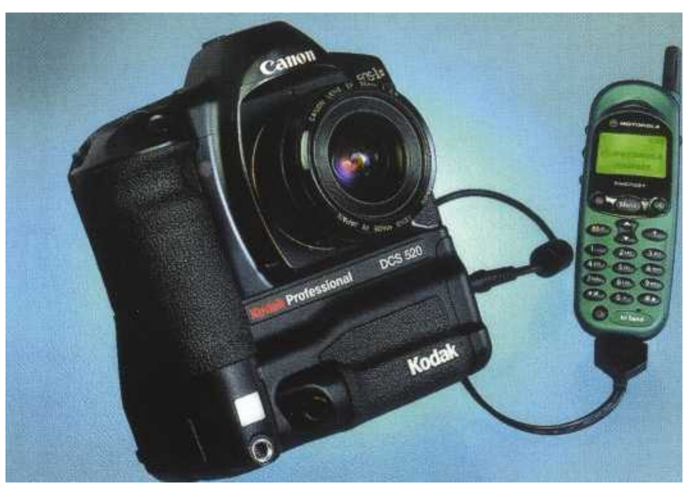
A few years ago, only professional photographers used the new technology because digital cameras were very expensive. However, relatively affordable appliances have been available for some time, whose pixel density still does not compare with that of professional cameras. The possibilities of the digital cameras are enormous. They are most suitable whereever the pictures need to be shown immediately and where there is a wish or need to process them further on the computer.

Resolution

The CCD sensors of a digital camera process information, which is expressed in pixels. The resolution is defined by the number of pixels per inch (ppi) or per centimeter (ppcm). The maximum picture format and the quality are determined by the pixel number.

Bit-depth

The bit-depth defines the maximum number of colors that a digital camera can capture. It not only determines the individual colors but also the hues and the shades of gray. If the gray is only divided into a few shades, an effect known as "posterization" will result.



33 Professional digital camera, single lens reflex with changeable lenses, allowing wireless transmission of graphic files to the laboratory or other recipients. Additional professional Kodak cameras are the DCS 330, CDS 500, 520, 600, and 620.

34 With an appropriate printer, the images can be printed in photographic quality; here the Kodak Personal Picture Maker Kit is shown.

No more than 256 (8 bits) shades of gray can be used by the usual computer programs during picture processing. Most digital cameras have a higher bit-depth. They dismantle the analogous data into 1024 (10 bits), 4096 (12 bits), or 16 384 (14 bits) steps. The computer then reduces the quantity of incoming data. Eight bits are available for each of the three primary colors, which means that it can process 16.7 million (256-256 . 256) colors.

Lenses

The quality of a picture is also determined by the quality of the lens. High-resolution, professional cameras with interchangeable lenses (e.g., Kodak of DCS 1 to DC 5, DCS 410 to DCS 460 with Canon or Nikon) are available. These modified 35-mm cameras offer a high picture quality, with, however, a concomitant large amount of image data. Only powerful computers with a large RAM can process this amount of data.

Normally, affordable digital compact cameras are sufficient for use in the dental practice. Figures 33 and 35 give an overview.

Technical Prerequisites for Digital Photography

For processing digital pictures in the dental practice the following equipment is needed:

- Camera (Figs. 34 and 36).
- PC with fast graphic card and a large RAM (preferably 64 MB or more RAM).
- Software: The most frequently used image-processing software is Adobe PhotoShop. For dental applications, a "light" version is available. However, the complexity of these programs should not be underestimated.
- Color printers: Most color printers by Canon, HP, Citizen, or Lexmark are suitable for printing the pictures immediately. The printer has become the most affordable component of the entire digital system.

Camera	Casio QVC 2000 UX/IR	Epson PhotoPC 800	Fujifilm MX-2900 Zoom	Kodak DC280 Zoom	Olympus Camedia C-21	Sony DSC-F505
Resolution	1600 x 1200	1600 x 1200	1800 x 1200	1760 x 1168	1600 x 1200	1600 x 1200
Focal length	36 – 108 mm	38 mm	35 – 105 mm	30 – 60 mm	38 mm	38 – 190 mm
Removal storage type / size	CompactFlash 8 MB	CompactFlash 8 MB	SmartMedia 8 MB (2x)	CompactFlash 20 MB	SmartMedia 8 MB	Memory Stick 4 MB
Storage	yes		yes	2 MB		
Manual focus	yes	yes	yes	no	yes	yes
Finder / monitor	yes/yes	yes/yes	yes/yes	yes/yes	yes/yes	no/yes
Flash / external flash plug	yes/no	yes/no	yes/yes	yes/no	yes/no	yes/no
Interfaces	USB, seriel, IrDa-Ir, PAL	USB, seriel PAL	seriel, PAL	USB, seriel, PAL	seriel, PAL	seriel, USB, PAL
Minimum focus	50 cm	50 cm	90 cm	50 cm	60 cm	50 cm
Minimum focus macro	50 cm	15 cm	25 cm	25 cm	15 cm	8 cm
Lightmeter: integral, spot, matrix	integral, spot, central emphasis	integral, spot,	integral, spot, matrix	integral, spot	integral, spot	integral
White compensation automatic, manual, stepped	manual	manual	manual	stepped	stepped	manual
Sensitivity (ASA)		100, 200, 400	125	70	100, 200, 400	100
Microphone, maximum length of recording	no	10 s	no	no	no	5 s per image
Video, maximum length	30 s	mp	no	no	no	60 s
Shutter speeds	1/800 – 1 s	1/750 – 1/30 s	1/2000 – 3 s	1/755 – 1/2 s	1/750 – 1/2 s	1/750 – 1/6 s
Power supply	4 batteries type AA	2 NiMH rechargeables	1 NP-80	alkaline batteries or NiMH rechargeables	lithium block CRV3 or 2 NiMH AA	lithium ion rechargeable NP-FS11
Size / mm	130 x 75 x 61	113 x 67.5 x 35.5	129.5x68.5x60	133 x 52 x 76	106 x 62 x 35.5	107 x 62 x 136
Weight	435 g	280 g	400 g	460 g	240 g	485 g

35 Digital camera systems (amateur systems)
Technical specifications.

Summary

Digital technology is undoubedly the future of photography. Within a few years we will see the film as a medium for photography become a relic from the early days of photography. Digital photography offers fantastic possibilities: the pictures can be printed out immediately, text can be inserted (e.g., a treatment plan), and these pictures can be transferred using a modem.

However, the biggest advantage of processing the images directly is at the same time associated with some major risks: a digital image that has been altered cannot be distinguished from an original picture. Today, many dental presentations in the international continuing education circus are already using digital images. Hardly a printed medium still contains unmodified original pictures. The pictures are digitized when they are scanned into the computer and then they can easily be reworked using image processing software. The gingiva from one tooth site can be spliced electronically and inserted at another tooth site, tooth color can be altered ... the way has been opened for liars and cheaters, and it is appropriate to be doubtful when the results are all too perfect. Therefore, digital technology may also be a great danger for photography.

When one decides to buy a system for the practice, one should not automatically decide in favor of digital photography systems. One must be familiar with such solutions and want to solve problems associated with the computer and their programs. The existing image processing programs are still very complex. That means that digital photography can soon become frustrating. At the moment, therefore, the computer lay person should stick to conventional photography.

APS technology has some advantages over the classic 35-mm film. However, it also requires a particular film development process that is not available everywhere. If there is only a 1-hour development photo laboratory nearby, the conventional film is more advantageous. The decision to choose APS technology with its peripherals and the different formats should mostly depend on whether or not a photo laboratory close by can develop the new film system within a few days.

It is important to develop experience of photography. A patient education album with one's own exposures can be put together. Such documentation has great power of persuasion. For example, the photos can be printed in a patient newsletter. The future of a successful dental practice lies in which treatment alternatives the practice can offer to patients. An active marketing of the performance spectrum of the practice is necessary. An important prerequisite is an extensive archive with one's own, good-quality pictures.

Dentists also can determine their own quality performance by studying the photographs they take. By regularly reviewing their own treatment cases, critical observers can assess the regular ups and downs of normal human capability and their own mastery of the art of dentistry.

Finally, dental photography is used for documentation in forensic cases. In the United States, the oversupply of lawyers has turned into the "lawyer plague" for physicians and dentists. A similar development is occuring in other countries.

Thus, to successfully integrate photography into the dental practice, the dentist and the dental assistant need to learn how to handle the camera just as well as they now handle radiographic equipment.

36 Further example of a digital camera: Fujix DS-220
This camera not only has an optical viewfinder but also an LCD display. It can be used for photography in the macro range.

Intraoral Cameras

Originally purely a discipline geared at eliminating pain, dentistry has evolved into a discipline with many different complex treatment procedures. This change is, to a great extent, due to the longer life expectancy of people (see also: The Future of Dentistry, p. 279). The transition from symptomatic treatments to patient-preferred treatments requires extensive patient education by dentists and their staff. Practices in which there is no active patient education have recorded a decline in treatment activity; this is because of the general decrease in caries activity that has occurred in the population. In contrast, practices that provide extensive patient education have demonstrated fast and impressive growth and an increased use of new treatment techniques.

37 **Intraoral camera system (e. g.,** Reveal)
Does not every dentist like to practice state-of-the-art dentistry? For each tooth defect there are various restorative methods that have different prognoses and prices. Therefore, it is important that the dentist shows patients the status quo of their teeth and demonstrates the different treatment options. Intraoral cameras are imperative for these presentations.

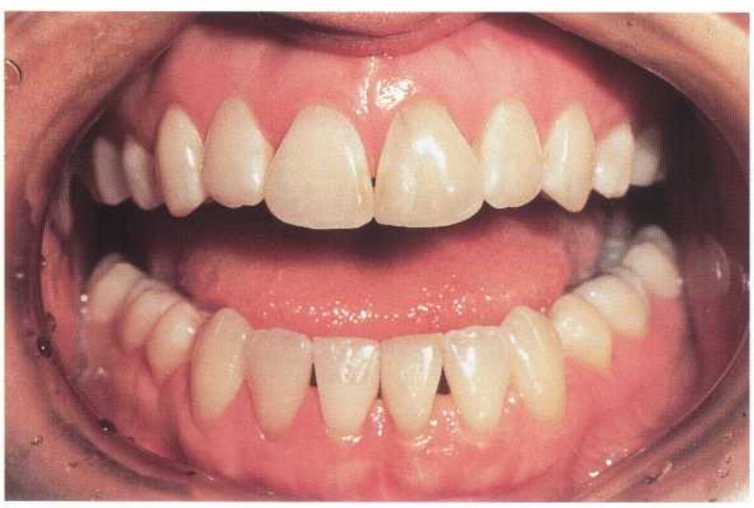
Use of Intraoral Cameras

In the late 1950s and the 1960s, different presentation techniques found their way into dental education. Video technology with close-up images was used to demonstrate treatment methods. Nowadays, video technology has become both a teaching and learning tool in all areas of education and training. Numerous training programs-used also in dentistry-are nowadays supported by instructional videos.

Dentists are somewhat restrained in their use of video technology in patient education. A possible reason is that the pain-oriented dentistry practiced earlier, which was primarily therapy-oriented, did not require any detailed patient education. However, because of the changes that have occurred in dentistry, new methods are needed for patient education, including video technology. Since the 1970s, many health-related organizations have developed films targeting patient education. This method of education is meaningful and should be used by all dentists.

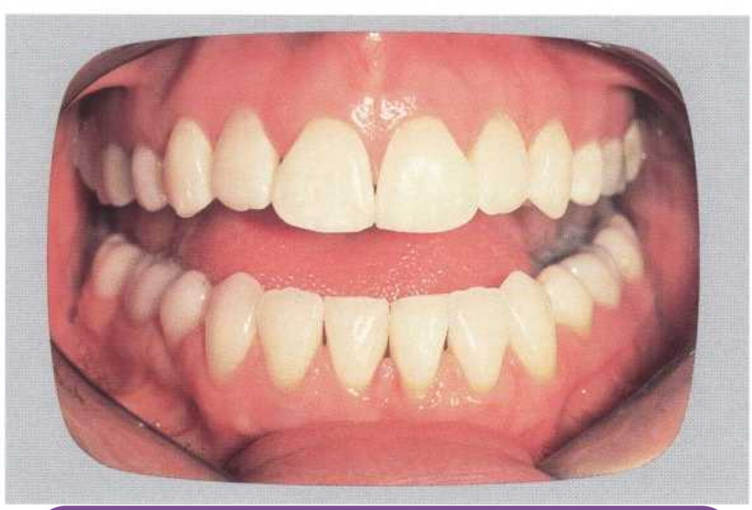
In different areas of medicine-particularly in gastroenterology-endoscopes have been used for many years. The first intraoral video camera, the *Fuji DentaCam,* was developed from these endoscopes in 1987. Even though interest in the camera disappeared soon after its introduction, there were some dentists who realized the potential of intraoral miniature cameras. Since then, many manufacturers have made developments or improvements in intraoral cameras.

Simultaneously, so-called imaging systems were being used in many areas of industry and medicine, with which digital pictures (of houses, cars, faces, etc.) were taken and later processed with the help of a computer. This imaging concept was also introduced into dentistry in the late 1980s and was used to change electronic images of anatomical, oral outlines to be used in treatment planning and in patient education. Although many users assumed that this imaging concept would be an extraordinarily successful method for improved patient education, it has not yet found the acceptance it deserves among users of intraoral cameras.



38 Computer-based patient information
A patient wishes to have his/her teeth bleached. One can demonstrate the status quo by means of this picture.

Right: Newsletters are not only brochures forthe practice, but are also useful for informing patients about certain treatments or as a marketing tool. However, it must be remembered that brochures distributed by the industry are often of questionable value.



39 Computer-generated simulation of the treatment goal
Tooth color can be brightened on the screen according to the patient's wishes. The dentist can then determine whether it is possible to do justice to the patient's ideas using the available methods. If this is not possible, the dentist can demonstrate a more realistic treatment goal to the patient before treatment starts.

Patient Education

Dental practices that are equipped with intraoral cameras use them, first and foremost, to show patients their own intraoral images. Video films, watched in the practice or at home, can also be used to promote patient education. These two ways of using video technology predominate in dentistry today.

How Can the Intraoral Camera Be Used to Educate Patients?

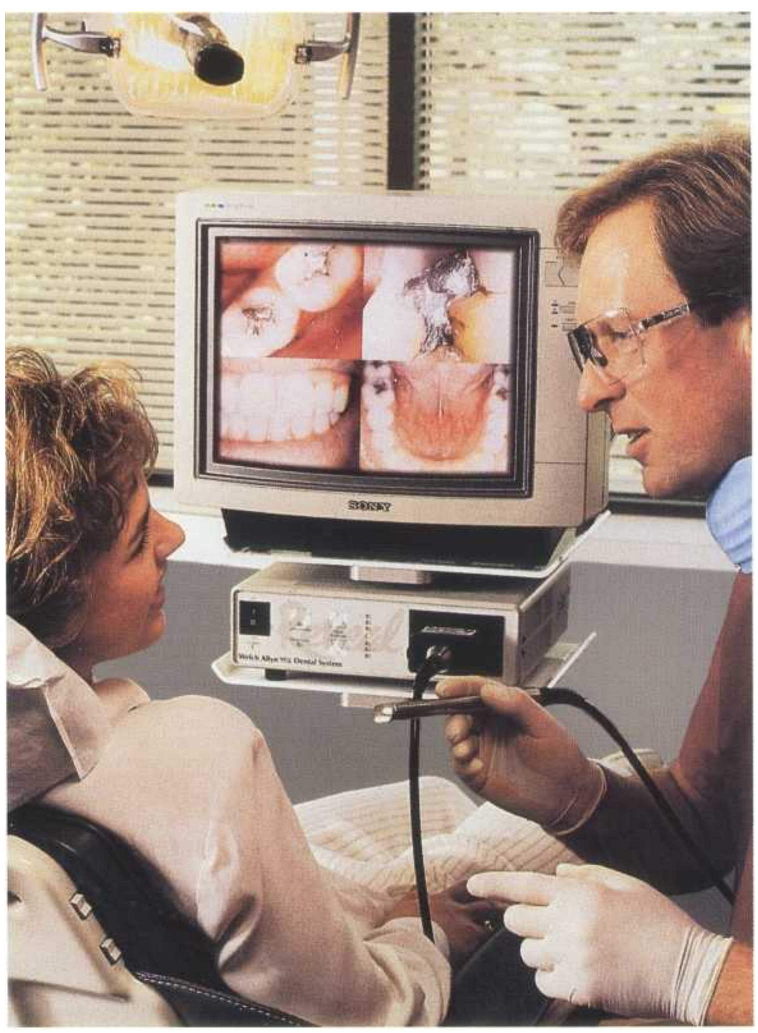
Diagnosis and Treatment Planning

Each dentist uses different methods to modify patient behavior and acceptance of treatment plans. The intraoral camera allows the patient to directly observe the intraoral situation for the first time. Thus, the patient can participate directly in the decision-making process as far as the treatment plan is concerned. The dentist or staff can use an intraoral camera to explain any relevant details to the patient. In a dental office with well-trained staff, patient education is usually performed by the staff. This is cost-saving and, furthermore, the staff are often more thorough than the dentist in presenting the instructional aids.

Intensive patient education with the use of intraoral images is recommended because these images show the necessity of a treatment or a particular, selected treatment method. The intraoral camera is a simple, easy-to-use medium for educational purposes. The areas of the mouth requiring therapeutic measures are shown on the screen situated in front of the patient. This relatively self-explanatory method usually leads to acceptance of the proposed therapy.

A diagnostic session which also uses an intraoral camera takes only a little longer than a regular session. Patients taking advantage of such a diagnostic session alter their behaviour and develop, often spontaneously, an astonishing interest in the condition of their oral health. The advantages for the dentist lie in having an increasingly active practice and the introduction of new clinical techniques.

The intraoral camera is used primarily for patient education in the dental practice. The integration of an intraoral camera in the diagnostic session necessitates neither radical administrative changes nor other serious alterations.



40 Intraoral video appliances used chairside
The intraoral video camera and the monitor should be installed close to the dental chair so that they can be used without significant time delays.

Cosmetic Imaging

Imaging methods are used to demonstrate to the patient possible modifications, for example, by means of aesthetic dentistry. Moreover, they open up new possibilities for the dentist in aesthetically-oriented therapy. After images of the oral structures have been made, they can be modified electronically. For example, a diastema can be closed, tooth color can be lightened, the visible gingiva can be increased or reduced, a chin remolded, class-III malocclusions altered, etc. These results can consequently be seen by both the dentist and the patient.

If "before and after" pictures are shown, the computer-processed electronic image becomes particularly impressive for patients and often results in behavioral changes. However, use of intraoral images results in significantly greater changes in the routine of the practice than use of intraoral camera does. More time is required for a diagnostic session. Normally, a separate room must be available, and highly motivated and well-trained staff are needed who have sufficient time and creativity to demonstrate the different therapeutic options to the patient.

During Treatment

The necessity of altering a treatment plan during therapy arises relatively frequently. Generally, many patients cannot accept this. The intraoral camera can substantially improve the patient's acceptance. If, whilst restoring a cavity, a full crown becomes necessary, the reason for the altered treatment plan can be explained to the patient on the spot with the help of the intraoral camera. The result is an improved dentist-patient relationship and increased acceptance.

After Treatment

Nowadays, it is especially important to gain patients' trust, so that they accept the chosen therapy. By using "before and after" pictures after treament has been completed to tactfully demonstrate differences to the patient, the dentist has a reliable way to build up trust and improve the dentist-patient relationship. The intraoral camera is also an outstanding tool for this task.

41 Mobile cart with integrated intraoral video player
The advantage of a mobile cart is that it can be used in several treatment rooms.

Documentation

The following section gives examples of situations in which it is necessary for the dentist to take pictures of oral conditions.

Informing Family Members

Frequently, it is not the patient to be treated (child, spouse) or the patient alone who decides how the therapy will be carried out and paid for. Many intraoral camera systems now offer printouts of the oral conditions displayed on the monitor. These printouts can be given to the patient to be take home, thus facilitating the decision as to whether or not to execute the treatment plan.

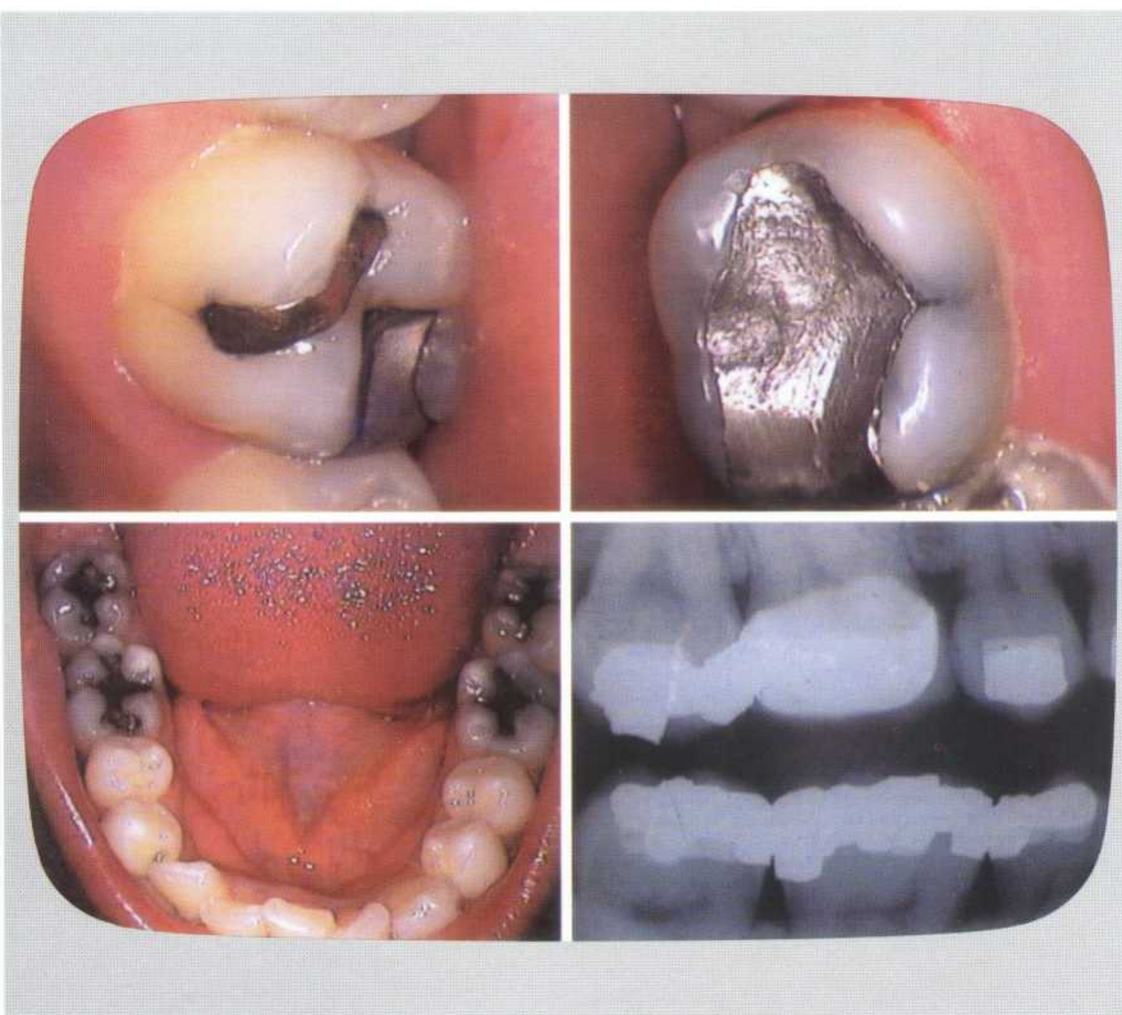
Insurance Companies

Prints of intraoral conditions, showing the necessity of a proposed treatment, are invaluable for dentists when they are negotiating with insurance companies. An excellent example of this is a patient with a root fracture, of which no radiographic image is submitted, but instead a picture of the current condition in the mouth. Insurance companies can be positively influenced by such pictures.

Dental Picture Archives

The pictures generated by an intraoral camera are excellent for clinical research documentation, patient information, or for documentation of situations that do not (yet) require treatment, but need to be observed further. Some dentists also prepare patient portraits that are attached to the patient records.

The storage of digital image data requires a large memory capacity. As well as the normal disks (Compaq), special ones are available, namely, Zip and Jaz drives, streamer, interchangeable hard disks, and rewriteable CD-ROMs in conjunction with a CD-ROM recorder.



42 **Oral images on the monitor**
Every dentist is familiar with the problem of showing the patient defects on posterior teeth using two mirrors. Despite the dentist's efforts, the patient, in general, neither recognizes the problem correctly nor understands it.
On the screen, the defective amalgam fillings can be demonstrated much more clearly and digitalized radiographs can be used to give added weight to the arguments previously put forward.

Improved Vision During Treatment

There are certain situations in the daily routine of a dental pracatice in which the dentist cannot adequately see the area which is being treated. The intraoral camera enables the dentist to see the area or to freeze a specific image on the monitor which can then be used for guidance during the treatment.

Although learning how to manipulate the camera in order to improve vision during treatment requires time, this pays off later.

Treatment Using Indirect Vision

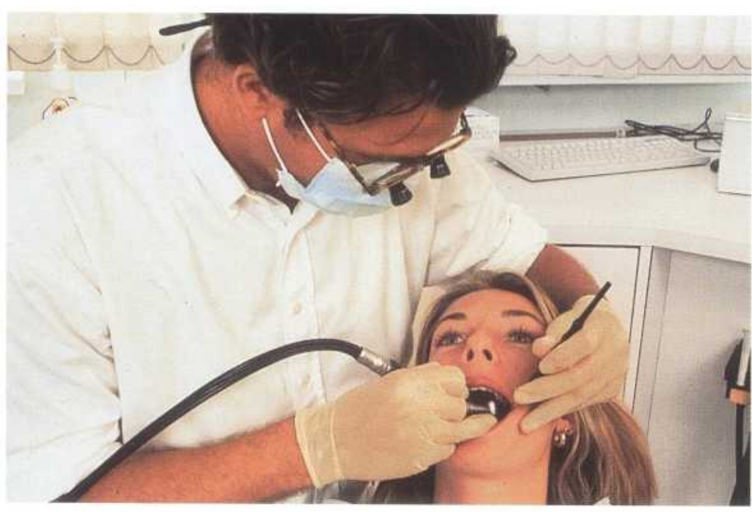
In some areas of medicine, doctors have already used monitors for some time to perform surgery and other treatments. Some dentists have also gone through this transition, at least regarding certain procedures.

Presently, images on the monitors are two-dimensional, without recognizable depth and width. Therefore, certain procedures are more difficult to execute with indirect vision. Simple procedures suitable for learning the method include adjustments of occlusion, which is of a two-dimensional nature.

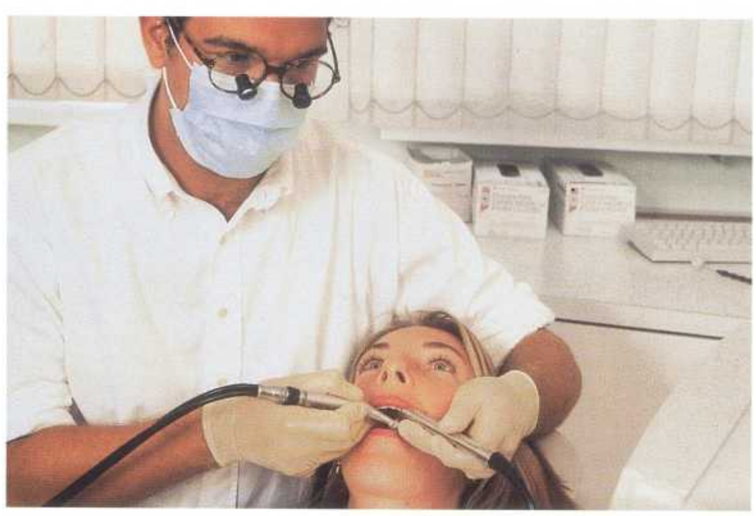
The advantages for the dentist are:

-A relaxed upright working position,
-Magnifying eyeglasses are not necessary,
-Enlargement on the monitor can be achieved by zooming,
-Regions that are difficult to access can be viewed.

It is expected that the indirect procedure will develop further in the future and gradually become routine in dentistry. The intraoral cameras of the future will probably be located in the head of the handpiece or the turbine.



43 **Treatment using direct vision**
Following the course of the treatment directly in the patient's mouth is often quite cumbersome. Under these conditions, the dentist is often forced to adopt a very unhealthy posture that can result in early wear and tear of the spine.



44 **Treatment using indirect vision**
In many areas of medicine, treatment is already being carried out using image-generating procedures that use indirect vision. Today, certain methods are already available to dentists as well, enabling them to treat patients via a monitor. The use of an intraoral video camera is a prerequisite for this.

Using Videos for Patient Education

Use of video for patient education is the simplest and most advantageous method. It has already become standard practice for a large number of dentists to show short video-tapes in the treatment room. These films can be shown in the following ways:

- -on the monitor connected to the intraoral camera
- -on a standard VCR monitor, similar to a regular TV
- -on a special monitor located on the ceiling of the treatment room

In order to reduce the noise level typical for a dental practice, the patient is given headphones. There are numerous opportunities to show the films, for example, during the diagnosis session, at preoperative or postoperative treatment sessions, or during treatment.

If patient education using video films takes place during treatment, the best place to install the monitor is just below the ceiling. By doing so, the patient can be informed during less demading treatment. If patient education is to be integrated in the routine of the practice, suitable VCRs, monitors, headphones, and tapes must be available.

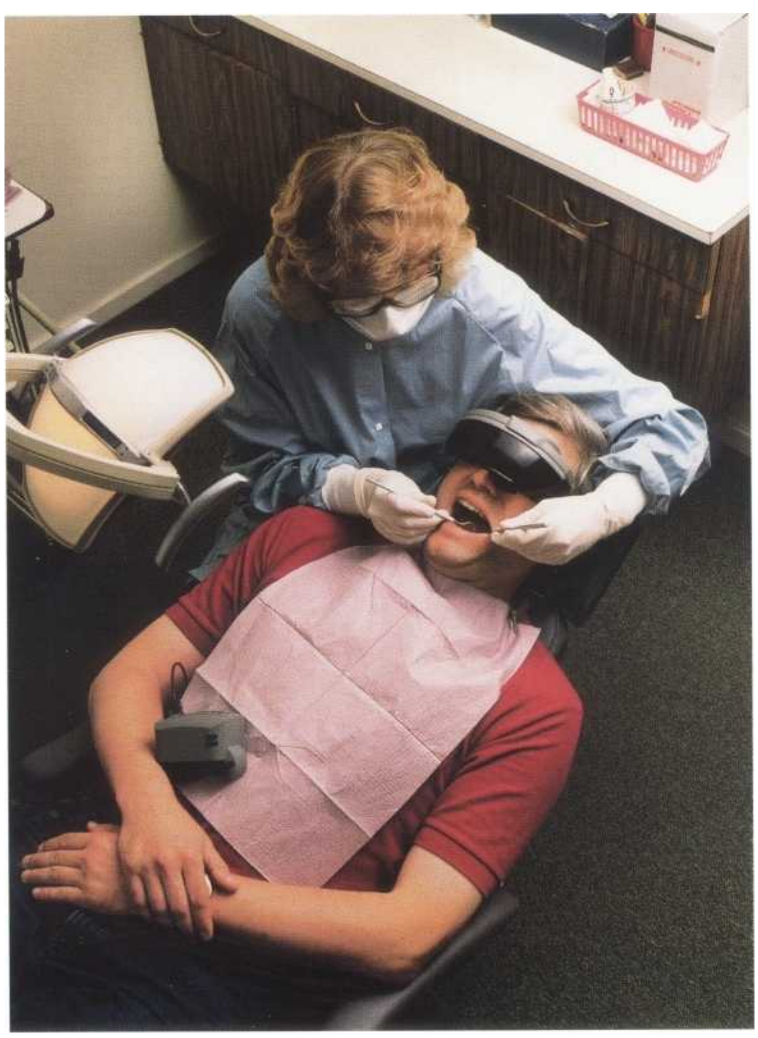
Cost-Benefit Considerations

Most dentists are worried about the expenses incurred by the intraoral camera, imaging system, or patient education by use of video technology. At first, the cost of purchasing the technical equipment and the tapes appears high, and integrating the equipment takes up a great deal of time. However, dentists should not be discouraged by this. Those who have already beeen using these concepts in their practices for some years confirm that the expense and effort involved pays off within a short period due to the patients' increasing acceptance of the proposed treatment plans.

The following three priorities emerge from the concepts introduced in this chapter:

1. Videos for patient education
2. Intraoral cameras
3. Imaging

Some systems are available that combine video technology and intraoral cameras; other complete systems combine all three concepts in one single system.



45 **Video films during treatment**
Some patients like to watch a video movie during a treatment. Video glasses and glasses with an integrated monitor help fulfill such a wish. Who would not like to pursue the course of his/her own treatment with a pair of such glasses? This is the concept of virtual reality in dentistry.

Characteristics of Intraoral Camera Systems

Clinical Research Associates (CRA) in Provo, Utah, identified the requirements that an intraoral camera should fulfill (1991). They are:

Manipulation: Only one hand should be needed to operate the camera.

Wide observation field: The camera should be able to view several teeth (a quadrant) simultaneously. This provides better orientation for the patient and makes it easier for the dentist to perform treatment with indirect vision. The ideal intraoral camera should be easy to adjust from close-up pictures of the teeth to pictures of the entire dentition.

Small camera hand-pieces: These should allow distal tooth surfaces and posterior teeth to be visualized.

High resolution: An intraoral camera should have high resolution without noticeable distortion.

Stills: It should be possible to take stills with an intraoral camera at high resolution. A still picture is helpful when analyzing and discussing a particular intraoral condition.

Accurate color reproduction: Poor color reproduction is confusing for both patient and dentist.

Automatic light regulation: Additional light sources to improve the light conditions for the intraoral camera should not be necessary.

Sterilization: An intraoral camera that can be sterilized would be desirable. However, sufficient disinfection is guaranteed by means of plastic foil wrapping.

Printing the pictures: A high resolution is necessary for documentation. The printer should be equipped with a large RAM (16 MB).

Rotation of pictures: It must be possible to rotate a picture by 180 and to change left-right orientation to execute a left-right switch.

Activation of the appliance: The intraoral camera should have a simple "on-off' switch and a short or no warming-up period.

Size of the unit: The smaller the better.

Further aspects: Multifunctional applications are advantageous, i.e., the camera can be networked to additional monitors and connected to other VCR equipment.

New developments are constantly taking place in intraoral cameras, which means that we will see new, improved features on a regular basis.

46 **Components of an intraoral camera**
An intraoral camera consists of a camera with interchangeable lenses (left) and a device capable of processing the video signals (right).

47 **Intraoral camera**
The lens of the intraoral camera should be very small, so that it can be used for endoscopy as well as in the oral cavity.

Using Intraoral Cameras

While some dentists use only one treatment room, others use several simultaneously. Ideally, one monitor should be available in each room. Some systems allow the camera to be connected to the monitor or printer in each treatment room. Portable complete systems, easily transferred, can also be used.

Many dentists start off with a simple portable system and then later progress to installing a monitor in each treatment room.

The four most important applications of the intraoral camera include:

- -Showing the present condition of the teeth
- -Describing the condition of the teeth after treatment, using an imaging system
- -Explaining different treatment methods by means of a video
- -Documentation

Summary

Different recording techniques are now available, which enable dentists to provide patients with information in a manner which was previously not possible. This obviously contributes considerably to improving patient education. The best known concept in dentistry is the educational use of videotapes and intraoral cameras. The integration of both techniques in a practice should be recommended to every dentist. This increases patients' acceptance of different treatment alternatives that are now offered by modern dentistry.

Imaging systems allow dentists and patients to visualize and judge the planned treatment and its aesthetic impact even before beginning therapy. Imaging systems are less common than intraoral cameras, but they can be of great value when properly applied. The use of video technology can also be expected to spread in the future in indirect dentistry, i.e., the dentist performs the treatment with the aid of a camera and a monitor.

48 **Integrated video system with flexible camera**
To reduce the disadvantages of a mobile cart (preparation time, installation), and to make use of the advantages of integrated systems, some manufacturers now make the expensive camera the only mobile part of the system. This enables the camera to be used in several rooms with integrated systems.

Recommended Cameras

Several brandname appliances reflect how fast technology is evolving. They all have the required characteristics outlined on p. 32. The following appliances represent the spectrum of developments in intraoral cameras that are currently available. Three of them (Acucam, Reveal, and Cygnascope) have a relatively wide depth of focus and only one lens. This enables the camera to be used in all four of the important areas of application of the intraoral camera.

However, the technological advances in this area are so rapid that it is recommended that all available appliances on the market are checked for the desired characteristics.

Acucam

This camera system has been the market leader for several years. It has been improved continuously. Acucam can be installed as a mobile unit, but it is also available as a multifunctional appliance, so that this camera can be connected to the monitor installed in each treatment room.

Reveal

This intraoral camera system is relatively new on the market. The manufacturer mainly produces endoscopes for various uses in medicine. Reveal was one of the first companies to make sterilizable, lightweight camera systems that could be combined with an easy-to-use, multifunctional concept. It is also available as a mobile standard unit.

Cygnascope

This is the smallest intraoral camera system available on the market. It can be carried by hand from one treatment room to another. In addition, the camera is currently the smallest available.

Insight

This company is one of the pioneers in the field of digital graphic representation, which has helped this camera concept to increase its versatility and broaden its area of application. It is very useful for both patient education as well as for documentation.

49 **Comparison of eleven currently available intraoral cameras**
Clinical Research Associates in Provo (Utah, USA) performed currently the most extensive comparative study on intraoral camera systems.

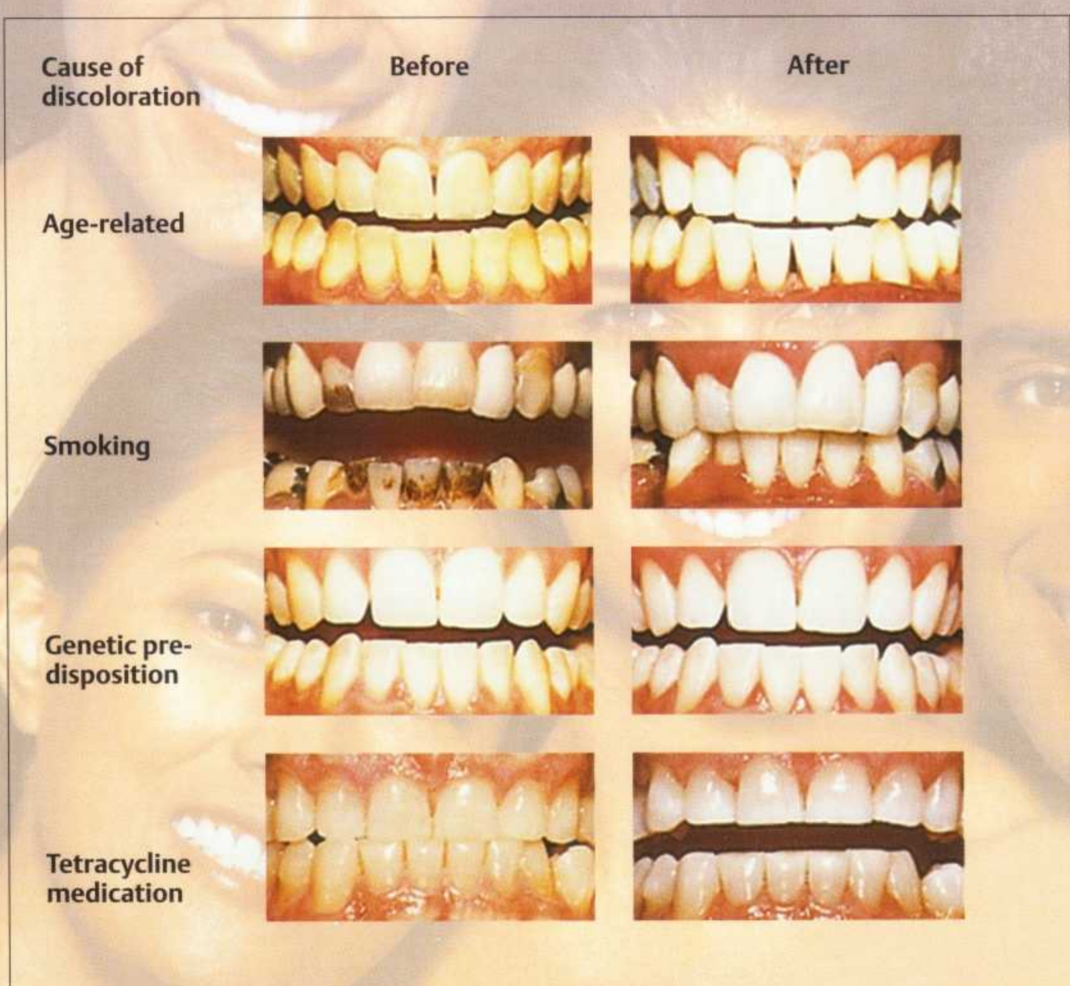
7 excellent
5 good
3 acceptable
1 inadequate

(Adapted from: CRA Newsletter, May 1996)

Camera type	Simplicity of setup	Mobility	Electrical safety (certificate)	Convenience of switch	Warm-up time after cold start	Time until operative	Ease of use (handpiece)	Intra-oral access	Infection control	Focussing, sharpness	Light, fast, simple switch	Image resolution and natural color: monitor/print	Fast test photos possible?	Overall assessment
Vistacam	7	6/7	UL	5	7	7	1	7	5	7	7	7/7	1	6.1
Acucam Plus	7	7	UL	5	7	7	2	6	5	7	6	7/6	1	6.0
Cygnascope 240 E	6	6	CE	6	6	7	6	6	5	6	6	6/6	7	5.8
Insight 20/20	6	5	UL	6	6	7	6	6	5	6	6	6/5	7	5.5
Ultracam II	5	6	–	5	6	5	6	6	5	6	4	6/6	3	6.0
Reveal	3	7	UL; CSA; CE	5	6	4	4	6	6	6	5	6/6	3	5.3
Proscope 1000	5	7	UL	3	5	5	5	7	5	3	3	5/5	5	4.8
Easy Cam	3	6	–	5	3	5	6	7	2	4	3	7/3	6	4.5
Toothpix	5	7	–	4	4	5	5	7	3	2	5	4/3	6	4.5
Computer integrated: STV-HD	1	7	–	4	1	7	4	6	4	7	1	7/5	2	4.5
Computer integrated: Power 20/20	1	1	UL	1	1	7	6	6	4	6	1	6/5	7	3.8

Bleaching

Beautiful white teeth were already important to the Romans. They polished their teeth using urea (carbamide), especially urea from Portugal because this was known to give the teeth a brillant white appearance. During the Middle Ages, tooth bleaching was a barbaric treatment. The barbers not only extracted teeth, they also bleached teeth with aqua fortis, a mixture containing nitric acid. This treatment was initiated by first filing the patient's teeth—today one would call the process "recontouring"—with an iron grater. At the beginning of the 20th century, teeth were bleached with high concentrations of hydrogen peroxide (H_2O_2). The micro abrasion technique, i.e., the use of a weak hydrochloric acid solution, was used to remove stains. These treatment methods were first published in 1895 in the American Journal of Dental Science (Westlake 1895). At the beginning of the 20th century, "Colorado brown stains," a form of fluorosis, were also removed with diluted hydrochloric acid (micro abrasion) and hydrogen peroxide (bleaching).



50 Various causes of teeth discoloration before and after bleaching
Many teeth have discolored surfaces. As one ages, teeth become darker and change to a brown-orange color. In addition, external effects of tooth discoloring are observed, such as those from smoking and some beverages (coffee, tea, red wine, etc.). However, discolorations are also due to genetic conditions or caused by the use of certain medicines (tetracycline).

Courtesy of *Discus Dental Corp.*

History of Bleaching

Bleaching in the Practice

At the end of the 19th century, dentists began to bleach vital teeth. Westlake (1895) used a mixture of peroxide and ether. Abbot used Superoxol, a stabilized mixture consisting of 30% H_2O_2 to bleach teeth discolored by fluorosis (Abbot 1918; Prinz 1924). Ames earned his fame with a mixture consisting of 30% H_2O_2 and ether that he used with a source of heat (Ames 1937). Indeed, a treatment lasted approximately 30 minutes and the sessions were repeated up to 25 times.

Zack and Cohen (1965) were the first to conduct a scientific evaluation on how the effect of the source of heat affected the pulp. They found no pulp damage. The results were later confirmed by Nyborg and Brannstrom (1970).

Since 1972 Arens has also tried to bleach tetracycline disco]-orations with 35% Superoxol kept at a temperature of 10'C below the pain threshold.

Home Bleaching

The orthodontist Klusmier from Fort Smith, Arkansas, had, like so many other orthodontists, patients with problematic gingivitis. He examined the effect of Gly-Oxid (Marion), which his young patients used during the night in a removable appliance. This treatment resulted in a close-to-healthy gingiva. After some patients had used this gingivitis therapy for some time, Klusmier discovered that the teeth had become brighter and that lighter tetracycline discolorations had disappeared. He presented his observations between 1970 and 1975 at different "table clinic" meetings. In 1972 he experimented with the somewhat thicker Proxigel (Reed & Carnrick Pharm.) retained in a tray.

The periodontist Wagner, a colleague of Klusmier's, explored the use of the method in adults and subsequently discovered that the gingiva was somewhat less inflamed and that the teeth appeared whiter. Slowly the method spread and was adopted in 1988 by Haywood at the University of North Carolina. Haywood and Heymann (1989) developed a home bleaching technique that is still the currently used standard of care.

Carbamide peroxide has been long known among periodontists as an oral antiseptic substance. Munro described in 1968 that as a side effect of using carbamide peroxide in a splint, the teeth became whiter.

51 Survey of dentists opinion on bleaching
Survey of members of the American Academy of Cosmetic Dentistry, conducted in 1992.

Dentists

- 67 % use bleaching techniques in their practices.
- 88 % are convinced that bleaching is not harmful.
- 99.2 % found no damage to teeth after bleaching.

Patients

- 46 % were very satisfied after bleaching treatment.
- 43 % were satisfied after bleaching.
- 10 % had expected more from bleaching.
- 57 % return after approx. 1 year to receive follow-up treatment.
- 61 % experienced no or only little tooth sensitivity pain during the bleaching treatment.
- 34 % had moderate tooth sensitivity during the bleaching treatment.
- 2 % had very sensitive teeth during the bleaching treatment.
- 68 % expressed no tooth sensitivity 1 week after bleaching.

Based on his findings, the first commercial bleaching agent was developed for bleaching vital teeth, namely White & Brite (Omni) containing 10% carbamide peroxide.

Vital and nonvital tooth bleaching has not been around for very long, which is reflected in the list of commercial products being introduced on the market:

1989	White & Brite by Omni
1991	Opalescence by Den-Mat
1992	Nite White by Discus Dental
1994	Platinum by Colgate

The sales figures during the past 4 years have more than quadrupled. Bleaching is popular: patients wish to have white teeth and dentists see this as a new area to do business in.

A survey conducted by the Clinical Research Associates in 1994 gave an extremely positive trend: 92% of the 7 617 dentists surveyed bleached their patients' teeth patients as a matter of routine-in more than 90% of cases to the fullest satisfaction of the patients.

Only few innovations have had such a high degree of acceptance among both the public and professionals.

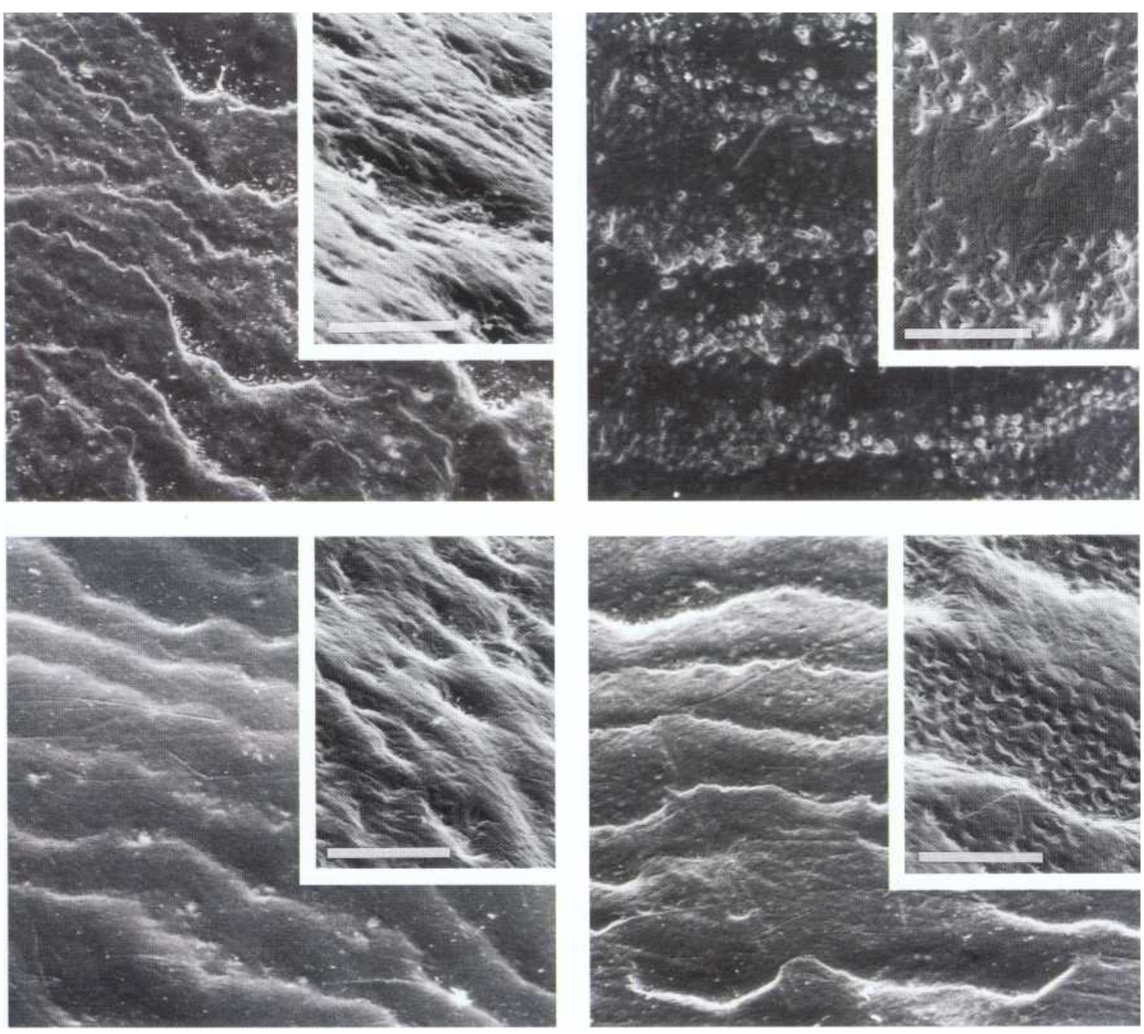
Scientific Studies

Haywood published his first studies in 1990. Extracted teeth were bleached for 5 weeks in the usual manner. Examination of the teeth using the scanning electron microscope revealed no changes in the enamel. The type of bleaching materials used did not affect the topography of the enamel.

In 1991 Yarborough published a literature review of the topic regarding effectiveness and safety of bleaching. Bleaching can be performed effectively with two substances, namely *carbamide peroxide* and *hydrogen peroxide.* Carbamide peroxide disassociates into H202, C02, urea, and NH_3. H_2O_2 is the effective agent here as well. Bleaching with H_2O_2 has the advantage that it takes place 3 to 6 times faster than with carbamide peroxide.

Murchison examined the effect of carbamide peroxide on enamel and concluded that a short-term application did not cause any significant change to the surface and physical properties of enamel (Murchison et al. 1992).

The majority of scientific studies show that it is safe to bleach teeth with 10% carbamide peroxide (Haywood 1992).



52 **Effect of bleaching on micro hardness and morphology of enamel**

Left (above): A natural enamel surface exhibits well-defined perikymata with irregular contours. It was used as a control and placed in saline.

Right (above): This enamel surface was etched too aggressively (5O% H202). It is relatively porous and has poorly defined perikymata.

Left (below): Enamel bleached with Accel (35% H_2O_2) has clearly defined perikymata and a smooth surface. It was not damaged by bleaching.

Right (below): The enamal appears to be relatively intact after the surface was bleached with HiLite (main component also 35% H202).

Bar = 5O pm

Courtesy of C. Q. Lee

A Review of Bleaching Methods

Bleaching Vital Teeth

To bleach vital teeth, chemicals are placed on the enamel surface. This method is called *external bleaching* and can thus only change the discoloration of enamel.

Bleaching Nonvital Teeth

To bleach nonvital teeth, the chemicals are placed in the pulp chamber. In this way the coronal dentin is changed. The process is called *internal bleaching.*

In-Office Bleaching

These are very aggressive bleaching methods that were used previously when bleaching was done in-office: usually 33% H_2O_2 was used together with heat and light. Damage to enamel could occur with this method. The technique has been named *power bleaching.*

Bleaching teeth in the dental practice continues to play an important role. For example, when front teeth are treated with veneers, the cuspids can be brightened up by in-office bleaching. If one wants to achieve results very quickly, then in-office bleaching is preferred to home bleaching. Stronger chemicals are applied in such situations, but no additional energy sources (heat and light) are used. In most cases, three bleaching treatments are necessary.

Home Bleaching

Advantages

- The dentist needs to spend very little time treating the patient. A requirement is that the dentist has a dental assistant or hygienist who has the necessary qualifications needed for instructing the patient about the home bleaching procedure.
- This bleaching technique is usually more affordable than the in-office bleaching.
- The patients bleach their teeth whenever they wish to do so. They do not have to come to the dental office to do this.
- In home bleaching, in contrast to in-office bleaching, no rubber dam is required. Many patients have an acquired latex allergy and cannot tolerate the rubber dam.
- The bleaching process takes longer and is therefore safer for teeth.

Disadvantages

- Patients must collaborate actively. If they do not wear the bleaching tray, no therapuetic effect will occur. If they use their tray too much each day, the result is often hypersensitive teeth.
- There are patients who prefer to get their teeth bleached by the dentist or dental staff, even if this is means higher costs and longer treatment times.
- The bleaching process takes longer in the case of home bleaching than in the case of in-office bleaching.

Side Effects of the Bleaching Agent

- Bleaching agents contain *peroxides.* These enhance mutagenic effects of other chemicals, such as those present in cigarette smoke. Based on present scientific knowledge, patients should not smoke while wearing a bleaching tray. In the long run, the peroxides can also change oral flora. If bleaching is done over too long a period of time, Candida albicans can accumulate and hypertrophy of the papillae can occur.

- *Power bleaching* changes the structure of the hard tooth tissues and resulted in pulpitis in an animal experiment.

- A common adverse effect that occurs during bleaching is *temporary hypersensitivity.* This disappears in almost every case when the bleaching process is interrupted and the teeth are remineralized using a toothpaste containing fluoride.

- During in-office bleaching, etching bleaching agents are used. If the gingiva is not protected it can be *etched.* However, the damage is temporary and disappears after a few days.

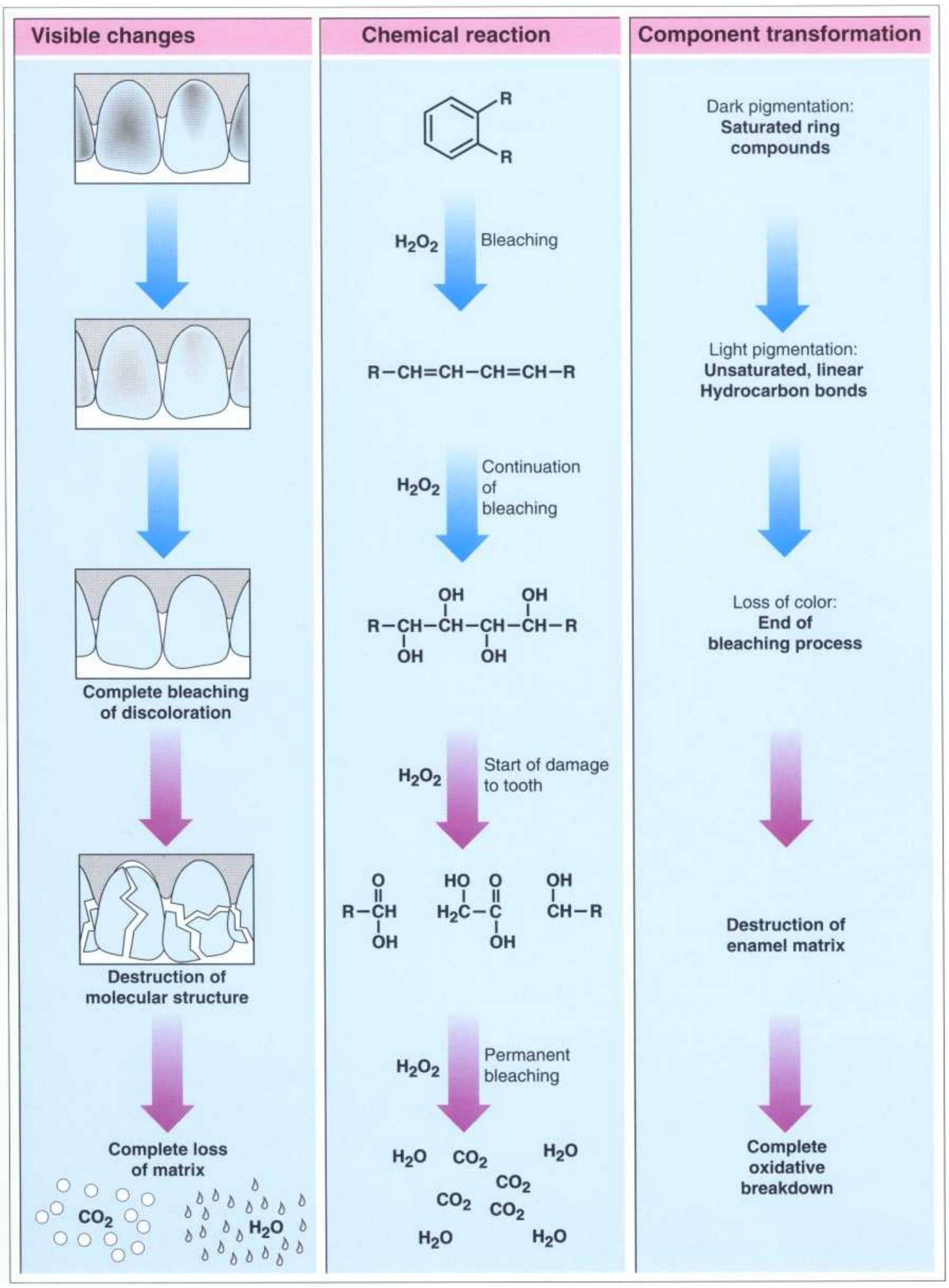
- Patients with *tooth hypersensitivity* should not have their teeth bleached because of the risk of postoperative sensitivity.

-When bleaching nonvital teeth, *root resorptions* may occur. Since the teeth are prepared internally, crown fractures are also possible.

-No restorations should be bonded directly after bleaching because the bonding ability of the adhesive material is greatly reduced. A period of approximately two weeks should elapse before any resorations are bonded.

-The patient should be informed that the bleaching result will decrease with time and it may be necessary to do a supplementary bleaching (after approximately one year). This change in color has several causes (coffee, red wine, fruit juices, soft drinks, and other drinks with low pH-values, smoking, etc.). As long as these *external factors* are present, the teeth will become darker.

Despite these potential risks, bleaching of vital and nonvital teeth is the most *conservative therapy* available in dentistry.



53 Chemistry of the bleaching process
When bleaching teeth, oxidation reactions take place. After a certain amount of bleaching time, the enamel surface is saturated with the bleaching agent. When this happens, the bleaching process must be stopped, because otherwise the enamel could be damaged.

(Adapted from Adept Report)

Which Discolorations Can Be Bleached?

Tetracycline Discoloration

The first tetracycline compound was purified in 1948, and the first tetracycline-induced tooth discoloration was described in 1956. Only some of the tetracycline accumulates in the enamel, while a much larger proportion accumulates in dentin (Brown 1974). After light-induced oxidation, a red quinone compound forms (4-a, 12-a anhydro-4-oxo-4-dimethyl-amino-tetracycline). Different bleaching agents can reduce this dye.

Tetracycline discolorations can be brownish, grayish, or bluish. They usually occur bilaterally and can involve several teeth in both upper and lower jaws. If the anterior baby teeth are involved, the tetracycline discoloration was induced some time between the fourth month of pregnancy and the ninth month after birth. However, if the permanent front teeth are discolored, the tetracycline medication most likely occurred between the third month after birth up to the seventh year of age.

The strength of the discoloration depends on duration and quantity of the tetracycline application. The type of color change depends on the type of the tetracycline derivate. Gray-brown discolorations are due to Aureomycin (Haywood and Heymann 1994). Yellow discolorations are due to Ledermycin, Terramycin, or Achromycin (Bailey and Christen 1968). Yellowish evenly discolored teeth can be successfully bleached (Bevelander 1961).

The three categories of tetracycline discolorations are:

Category 1:
Slight (yellow, brown, or gray) discolorations that extend evenly over the whole tooth. They can usually be removed after three to five bleaching treatments in-office or through a 4-week bleaching treatment at home.

Category 2:
A strong, but even discoloration that can normally be removed after five to seven in-office bleachings, or after four to six weeks of treatment with the home bleaching method.

Category 3:
Strong discolorations using horizontal strips. This requires veneers or even crowns.

54 **Causes and therapy of tooth discoloration**
The best results with bleaching are achieved with color changes caused by the aging process, light fluoroses, and tetracycline discolorations of Category 1. All other discolorations should be treated using restorative methods.

Color	Cause	Therapy
White	Fluorosis	Micro abrasion, veneers
Blue-gray	Dentinogenesis Tetracycline Category 2 and 3	Veneers Veneers
Gray	Silver oxides from root canal fillings	Veneers
Light yellow	Fluorosis Age-related discoloration Obliterated pulp Tetracycline Category 1	External bleaching, micro abrasion External bleaching Internal bleaching External bleaching
Dark yellow	Age-related discoloration Tetracycline Category 2 Pulp necrosis	External bleaching Veneers Internal bleaching
Brown	Fluorosis Tetracycline Category 3 Caries	Micro abrasion, veneers Veneers Restoration
Black	Caries Fluorosis Amalgam-related discoloration	Restoration Veneers, crowns Restoration

Fluorosis

Dental fluorosis can be induced between the second trimester of pregnancy and the ninth year of age, i.e., during *tooth development* when fluoride uptake is in excess of 1 ppm in the drinking water. (The fluoride level of the drinking water should be checked before fluoride medication is prescribed.) The degree of tooth discoloration-which varies from slightly chalky to strong yellow-brown spots due to precipital accumulations (secondary) after the eruption of the teeth-correlates directly with the fluoride uptake. The discolorations are restricted to the enamel (true enamel formation defects or hypoplasia); they are usually found bilaterally and in both jaws.

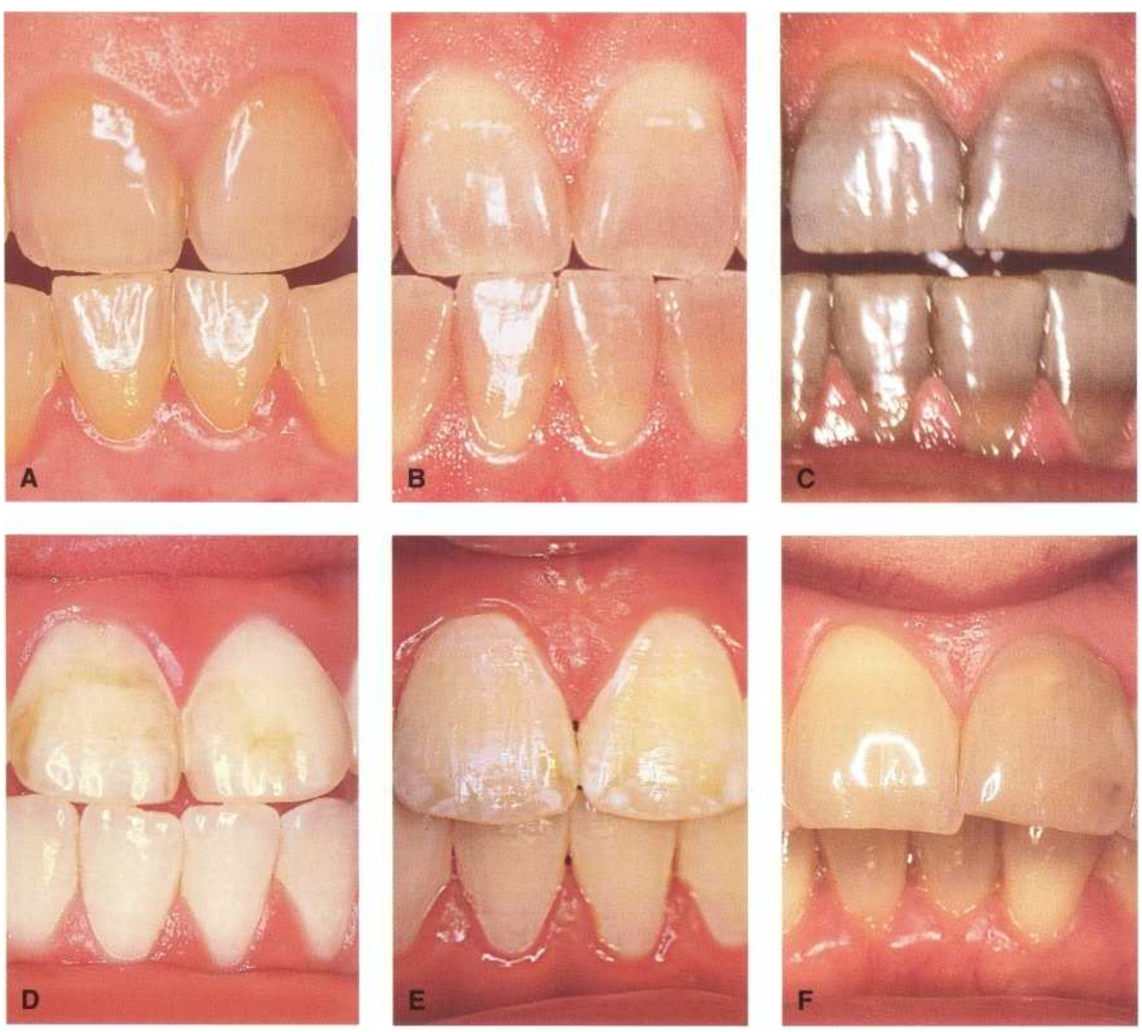
Bleaching is only successful when the enamel discolorations are superficial. A combination of micro abrasion and bleaching (two to four bleaching treatments), followed by facets or reconstruction of the enamel with microfilled composite is the treatment of choice. Alternatively, veneers can be made.

White Spot Lesions

These discolorations are innate or acquired during enamel formation and result from incomplete mineralization, due to a trauma, high fluoride exposure, genetic disposition, or illness. *Acquired* white spots are incipient carious lesions caused by plaque. They are often found around orthodontic brackets. The cause of innate acquired white spots must be removed first. That means that good oral hygiene must be established and low bacteria (caries) activity must be achieved.

Color Changes Due to Aging

Teeth become darker with age. Thus, a youthful tooth color of, for example, Al, becomes A2, A3, and A4 with age. This is a natural process which is enhanced by the presence of certain components in spicy food, alcoholic beverages, cigarette smoke or tobacco. Color changes caused by aging are ideal for bleaching.



55 **Types of discolorations**
A Mild tetracycline discoloration (bleaching time: three months).
B Mild tetracycline discoloration.
C Strong tetracycline discoloration (bleaching time: six months).
D Fluorosis with brown color changes.
E White spot discolorations after orthodontic treatment.
F Nonvital tooth.

Courtesy of *Van B. Haywood*

Bleaching Vital Teeth

Prerequisites and Pretreatment

Radiographs must be available and the question of *tooth vitality* must be clarified. Existing restorations must be tight to avoid H_2O_2 reaching the dentin and the proximity of the pulp.

Acid treatment: The enamel of single, strongly discolored teeth can be locally etched with phosphoric acid. This improves the penetration of the bleaching agent and accelerates and reinforces the bleaching process. A general etching of enamel is not recommended. The result can be a rough enamel surface which later changes color more quickly.

In principle, *tooth color* should be determined before each treatment. Many patients wish to have snow-white teeth. Those beyond A1 tooth colors are also marked as "Hollywood toilet white." One should not strive for such a goal. A tooth color change of about two shades is more realistic. Usually it is possible to reduce a tooth color of A3.5 to A2. The bleaching treatment should not proceed after A1 color has been achieved, because an uncontrolled, long bleaching treatment can damage the tooth structures.

Use of *anesthesia* during the bleaching treatment is neither necessary nor sensible. The patient should register and report pain reactions (e.g., injuries to the gingiva or disturbances of the pulp caused by heat generation).

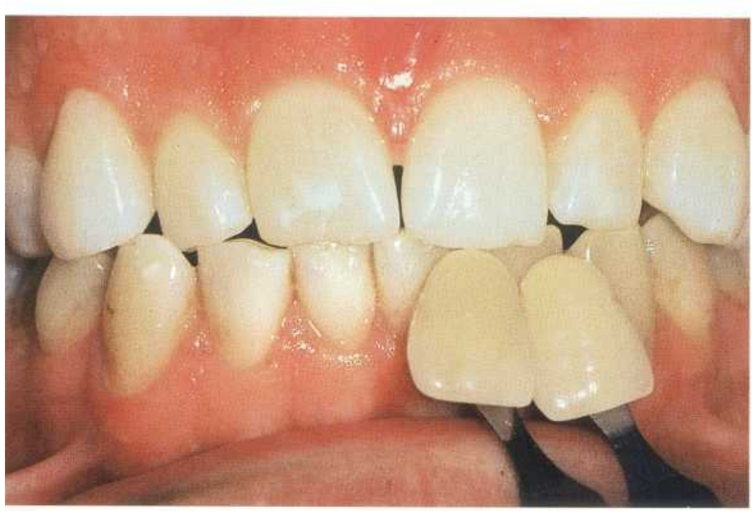
Bleaching Effect on Restorations

Patients should be informed that only enamel surfaces will be bleached and not existing restorations. That means that crowns and fillings may appear darker after bleaching treatments. In the case of fillings, one can remove the outmost layer of the filling and replace it with a new filling layer in a suitable tooth color. In the case of crowns, it may be necessary to renew these completely.

Swallowing the Bleaching Agent

In the stomach, carbamide peroxide is broken down into H_2O_2 and urea. H_2O_2 then disintegrates into water and reactive oxygen. Urea is produced naturally in the body and is removed by the kidneys.

56 **Status before start of bleaching treatment**
Before treatment begins, the color of the teeth should be determined and the teeth should be photographed with shade tabs present. Here, the color is found to be A3.5/A4.



57 **Outcome of home bleaching treatment**
After completion of the treatment, the color of the upper incisors, originally A3.5/A4, has changed to Al /A2.

Courtesy of *Ultradent Prod. Inc.*

Home Bleaching

This bleaching method has been available since 1989. It is most effective when treating orange-brown and age-induced discolorations (age-induced staining). Most bleaching agents are slightly acidic. Consequently, it is possible that exposed root surfaces respond very sensitively. Therefore, patients with exposed root surfaces should use desensitizing toothpaste with sodium fluoride right from the beginning (e.g., Sensodyne).

Possible side effects of home bleaching are:

- Gingival irritation (leaky tray)
- Temporomandibular joint disturbance (carrying the tray during the night)
- A feeling of pressure in the stomach (overfilling of the tray and swallowing the excess bleaching agent)
- Hypersensitive dental necks (excessive exposure to tray covering)

Treatment Procedure

1. Professional tooth cleaning, polishing of all tooth surfaces.
2. Determining the tooth color with the patient.
3. Radiographs of the teeth to be bleached (to detect possible internal damage).
4. Photographs with the shade tabs.
5. Diagnose and determine the causes of the tooth color changes (describe external factors).
6. Make a dental impression.
7. Fabricate a bleaching tray.
8. Hand the bleaching agent over to the patient. Demonstrate how to use the tray and the bleaching agent and hand over written instructions.
9. Recall and check the progress of treatment.

58 **Adding bleaching agent to the tray**
The patient is shown how to fill the bleaching tray. The patient takes the tray and sufficient bleaching agent home.

59 **Inserted bleaching tray**
To prevent any tooth hypersensi-tivity, the patient should wear the bleaching tray for only one hour per day over the first few days. Then, the patient can increase the time step-wise until a maximum of five hours per day is reached.

Indications

Yellow-orange and light brown discolorations of teeth are the ideal indications for home bleaching (age-induced staining). Also teeth with a mild form of fluorosis or a slight tetracycline discoloration can be bleached. According to newer studies by Haywood (1997), the success of bleaching tetracycline-induced discolorations increases if the patient is ready to wear a bleaching tray for half a year.

Whenever there are anatomical changes in the enamel surface, the patient should be informed in advance that it is unlikely that an ideal result can be achieved.

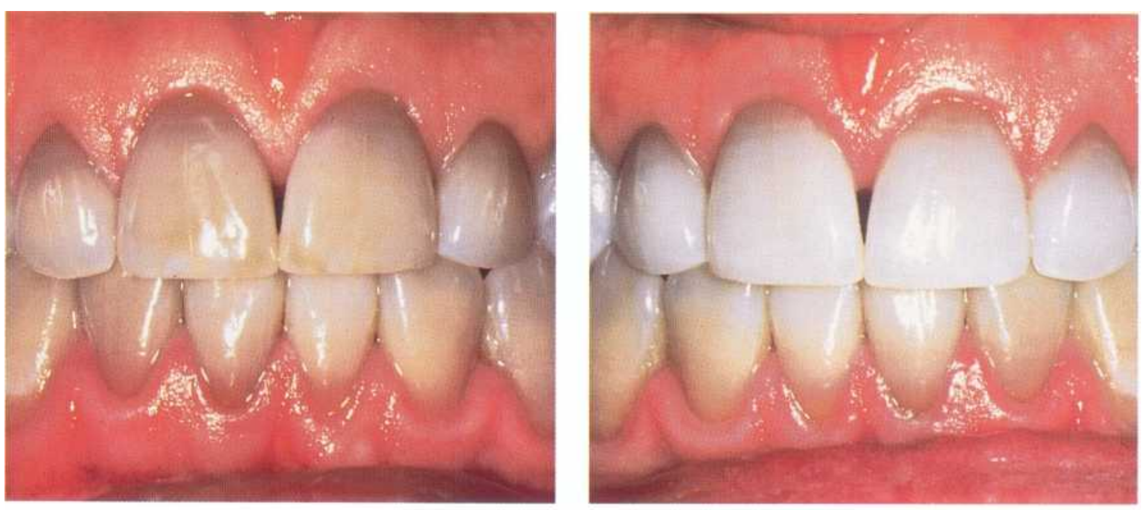
Home bleaching is ideal as a part of preprosthetic therapy. If the teeth are bleached before a general dental treatment, an essentially more aesthetic result can be achieved during the restorative phase.

Chemically-induced strong discolorations are a possible contraindication for home bleaching. Here the tooth colors are are usually blue or grayish. Patients with very sensitive teeth are another contraindication. Teeth that already exhibit hypersensitivity to tooth polishing should not be bleached.

Contraindications

Home bleaching is not suitable for:

- patients with a serious systemic illness
- patients using strong medications
- pregnant or breast-feeding women
- patients who suffer from allergic reactions to bleaching agents or the bleaching tray resin
- patients with extensively destroyed or extensively filled teeth
- patients who are heavy smokers or chew tobacco
- patients with temporomandibular joint disorders. The bleaching tray is not a bite splint. In fact, the bleaching tray can temporarily reinforce existing joint disorders.
- patients with extreme blue-gray discolorations
- patients with tooth hypersensitivity



60 Bleaching tetracycline discolorations
A distinctive blue-gray discoloration (left) has been significantly brightened (right).

61 Bleaching brown-orange discolorations
A strong brown-orange discoloration (left) has clearly been brightened (right).

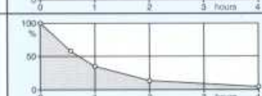
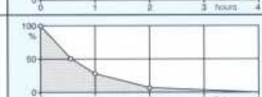
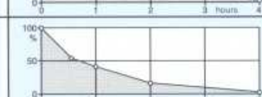
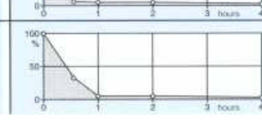
Bleaching Agents

The newest bleaching agents for home bleaching contain carbamide peroxide. Gels containing 10-15% bleaching agent are currently being used. Carbamide peroxide is a compound consisting of urea and hydrogen peroxide. During decomposition, hydrogen peroxide splits off and disintegrates into reactive oxygen and water. A 10% carbamide peroxide solution is as effective as 3% hydrogen peroxide.

There are incidentally also home bleaching products that are purely hydrogen peroxide-based. These bleach 2.76 times faster than the same concentration of carbamide peroxide. One of the first products on offer was BriteSmile. A disadvantage of such products is that an opened package must be stored in the refrigerator.

Home bleaching products must be applied to the teeth by means of a bleaching tray. These trays must have space for the bleaching agent.

62 **Bleaching equipment for home use**
Many home bleaching products have been introduced on the marl<et over the past few years. However, up until now only few have been given a CE certification.

Product	Cost (US$/mL)	Active Component	pH-Value	Concentration (%)	Bleaching Action of Active Component Over Time	Evaluation
Nupro Gold Total Tooth Whitening System (Dentsply/Ash)	1.60	Carbamide peroxide (10%)	5.9	10		3.3
Platinum (Colgate Oral Pharmaceuticals)	0.86	Carbamide peroxide (10%)	5.5	11, 5		3.2
At-home Tooth Whitening System (ILT/Brite Smile)	0.21	H_2O_2 (10%)	6.7	6, 8, 10		3.1
Nite White Excel (Discus Dental)	2.40	Carbamide peroxide (10%)	7.5	5, 10, 16, 22		3.1
Nite White Excel (Discus Dental)	1.91	Carbamide peroxide (10%)	6.6	10, 16		3.0
White & Brite (Omni International)	1.83	Carbamide peroxide (10%)	5.9	11, 16		2.9
Opalescence (Ultradent Products)	2.15	Carbamide peroxide (10%)	6.5	10, 35		2.7
Rembrandt (Den-Mat)	1.42	Carbamide peroxide (10%)	6.1	10, 15, 22		2.6
Spring White (Spring Health Products)	0.40	Carbamide peroxide (10%)	5.8	11		2.6
Denta-lite (Challenge Products)	0.28	Carbamide peroxide (10%)	5.6	10		2.3

63 Overview of products used for home bleaching
(Adapted from CRA Newsletter, April 1997)

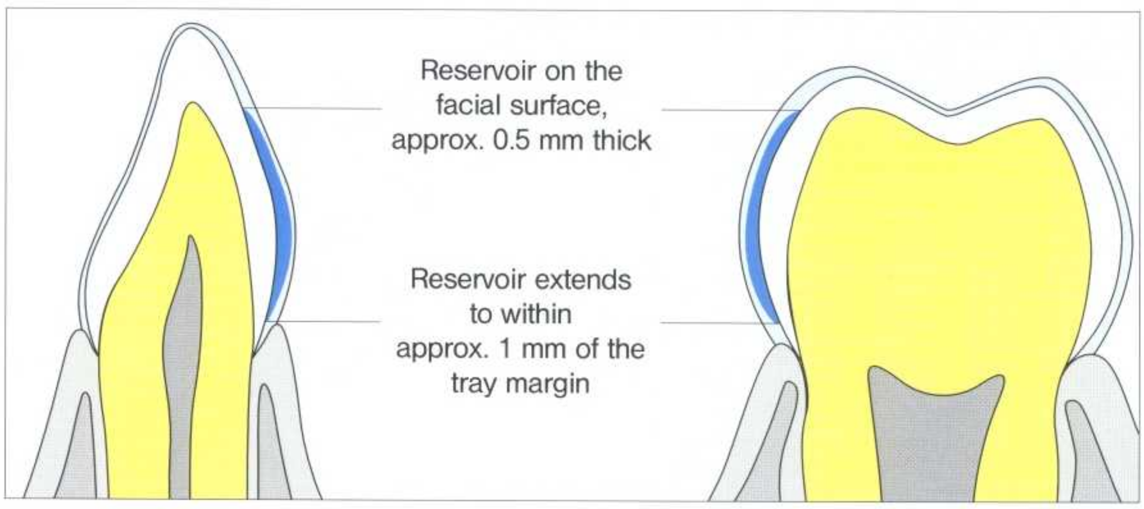
Fabricating a Bleaching Tray

Bleaching trays are medicament carriers that keep the bleaching gel in a certain position on the tooth. They are made of soft plastic. It is important that the trays adapt well to prevent the bleaching agent from being quickly diluted by saliva, which could reduce its effect.

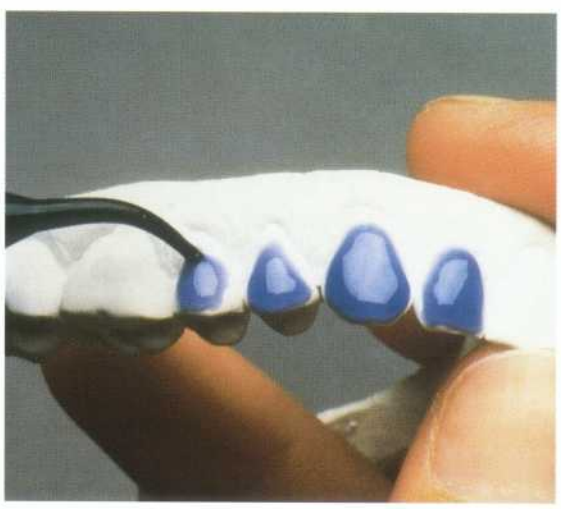
The bleaching agents should only and exclusively be located on the teeth and not on the gingiva. If the tray adapts insufficiently, allowing the bleaching agent to leak, it can lead to gingival irritations over a longer period of application.

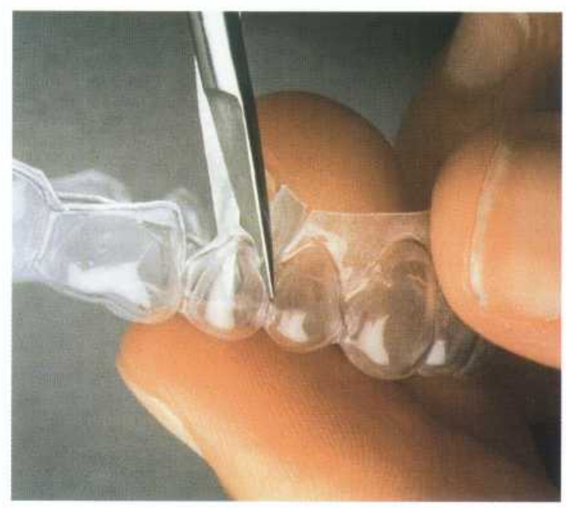
In order to achieve a greater effect with the bleaching agent, a reservoir is created on the tooth surface by means of a light-cured plastic. The tray material is available in thick-nesses of 0.053-0.06 inches. The thicker tray material is preferred for patients with a tendency to grind their teeth.

The illustrations (Figures 64-66) show the procedure for malting a bleaching tray. The technique can also be used to manufacture a medicament carrier.



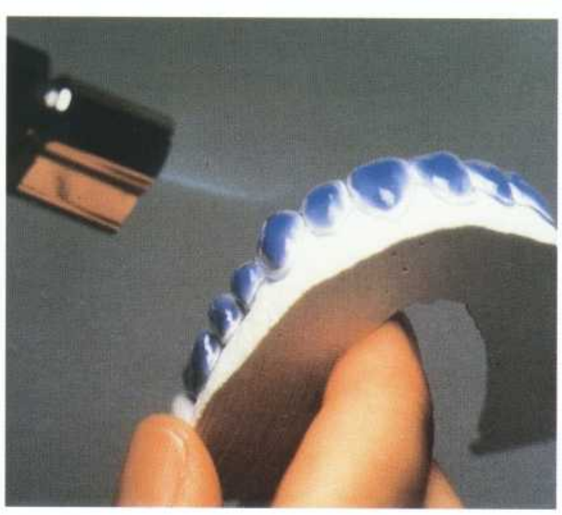
64 **Reservoir formation for the bleaching agent in the tray adjacent to the tooth**
A reservoir for the bleaching agent is formed on the facial surface in the tray. The reservoir extends to within approx. 1 mm of the tray margin.





65 **Making the bleaching tray**
Left: Light-cured blocking resin is placed where the reservoirs are going to be located.

Right: The overextended tray is cut to its right extension.



66 **Completing the tray**
Left: The tray margins are readapted with a flame in order to enable optimal marginal adaptation.

Right: Finished bleaching tray

In-Office Bleaching

In-office bleaching is carried out using more aggressive materials and consequently leads to quicker results. Products with a higher concentration of bleaching agents (e.g., Quickstart with 35% carbamide peroxide or Accel with 35% H_2O_2) are mainly used. Because of their aggressivity, one must keep an eye on the bleaching process and make sure that the gingiva is sufficiently protected by the rubber dam.

The drawback of in-office bleaching is the expensive treatment time.

Indications

- Goal: fast result
- The patient prefers the treatment to be conducted in the office
- Only single teeth to be bleached
- As a preprosthetic procedure

Contraindications

- Patients with hypersensitive teeth
- Patients with large fillings

Treatment Procedure

1. Diagnosis and treatment planning as in the case of the home bleaching procedure (oral diagnosis, professional tooth cleaning, radiographs).
2. Color determination together with the patient.
3. Preoperative photographs.
4. Placing the rubber dam.
5. Place bleaching agent and replace after 10-20 minutes. A treatment lasts 30 to a maximum of 60 minutes and normally causes a color change of 1 to 1.5 shades on the Vita color scale.
6. After the rubber dam has been removed, remineralize the teeth with a fluoride gel.

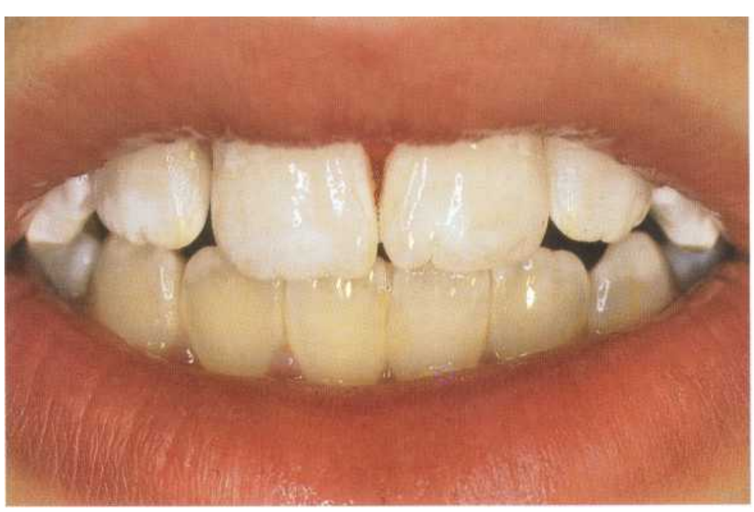
The treatment can be repeated two to four times.

Possible Postoperative Complications

Gingiva etching: Let the patient rinse for a few minutes. Most gingiva irritations disappear after two hours.

Pain: Raised level of sensitivity usually vanishes within a few days. Use toothpaste for hypersensitive teeth as a possible accompanying treatment.

67 **Bleaching procedure**
Since one is working with highly concentrated bleaching agents, it is necessary that a rubber dam be applied before treatment is carried out. Fresh bleaching agent is placed on the teeth at 10-minute intervals. The bleaching process can be accelerated by exposing the tooth being bleached to the light of a polymerization lamp.



68 Effect of a 30-minute in-office bleaching treatment

69 Bleaching agents forin-office bleaching
Highly concentrated carbarnide peroxide (35%) or concentrated hydrogen peroxide (35%) is used for in-office bleaching.

70 Useful bleaching agents, composition, and effects of external factors

Superoxol	Stabilized 30–35 % H_2O_2; store at cool temperature.
H_2O_2	Is also available as a 30–50 % H_2O_2 gel; sodium bicarbonate increases the pH value and stabilizes the H_2O_2; magnesium sulfate serves as a photocatalyst: it accelerates the breakdown of H_2O_2.
HiLite (Shofu)	Liquid, 35 % H_2O_2; activated by magnesium sulfate and light; magnesium sulfate accelerates the reaction of the H_2O_2.
Quickstart (Den-Mat)	Gel contains 35 % carbamide peroxide; very active; protect the gingiva with rubber dam.
Life-Like	44 % carbamide peroxide
Phosphoric acid	Phosphoric acid gel can be placed locally at separate, strongly pigmented locations and the bleaching agent can penetrate the enamel more efficiently.
Heat	Increasing the temperature can accelerate the bleaching process.
Light	Does not accelerate the bleaching process substantially.

Power Bleaching with Superoxol

1. The patient's face and, above all, the eyes must be protected since one is working with aggressive chemicals. Dentist and patient should wear goggles; cover the patient's face.

2. Protect the gingiva with Vaseline or Orabase in case the rubber dam leaks.

3. Position the rubber dam. The holes should be made small to optimize the sealing ability. Invert the rubber dam.

4. Clean the teeth with pumice and water; do not use a polishing paste containing fluoride.

5. Stir the bleaching paste and place it on the teeth.

6. The additional use of heat and light speeds up the bleaching process. It is important, though, that the patient does not experience any pain due to the heat being used. Most patients can tolerate 50-60'C. These temperatures are also tolerated when malting a hydrocolloid impression. Do not use the heat on the tooth for more than one minute. Then wait for another minute before the heat is reapplied.

7. The power bleaching process should be stopped after 10 -30 minutes, even if the goal has not been achieved. If pain is registered, the treatment must be stopped immediately.

8. Remove the source of heat and wait five minutes so that the teeth can cool down. Then, the remaining bleaching agent is rinsed away using plenty of water and sucked away.

9. Finish the procedure by treating all teeth with a neutral sodium fluoride gel for two to three minutes, whereupon the rubber dam is removed. The patient should then rinse the mouth carefully.

Possible Side Effects

Instruct the patient that the teeth may be somewhat sensitive over the next few days. After approximately two weeks, the outcome of the bleaching treatment is reassessed and, if necessary, the teeth are bleached again.

Patient Information for Home Bleaching

Home bleaching of teeth with a bleaching tray is a new treatment that is controlled and supervised by the dentist. It is a simple and very effective technique used to brighten the teeth. An important component of this treatment is an individually made and precisely fitting bleaching tray. This tray prevents the bleaching agent from becoming diluted too quickly by the saliva and from leaking out into the oral cavity. It is the tray that distinguishes this bleaching method from those that are bought as kits in a drugstore.

Carbamide peroxide or hydrogen peroxide is used as bleaching agent. They are usually contained in gels based on glycerin. All degradation products of the bleaching agents are also materials produced naturally in the body and are consequently harmless. The oxygen released produces the bleaching effect. If the patient is allergic to any constituent in the bleaching material, the bleaching treatment should not be started or continued.

Peroxides have been used for many years as oral antiseptics (disinfectant mouthrinses). Only recently have they served as bleaching agents for teeth.

Possible *side effects* of bleaching are:

1. Gingiva irritation
2. Temporary hypersensitivity of the dental necks
3. Short-term nausea
4. Pain in the temporomandibular joint region

The bleaching agents bleach only natural tooth structures. Large fillings or crowns are not bleached and may have to be renewed later, since they no longer match the tooth color of the bleached teeth.

Instructions for Home Bleaching

1. Clean mouth and teeth.
2. Place a small quantity of the bleaching gel into the tray and position the tray slowly.
3. Remove excess bleaching agent.
4. Do not eat while you are wearing the tray. Do not chew on the tray. Do not try to suck out bleaching agents from the tray.
5. Leave tray in place for 45–60 minutes.
6. Remove the tray. Rinse mouth with water.
7. If desired, repeat steps 2 to 6. Increase the bleaching time step-by-step.
8. Never leave the tray in place for the entire night. Maximum bleaching time is five hours per day.
9. If you should have any problems with the bleaching treatment, stop bleaching and call your dentist's office.
10. Return to the dental office as agreed for checkups on the bleaching treatment.

What You, the Patient, Must Observe

Patients should not smoke during the bleaching process. It is possible that the effect of carcinogens present in cigarette smoke can be enhanced with the relase of oxygen.

Pregnant and nursing mothers should not bleach their teeth. It is not yet known whether there could be an interaction between free oxygen radicals released and other substances and whether they can affect the pregnancy. Patients with very sensitive dental necks should not bleach their teeth.

Attainable Goals of the Bleaching Treatment

The dentist has determined the tooth color on a shade guide before the bleaching treatment starts. One can expect the teeth to become about one to two shades brighter.

The average treatment time with the home bleaching method amounts to two to six weeks. The first results are usually already recognizable after five days. Particularly strong discolorations can make a longer treatment period necessary. Strong discolorations in deeper layers of the tooth cannot be altered through the bleaching treatment.

Yellow-brown color changes (age-induced stains) can usually be bleached very easily. According to type and cause of the discoloration repetition (after approx. one to two years) of bleaching is necessary. Therefore, the individually fabricated bleaching tray must be stored safely.

Bleaching Nonvital Teeth

When bleaching nonvital teeth, the bleaching agent is placed *into the pulp chamber* of the tooth. This method is effective when one wants to brighten nonvital teeth that have changed color after root canal treatments.

History and State of the Art of the Technique

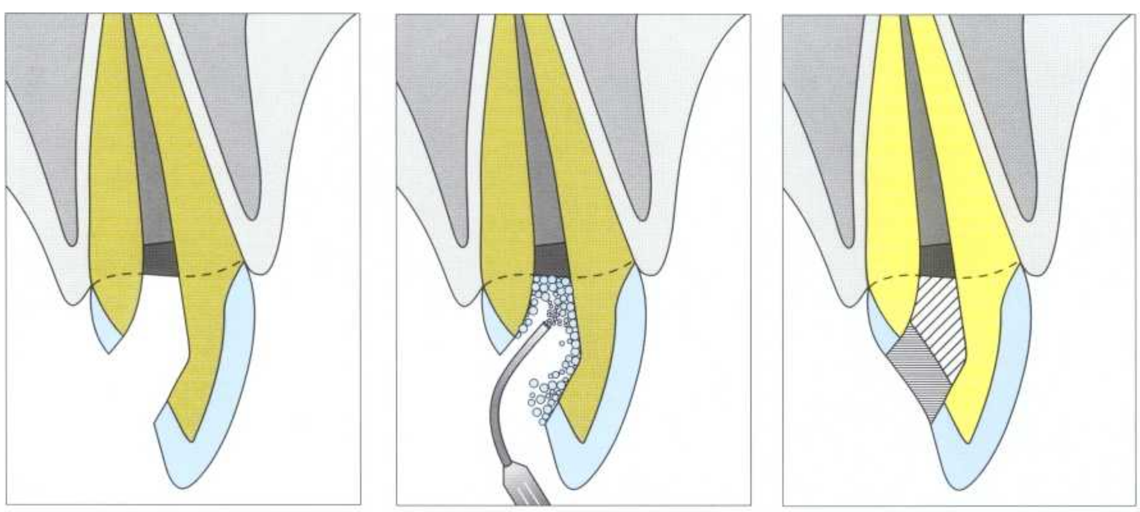
One of the first successful attempts to perform internal bleaching was described by Brown (1965). He mixed sodium perborate and hydrogen peroxide and placed the mixture into the pulp chamber. In 1963, Nutting and Poe proposed the technique in combination with the bleaching process of vital teeth. They used Superoxol, a stabilized hydrogen peroxide, and mixed it with sodium perborate. The mixture was put into the pulp chamber, which was then closed. Since the bleaching process extends over a relativel long period, it has also been called *"walking bleach"* in the American literature. If the internal dentin has been etched with 37% phosphoric acid before the bleaching agent is placed in the pulp chamber, the penetration of the bleaching agent is increased.

The bleaching process can be accelerated further if the tooth is heated. The bleaching agent in the pulp chamber is renewed after a few minutes' interval and heat applied to the tooth surface. This is known as *"power bleaching."* This treatment requires chemicals such as Superoxol (30% stabilized H_2O_2) and sodium perborate (Amosan by Oral B or sodium peroxyborate-monohydrate from a drugstore). The two products (Superoxol and sodium perborat) are mixed together.

Side Effects and Treatment Preparation

Patients must be informed about effects and side effects of the bleaching process. One of the side effects is that bleaching can cause *internal root resorption.* The teeth can become brittle with repeated internal bleaching and after time this can cause *spontaneous fracture* of the clinical crown. Root canal treatments should be completed before bleaching therapy is begun.

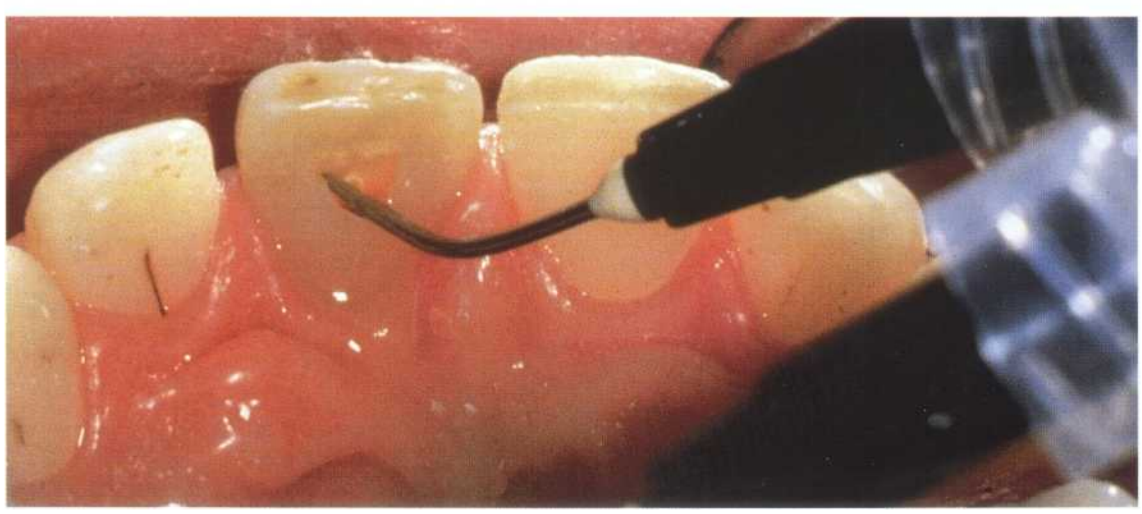
The coronal part of the root canal filling must be completely removed, including residual filling material located in the pulp horns. If it is a root canal filling with silver thread, the entire filling needs to be removed and filled again with gutta-percha. The root canal filling must be sealed before bleaching. A small quantity of glass ionomer cement is suitable for this purpose.



71 **Bleaching nonvital teeth**
Left. The coronal part of the root canal filling is removed.

Middle: Bleaching agent is inserted into the pulp chamber.

Right: The pulp chamber is closed with a temporary filling material (Cavit). After multiple changes of the bleaching agent and an approx. two-week total treatment period, the bleaching process is completed.



72 **Placing the bleaching agent in the pulp** chamber

Treatment Procedure for Power Bleaching

1. Determine tooth color and take photographs.
2. Isolate the treatment area with rubber dam.
3. Seal the root canal filling with a resin-modified glass ionomer cement. Perform radiographic control.
4. Etch the pulp chamber for no longer than 30 seconds with a 37% phosphoric acid.
5. Mix Superoxol and sodium perborate. Place it in the pulp chamber.
6. Apply heat for two to five minutes. Then remove the bleaching mixture and bring in new bleaching gel. Repeat this process every five minutes over a period of 30 minutes. Overly strong heat development can lead to root resorption.
7. When the bleaching process is finished, the tooth should be rinsed and the tooth color should be checked. Under some circumstances another bleaching session may be necessary.
8. To neutralize the pulp chamber, calcium hydroxide paste is brought into the tooth and left there for about two days. Place a tight temporary restoration.
9. If after two days the tooth color has attained a result which the patient is happy with, restoration of the tooth can take place. If another bleaching process is needed within the foreseeable future, a restoration should be made through which access to the pulp chamber can be gained in the future.

Walking Bleach

The first four steps are identical to those for power bleaching.

5. Place the bleaching agent in the pulp chamber.
6. Close the opening with a Cavit or an IRM restoration. Patients must be informed that the bleaching agent present in the pulp chamber releases gases, which could cause the temporary restoration to fall out.
7. The bleaching agent remains in the tooth for between two days and one week.
8. Repeat the process.
9. Restore the tooth.

Internal bleaching should not be repeated more than four times, because the inner tooth structure becomes weakened, increasing the risk that a crown fracture may occur.

73 Bleaching nonvital teeth
The bleaching agent is placed in the pulp chamber.

74 External bleaching
In addition to internal bleaching of the nonvital tooth, all teeth can simultaneously be given an external bleaching with a bleaching tray.

Courtesy of *Ultradent Prod. Inc.*

Long-term Results

In 1989 Haywood began a scientific study of the bleaching procedures. In 1994, he presented the long-term results of 300 patients.

Seventy-three percent of the patients were satisfied with the bleaching results after three years. Only a few noticed a slight darkening of the teeth. A total of 3% of the patients required a regular follow-up bleaching. No patient reported postoperative sensitivity, gingiva irritation, or had had a tooth fracture. Teeth of patients with an orange-brown discoloration were brightened by about 3.3 shades on the Vita color scale guide, and this result was confirmed after three years.

A survey among dentists by the CRA (Christensen 1997) showed that:

91% of the surveyed dentists bleach teeth
79% were very satisfied with the result
12% were disappointed
62% observed tooth hypersensitivities in 10.7% of all cases
45% said that 5.6% of the patients had gingiva irritations
2.1% recognized systemic troubles in 0.2% of the cases
18.8% had not registered any side effects

How Long Do Bleached Teeth Remain White?

After approximately one year, patients should give their teeth a slight after-bleaching. The original tooth color returns slowly over a time period of one to four years if no after-bleaching is carried out. The slow darkening process of the teeth depends on the original color. Light-yellow color changes do not come back as quickly as gray colors. In the case of younger patients the color change is retained longer than with older patients. It must therefore be clear to the patient that after-bleaching may occasionally become necessary. Because of that, the bleaching tray should be stored in a safe place.

Special whitening toothpastes support the bleaching process very greatly and should be used at regular intervals. Normally, patients who have their teeth bleached are well aware of their teeth and return regularly to the dental hygienist. Tooth-color can thus be reassessed and after consultation with the dental hygienist a schedule for after-bleaching can be outlined. It is quite difficult for the patient to properly notice the slow change in tooth color. Here, the guidance of a dental hygienist can be very helpful.

75 Before start of bleaching treatment
The patient's smile before treatment began.

76 After bleaching treatment
A follow-up picture after bleaching treatment was completed.

Courtesy of *Ultradent Prod. Inc.*

Micro Abrasion Method

Micro abrasion is indicated for solid color spots found in the uppermost tooth surfaces. Such color inclusions do not disappear through bleaching.

History

At the beginning of the 20th century, Black already described the micro abrasion procedure using hydrochloric acid. In 1984, McCloskey used pumice mixed with 18% hydrochloric acid to remove color changes on tooth surfaces. Six years later the Primier company brought the product Prema (Primier Enamel Micro Abrasion) onto the market. Prema consisted of pumice mixed with 10% hydrochloric acid. Micro abrasion can be combined with bleaching.

Treatment Planning

Superficial color changes (white spots, fluorosis, and slight tetracycline discolorations) can be removed with the micro abrasive procedure. Hydrochloric acid is a very aggressive liquid. Electron microscopic studies have shown that 18% hydrochloric acid removes approximately 10 pm enamel (7-22 pm) in five seconds. Because of this, the micro abrasive procedure should only be used for short time intervals (five seconds). A maximum of five repeated applications should not be exceeded.

Materials

Rubber dam, Dappen dish, 12-18% hydrochloric acid, pumice, sodium bicarbonate, fluoride paste, and possibly a bleaching gel.

Treatment Procedure

1. *Perfect isolation with rubber dam:* If this is not sufficiently tight, it should be additionally sealed by means of a ligature or liquid rubber dam. Patient, dentist, and dental assistant should all wear goggles.
2. Apply *the acid:* Mix 12-18% hydrochloric acid with pumice. This mixture is then placed on the tooth regions that are discolored. Now this paste is distributed for five seconds over the surface of the tooth with an extra slow contra-angle handpiece and a rubber polishing cup, with which the area is lightly polished. After completion, all of the hydrochloric acid-pumice mixture is immediately rinsed away with thorough suctioning, and afterwards the tooth color is checked.
3. *Repetition:* This process can be repeated up to a maximum of four times. However, if no drastic improvement can be seen after two to three applications, the treatment should be stopped.
4. *Polishing and fluoride treatment of the teeth.*

77 **Status before micro abrasion therapy and bleaching** in the case of micro abrasion therapy, pumice and an approx. 15% hydrochloric acid solution are used to remove the outermost enamel layer. In addition to this treatment, external bleaching can be carried out.

78 **Result of treatment** Result achieved after completed micro abrasion therapy. An external bleaching treatment was conducted simultaneously.

Checklist—Bleaching

Treatment Plan

Examination of the Oral Cavity

- Where are fillings?
- Are they tight?
- Are the teeth vital?
- Oral hygiene?
- Does gingivitis or periodontitis exist?
- Which discolorations exist?

Radiographs of Questionable Teeth

- Exclusion of apical processes
- Recognition of fillings

Nutritional Information

- Information regarding external factors, such as smoking, red wine, coffee, etc.

Oral Hygiene Instructions

- Use of whitening toothpastes

Professional Tooth Cleaning

Determining Color with the Patient

- Tooth color before bleaching
- What is the treatment goal?
- Document both in writing!

Photography (with Color Shade Guide)

In-Office Bleaching

- Install a rubber dam
- Apply the bleaching agent (20–35 % H_2O_2 gel or 35 % carbamide peroxide)
- Reapply bleaching agent twice after approx. 10 minutes.
- Repeat this bleaching procedure (total duration approx. 30 minutes) two to four times.

Home Bleaching

In the Office

- Make impressions
- Make a bleaching tray
- Check fit of the bleaching tray
- Patient is given the bleaching tray, the bleaching agent, and written instructions

For the Patient

- Bleach only for one hour during the day over the first three days.
- Increase use slowly to a maximum of five hours per day.
- Clean teeth before bleaching. Place the bleaching agent in the tray. Use only a small amount of bleaching agent in order to avoid excess.
- Place the tray in the mouth and spit out excess.
- After one hour the bleaching agent will have been diluted by the saliva and its effect reduced. Remove the tray and place more bleaching agent in it.
- Do not use the tray over night.
- Attend your next appointment at the dentist's office.
- If you have one or several of the following problems, please call the dental office: hypersensitivity of the teeth, irritation of the gum, nausea.
- If you have other problems, please call the dental office, phone #...

Aesthetic Periodontal Surgery

It was Miller (1988) who established the concept of aesthetic periodontal surgery. He saw opportunities for expanding classic mucogingival surgery that dealt with broadening the vestibule and removing troublesome frenula. Aesthetic periodontal surgery does not primarily treat functional disturbances, but rather aesthetic problems, such as gingival recessions, defects, excesses, and proliferations as well as defects of the alveolar ridge and incompletely or unerupted teeth.

Many new surgical techniques are available for these conditions. The miscellaneous techniques use sliding flaps, gingival and connective tissue grafts, guided tissue regeneration with resorbable or nonresorbable membranes, reconstruction of bone **with bone substituting materials (e.g., tri calciumphosphate or decalcified freeze-dried bone), and growth factors to stimulate growth of new tissue and attachment.**

79 **Aesthetic periodontal surgery**
Aesthetic periodontal surgery corrects excessive tissue and tissue recessions.

Left. Excess tissue in the maxilla is removed and is used to supplement tissue in the mandibule.

Right: Situation after completed treatment and placement of new restoration.

Gingival Recessions

While a multiplicity of gingival problems can be improved with aesthetic periodontal surgery, the most frequent task is that of covering gingival recessions. A variety of treatments is available:

- laterally sliding flap (Grupe and Warren 1956)
- free mucous graft (Bjorn 1963)
- coronally repositioned flap (Bernimoulin et al. 1975)
- connective tissue graft (Kaldahl 1982; Langer and Calagna1982)
- free gingival grafts on conditioned root surfaces (Miller 1982)
- supraperiostal envelope flap (Raetzke 1985)
- semilunar flap (Tarnow 1986)
- guided tissue regeneration (GTR) with resorbable and nonresorbable membranes (Roccuzzo et al. 1996)
- a combination of methods with or without membranes, grafts, or growth factors

Classification

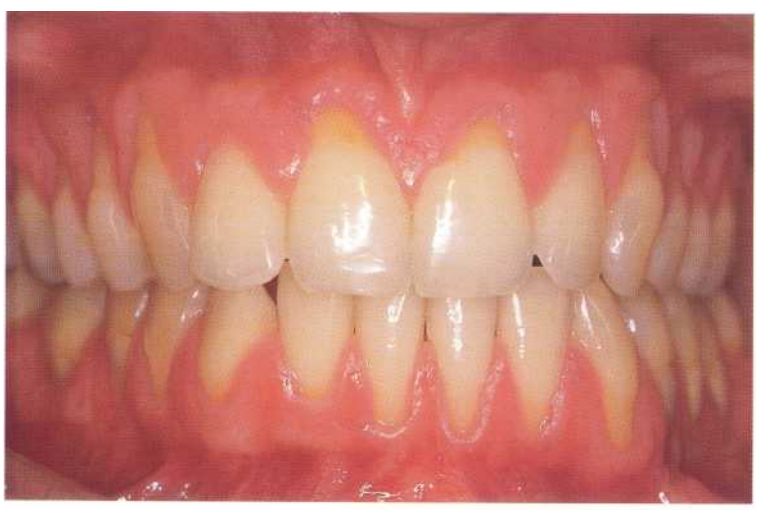
Miller (1985) classified gingival recessions in order to facilitate treatment planning and prognosis (see Rateitschak and Wolf 1989).

Class 1: The recession is flat and narrow, or flat and broad and does not reach the mucogingival junction. Interdental tissue has not been lost. Prognosis: very good.

Class II: The recession is profound and narrow, or profound and broad. It stretches apical of the mucogingival junction. Interdental tissue is not lost. Prognosis: good.

Class III: Recessions like those in classes 1 or 2. Interdental tissue (also bone) has partially been lost. Prognosis: complete root coverage is no longer possible.

Class IV: Recession extends apical of the mucogigingival junction. Interdental tissue has been extensively destroyed. Prognosis: poor.



80 **Gingival recessions before aesthetic periodontal surgical treatment**
The photo shows generalized recessions of classes I and II (Miller 1985). The class I recessions of the upper incisors were treated with a coronally repositioned flap procedure. The upper canines, premolars, and the lower incisors were covered with free gingival grafts.

81 **Treatment results**
Complete coverage of the root surfaces is achieved six weeks after surgical intervention.

Sliding Flaps

Sliding flaps can be used for final coverage of gingival recessions. They can also be combined with oral mucosa grafts or membranes. Beside aesthetic indications, these techniques can also be used to eliminate mucogingival problems. In implantology they can be used for alveolar ridge augmentation and to expose impacted teeth.

Laterally Sliding Flap

This technique is described by Grupe and Warren (1956). To be successful, it is important that
- the flap is sufficiently thick and wide,
- the flap is sufficiently large and appropriately shaped, and
- sufficient attached gingiva is available.

The flap should be three times as wide as the recession it is going to cover. This ensures that the flap area is sufficiently vasculated, since the root surface cannot contribute to the vascularization of the flap. The flap should cover at least 3 mm of vasculated gingiva on each side.

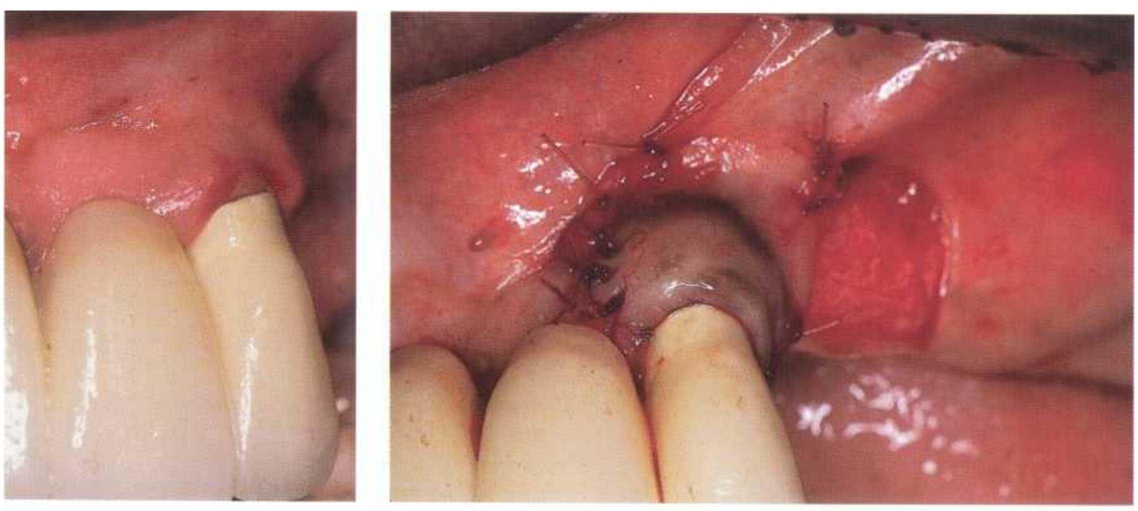
The flap must also be sufficiently thick to reduce the risk of later recession. A sufficiently extendable, attached gingiva is necessary to elevate the flap. If the flap can only be held in place by means of a suture, recession is probable.

Indication: Individual recessions. It is not necessary to remove tissue from a second location. This technique is especially indicated in the case of recessions adjacent to edentulous ridge regions (simple flap mobilization).

Contraindication: Deep proximal pockets, prominently protuberant roots, severe root erosion, and advanced proximal bone loss.

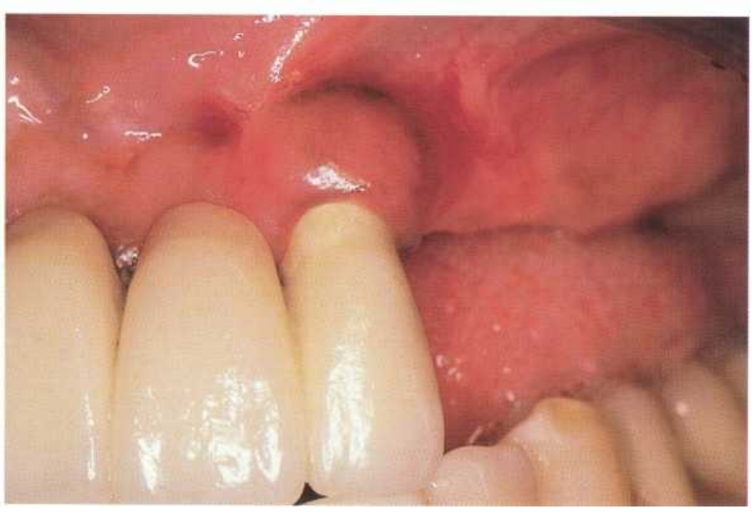
Advantages: Only one surgical area, good vascularization of the flap, high success rate with root coverage.

Disadvantages: Limited amount of available keratinized gingiva, possible recession on the removal site, limited to one to two teeth.



82 **Covering a class I recession by means of a laterally sliding flap**
A flap was elevated from the tooth-free region of the distally located ridge and then rotated mesially in order to cover the root. Then, it was attached by single sutures to the periosteum and the attached gingiva.

Left. Situation before treatment. The crown margin and the root surface are exposed. There is a removable denture distal to the recession.

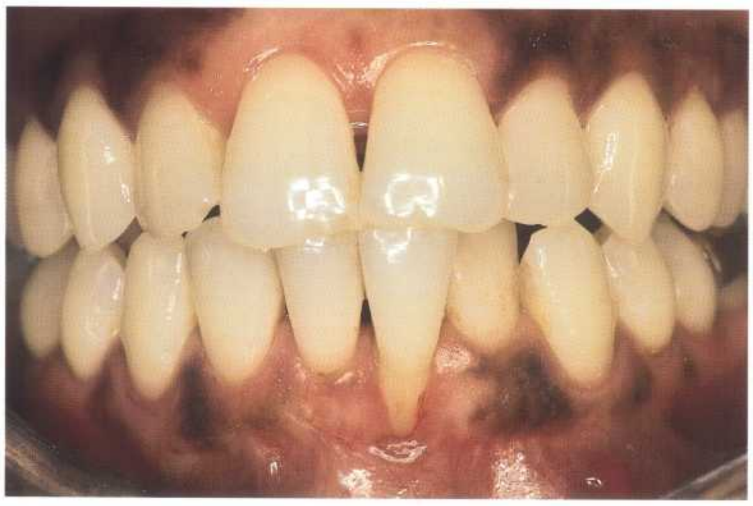


83 **Treatment result**
Two weeks after the intervention, all sutures have been resorbed and the root and the crown margin have been covered.

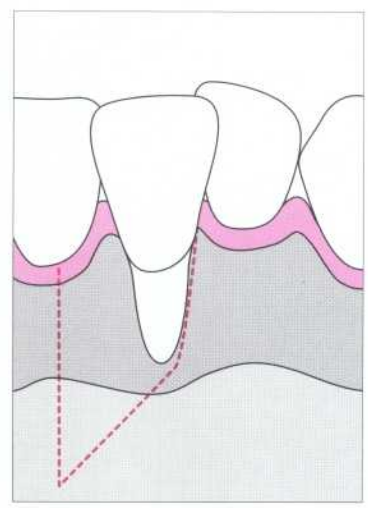
Surgical Procedure

1. A tissue bed is created adjacent to the exposed root at the recipient site. The incision begins at the adjacent tooth and is extended into the vestibulum.
2. The second incision begins at the border of the recession and reaches to the apical end of the recession. A slightly slanted incision connects the two incisions.
3. In this area, the epithelium and the uppermost layer of the tissue are removed in order to produce a suitable tissue bed. The recipient site is an exposed area where the uppermost layer of tissue has been removed, and it extends to the interpapillar region.
4. At the donor site, a vertical incision is performed to elevate a flap of sufficient size. The flap extends to the vestibulum and runs parallel to the former incision.
5. The flap is separated from the periosteum.
6. If a sufficiently large flap cannot be elevated, it is possible to extend the incision further into the mucosa.

Covering a class II recession with a laterally sliding flap

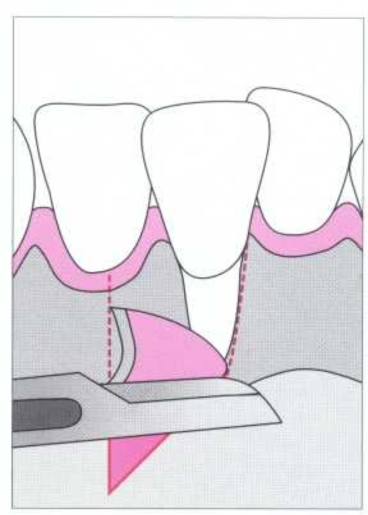


84 Initial situation
A class II recession located facially of a single lower incisor. There is a sufficiently wide removable region distal to the defect.



85 Conditioning of the root surface
The root surface was planed and etched with citric acid.

Right: **Adjacent to the recession, the epithelium is removed from a zone of gingiva at least 3 mm wide. This region is used for the reception and vascularization of the sliding flap.**



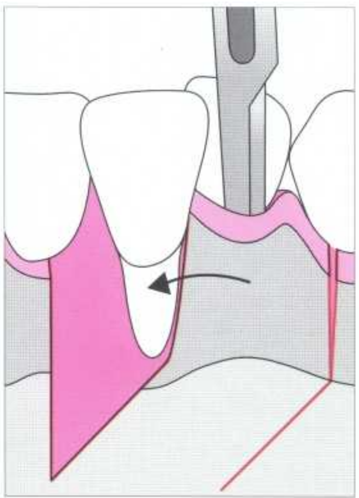
86 Preparing the recipient bed
Removing the covering tissue exposes a recipient bed.

Right: **The epithelium is removed with a scalpel.**

7. This is a split thickness flap that should be as thick as possible. Therefore care should be taken during elevation to avoid perforation.
8. The first suture is embracing and should keep the flap in the correct position. For this purpose nonresorbable sutures are used. This suture keeps the flap in position over the entire healing period.
9. The edges of the flap are attached to the periost using resorbable sutures.
10. The wound can be closed at the donor side with a free gingival graft

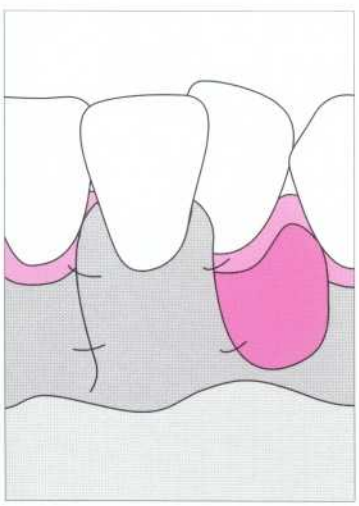
Causes of Possible Failure

-Tension in the flap-place a vertical releasing incision.
-The sliding flap is too narrow-no correction possible.
-Too much bone is exposed-this leads to recession.
-Inadequate stabilization of the flap-mobility prevents the formation of a contact between the flap and the recipient bed that leads to necrosis and loss of the flap.



87 Mobilizing a split thickness flap
The vertical incision extends from the gingival margin to the mesial part of the lower canine and continues apically until it reaches the mucogingival junction, where it is slightly angled in a mesial direction.

Left: The flap is elevated after sharp dissection.



88 Sliding the flap
A scalpel mobilizes the split flap. The incision extends into the vestibulum in order to guarantee sufficient mobility of the flap. This flap is slid mesially and sutured at the lateral borders to the attached gingiva or the periosteum.

Left: Graphic representation of the sliding flap technique.

89 Postoperative view
One week after surgical intervention the recession is covered and healing tissue can be seen at the donating site.

Surgical Procedure

1. The root is thoroughly scaled and planed.

2. Condition the root using citric acid or tetracycline. Other authors also use 32% phosphoric acid for this purpose. Regarding the possibility to improve reattachment, the root surface can be additionally treated with *Emdogain* (Biora). Emdogain is a derivative of the enamel matrix and stimulates cell growth on the root cementum-forming surface. After cementum is formed, a new periodon tium can regenerate with a new periodontal ligament and new alveolar bone. However, further studies will be needed to prove that this treatment would be advantageous to cover root recessions.

3. After the root has been conditioned, the recession is measured from the gingival margin to the cemento-enamel junction (distance A).

4. An apically located point is selected from the top of the papillae at distance A.

5. At this point, the incision begins and extends well into the mucosa.

6. A split thickness flap is elevated.

7. The recipient bed is prepared, by means of removing the epithelial layer with a scalpel.

8. The flap is undermined so it moves easily and is easy to reposition coronally.

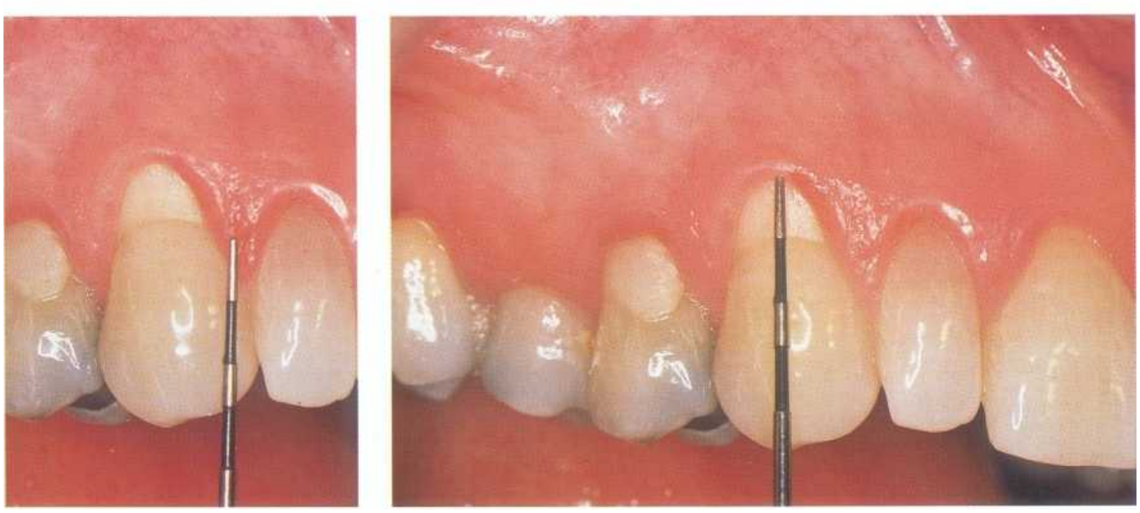
9. The flap is positioned coronally and is then attached with a nonresorbable embracing suture.

10. The lateral edges are sutured to the periosteum. Resorbable sutures are used for this purpose.

Allen and Miller (1989) and Harris (1994) have shown up to 98% root coverage can be achieved with this technique.

Coronally repositioned flap: surgical procedure

93 Initial situation
A class I recession is located at the upper cuspid 13.

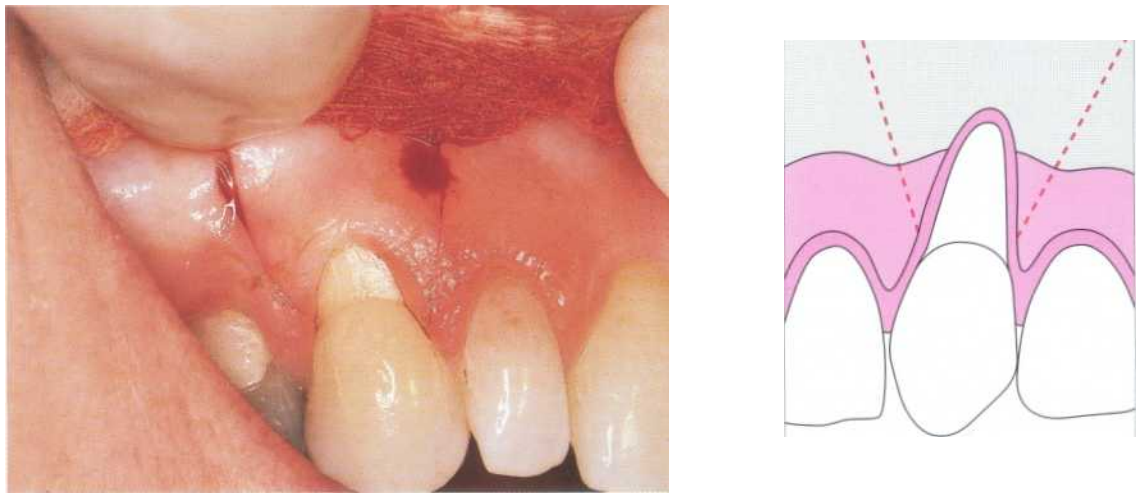


94 **Analyzing the recession**
After the exposed root surface has been planed, it is conditioned for five minutes with saturated citric acid (pH = 1). The exposed root surface is 3 mm wide.

Left: The initial incision begins approx. 3 mm below the tip of the papillae. This distance corresponds approximately to the size of the recession. The vertical incision extends well past the mucogingival junction.

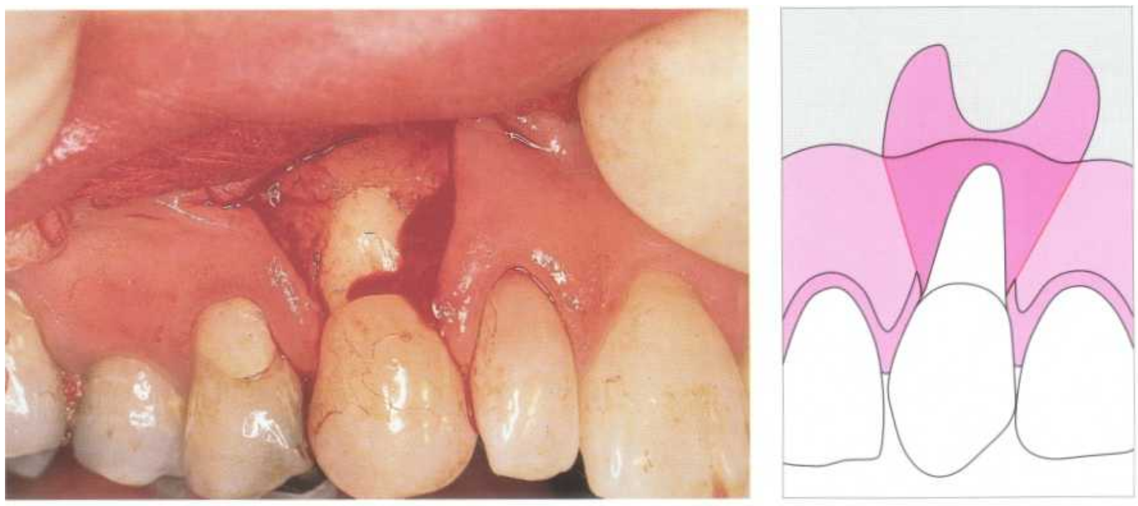
95 Incisions
Initial incisions for a coronally repositioned flap.

Right: The incision extends far enough into the mucosa so that sufficient mobility of the flap can be achieved.



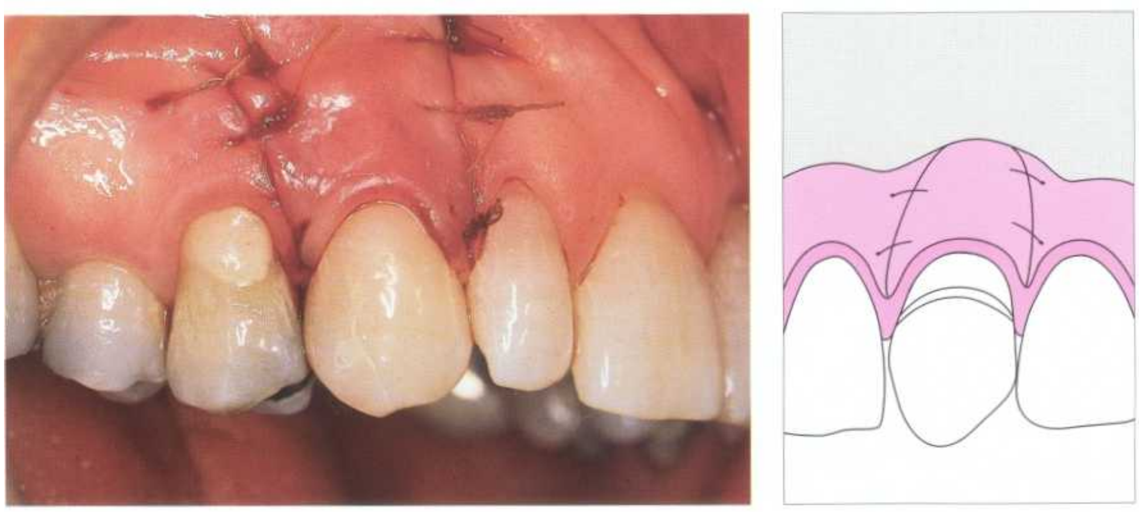
96 Mobilizing the flap
A split flap that extends well into the vestibulum is elevated. Sufficient mobility is guaranteed.

Right: In order to be able to coronally reposition the flap, it is important that the incisions extend well into the mucosa.



97 Fixing the flap
The flap is repositioned coronally with an embracing suture and attached via lateral sutures to the attached gingiva and the periosteum.

Right. An embracing suture keeps the flap in its coronal position. A small amount of composite material bonded to the palatal surface prevents the suture from slipping.



98 Result
Six months after surgery, a positive result has been achieved with complete root coverage and ideal aesthetic conditions.

Right: Two years after the intervention the entire root remains covered and pocket depths are normal.

Free Gingival Grafts

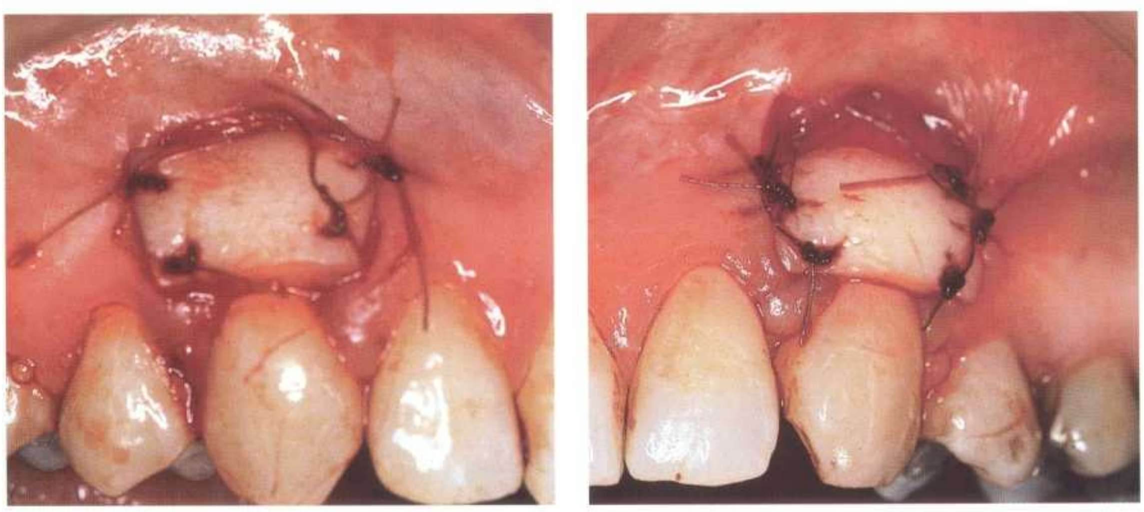
A free gingival graft is used for root coverage or rebuilding gingiva if required (augmentation). This technique, which has been significantly altered over time, produces acceptable aesthetic results.

Augmentation of jaw ridges is a recommended preprosthetic treatment. Insufficient amount of attached gingiva often leads to chronic inflammation adjacent to dentures, implants, or orthodontic appliances.

Advantages: High success rate, simple technique. Several teeth can be covered simultaneously. The technique also works when there is an insufficient amount of keratinized gingiva.

Disadvantages: Two surgical regions are needed. If the blood supply is poor, it may result in a partially unsatisfactory aesthetic outcome at the region of the root coverage. Pain may also be felt at the two surgical sites, particularly at the donating site.

99 **Preoperative findings**
This patient has class II recessions with cervical abrasions on the right and left maxillary canines.



100 **The Miller technique**
Left. A free gingival graft is attached to cover the root surface.

Right. Covering the root recession on the opposite side with a free gingival graft.

101 Result
Complete coverage on both sides of the previously exposed root surfaces three months after surgery.

Surgical Augmentation Procedure

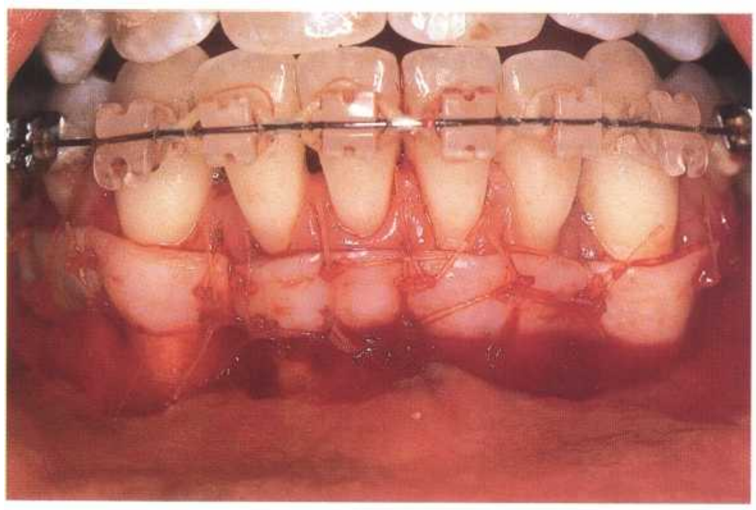
1. The recipient bed is prepared. A horizontal incision is made along the mucogingival junction and extended into the papillary region.
2. A vertical incision is made lateral to first incision and extends into the mucosa. The supraperiostal part of this area is exposed.
3. The flap is excised.
4. The recipient bed is measured and a 1-mm-thick gingival graft is taken from the palate.
5. The graft is adapted to the tissue bed with moist gauze and sutured to the papillae and the periosteum.

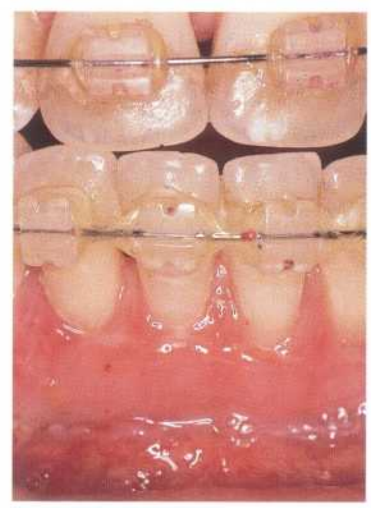
Causes of Possible Failure

- Failure of the recession coverage can occur if the defect is too wide and not completely covered by the graft.
- Mobility due to lack of sufficient stabilization leads to failure.

The graft can be stabilized by means of a good suturing technique and by maintaining solid pressure on the graft for five minutes.

102 Initial situation: recession through protruding orthodontic appliance resulting in a lack of attached gingiva
In this patient, who was undergoing orthodontic treatment, the roots are exposed in the whole of the mandible.





103 Free gingival grafts placed to create attached gingiva
Left: Two **free gingival grafts are attached. The aim is not to create complete coverage of the entire recession. Too much of the proximal tissue has already been lost.**

Right: Two **weeks after the surgical intervention, the grafts are integrated and gingiva has been sufficiently attached.**

104 Postoperative condition
Eight months after surgery.

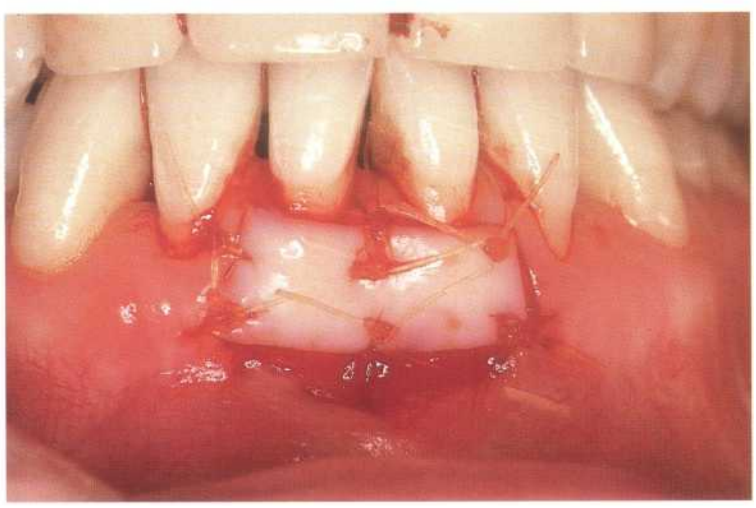
Surgical Processes to Cover Recessions

1. The root surface must be carefully scaled and planed.
2. The root surface is conditioned. Citric acid, phosphoric acid, or tetracycline can be used for this purpose. After conditioning, Emdogain may be applied.
3. The recipient bed is prepared. An incision is first made in the papilla against the cemento-enamel junction. The recipient bed should be at least 3 mm wide to assure a sufficient blood supply to the graft.
4. Lateral vertical incisions extend through the mucosa.
5. A supraperiostal flap is elevated and excised.
6. A well-fitting graft (1.5-2 mm thick) is removed from the palate.
7. The graft is firmly held in place with a moist gauze for five minutes and then sutured at the edges with periostal sutures.
8. The first suture is horizontally oriented. The graft is stretched about 2-3 mm with this *stretching suture* (Sullivan and Atkins 1968).
9. The graft is attached by means of an embracing suture in close contact with the root.
10. The graft is sutured interdentally.

105 Class III recession of the lower front teeth

The recipient bed is prepared. The vertical incisions are sufficiently extended into the vestibular mucosa. A sharp dissection creates the recipient bed.

Left. There is no attached gingiva at the central incisors, which justifies the use of a free gingival graft. The root surfaces have already been planed and conditioned with citric acid.



106 Placing a free gingival graft

The free gingival graft is tal<en from the palate and prepared to fit the created recipient bed. It is attached with resorbable sutures (size 5).

107 Result

The graft has been attached to the recipient site and the root surface has been sufficiently covered.

Connective Tissue Graft

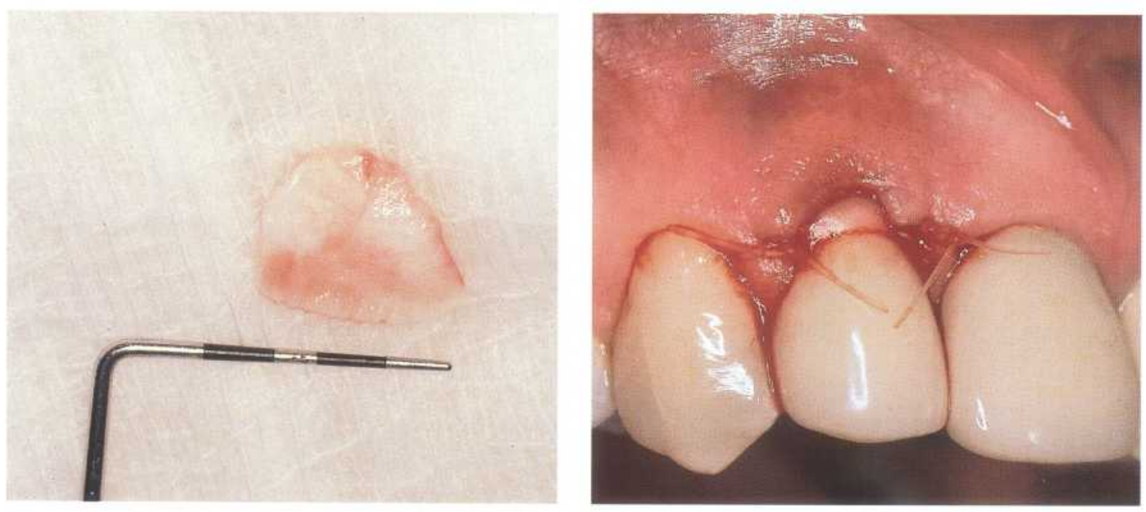
Karring and Ellegaard (1971) described how subepithelial connective tissue could be used as a source for epithelial tissue growth and to broaden the keratinized gingiva. Langer and Langer (1985) used connective tissue to cover recessions.

The connective tissue graft is a combination of a free autogenous graft and a sliding flap. The sliding flap supplies the graft and protects it against trauma. These optimal conditions at the recipient bed result in a high success rate.

The technique can also be used in complex situations. It no longer requires the sliding flap to cover the entire root surface. It is useful for single teeth as well as for several teeth with recessions. Graft removal from the palate is substantially easier, since rugae do not have to be taken into consideration. There is only a small wound at the donor site.

108 Envelope technique
Left: A gingival recession is seen at the root surface of the lateral maxillary incisor. The dark root surface is seen through the covering tissue.

Right. The tissue can be slightly elevated by means of a small incision.



109 Connective tissue graft
Left: A connective tissue graft is taken from the alveolar portion of the palate.

Right: The connective tissue graft is placed under the mobilized tissue and sutured to the papillae on both sides.

110 Result
Left: Twelve days after surgery, the graft has healed over the root surface.

Right: Six months after surgery, the dark root surface is no longer visible. The somewhat thicker fibrous tissue results in an excellent aesthetic outcome.

Surgical Procedures for Connective Tissue Grafts

1. The root surface is cleaned thoroughly (scaling, root planing). Carious parts of the root and old composite restorations are removed using a superfine diamond.

2. The root surface should then be conditioned with acid. Using Emdogain may increase the success rate.

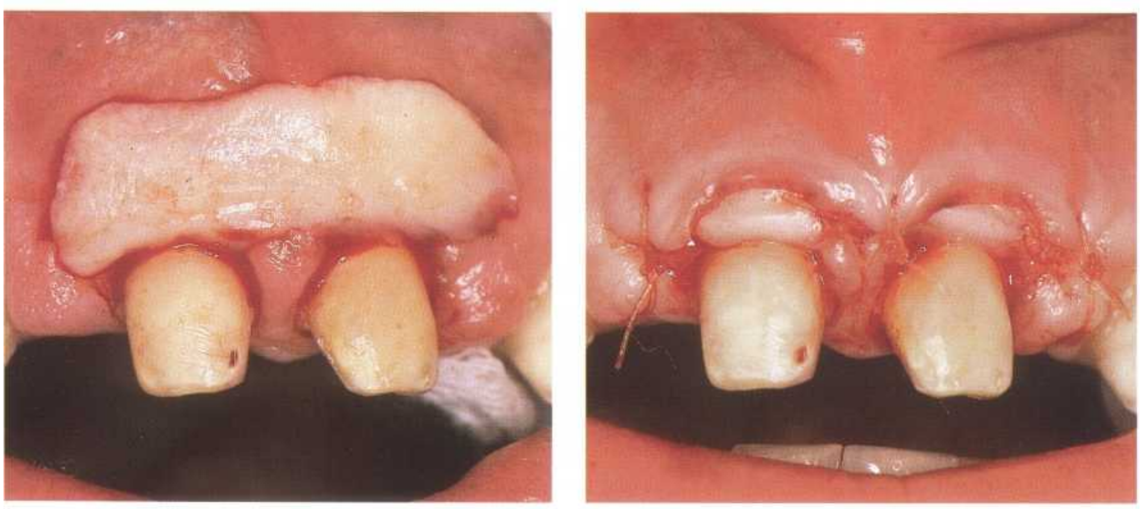
3. The recipient bed is prepared. An incision is made above the cemento-enamel junction using a no. 15 scalpel. Since it is a split thickness flap, the bone is not touched. The bed should be 3 mm wide to ensure sufficient blood supply.

4. A lateral vertical incision into the mucosa should enable a coronally repositioned flap.

5. The supraperiostal flap is released from its support, but is not excised. It is later used to cover the graft and supply it with blood.

111 Subepithelial connective tissue graft as a preprosthetic treatment
Left: Poor aesthetics-long front teeth, exposed dark roots-is visible. The cause is a greatly deviating course of the gingival margin.

Right: The crowns are removed and the tooth surfaces are smoothed.



112 Covering the root surfaces
Left: The connective tissue graft is taken from the palate and trimmed to the right size.

Right. A gingival flap is elevated by means of a small incision. The connective tissue graft is placed under the gingival flap and attached with single sutures.

113 Result
Left: The temporary restorations are removed two weeks after surgery in order to check wound healing.

Right: Four weeks after surgery, the normal gingival contour and good aesthetic result are visible. The temporary restorations should be left in place for at least three months until the final prosthetic treatment can take place.

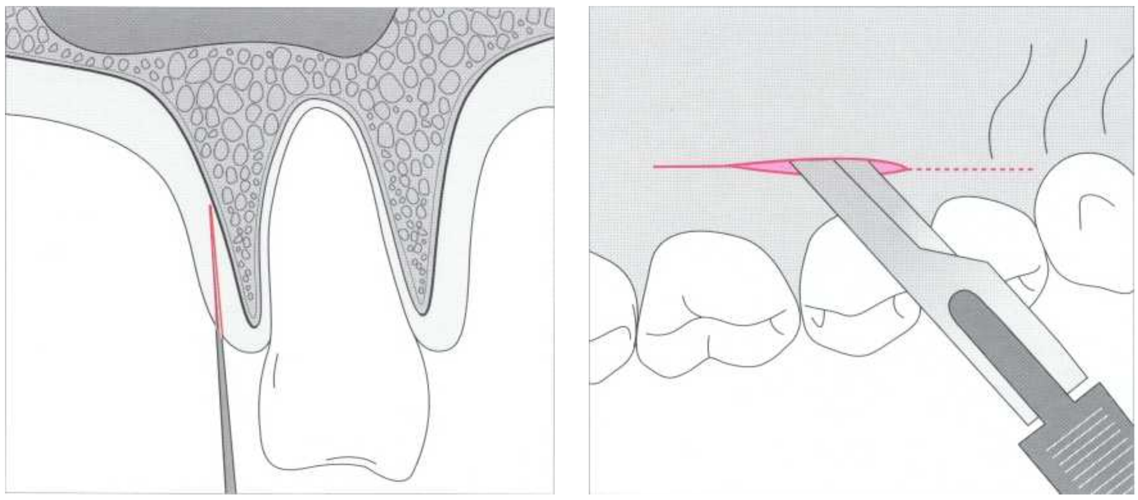
Surgical Procedures at the Donor Site (Palate)

1. In order to get a subepithelial connective tissue graft, an internal or subepithelial flap is created by means of parallel incisions. This flap should be approximately 1-1.5 mm thick. The length must be chosen so it covers the recession.

2. The flap is carefully removed. The size is adapted to cover the recession. A scalpel with two blades is very helpful for this purpose.

3. The connective tissue graft is then stored between moist gauze (saline solution).

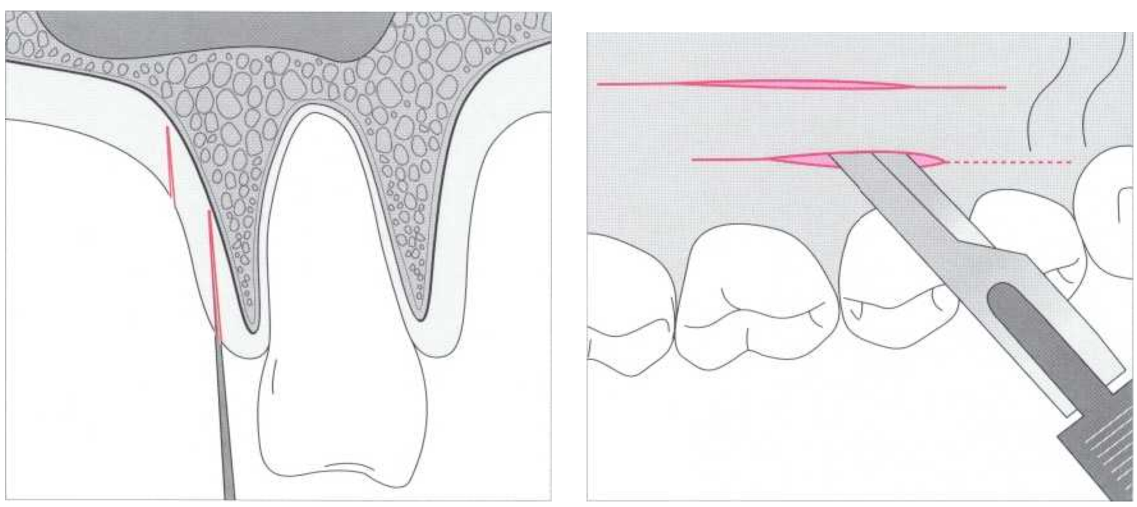
4. The palatal wound is immediately sutured. A consecutive mattress seam is possible. The wound can also be covered with *Histoacryl Blue.*



114 Removing the subepithelial graft
The connective tissue graft is retrieved from the palate in the region between the cuspid and the first molar.

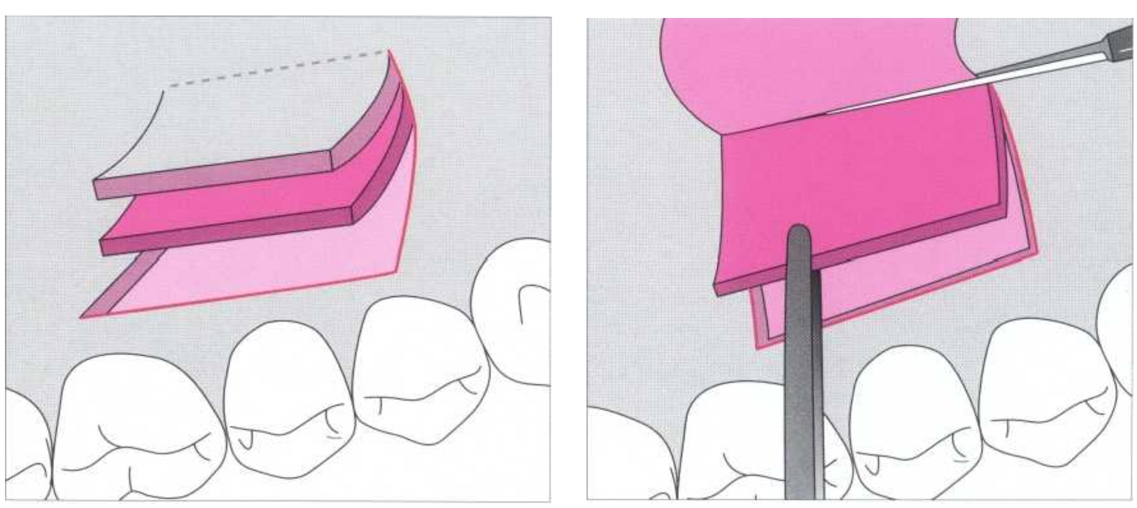
Left: The first incision is made supraperiostally, parallel to the vertical axis of the tooth.

Right: The length of the incision should be equal to the recession it will cover. Its maximal length is from the first molar to the cuspid.



115 Parallel incisions
Left: A second parallel incision is made at a distance of 1-2 mm.

Right. Horizontal incision. Both incisions can be made in a single action using a Harris scalpel, which has two blades mounted 1-2 mm apart.



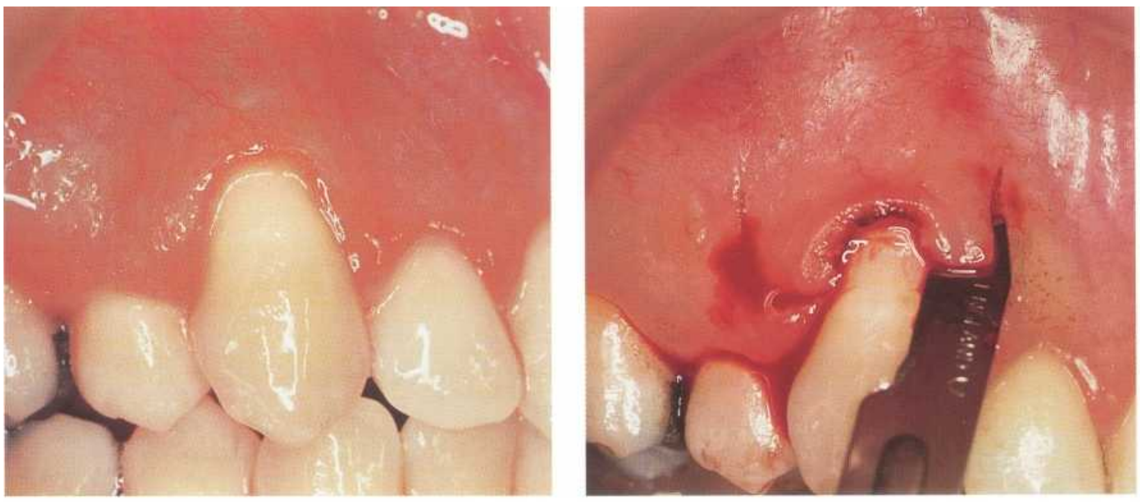
116 Removing the transplant
Left. If necessary, a small, horizontal release incision can be made.

Right: The subepithelial connective tissue graft is removed.

Grafting Procedure

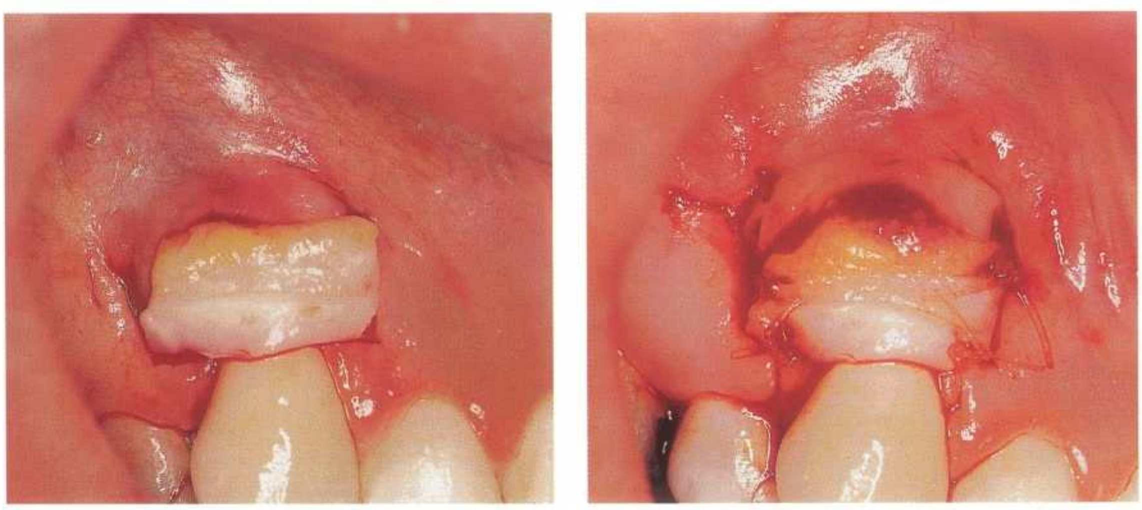
1. The graft is trimmed to the right size and...
2. ...adapted slightly coronally to the cemento-enamel junctions.
3. Using resorbable sutures, is it firmly attached to the papilla and the periosteum.
4. First, resorbable sutures are attached, then a cervical embracing suture is placed.
5. The previously prepared flap is then placed as coronally as possible to cover the graft, and attached with a suture. Part of the connective tissue graft may be exposed.

If the recession is wider than 3 mm, this technique should always be combined with a coronally repositioned flap to avoid too much graft exposure. This procedure has the advantage that a smaller graft is needed, since part of the root is covered with the coronally repositioned flap. This is important when the recession is wider than 5 mm. A split thickness papillary flap can be chosen instead of the coronally repositioned flap if there is insufficient attached gingiva.



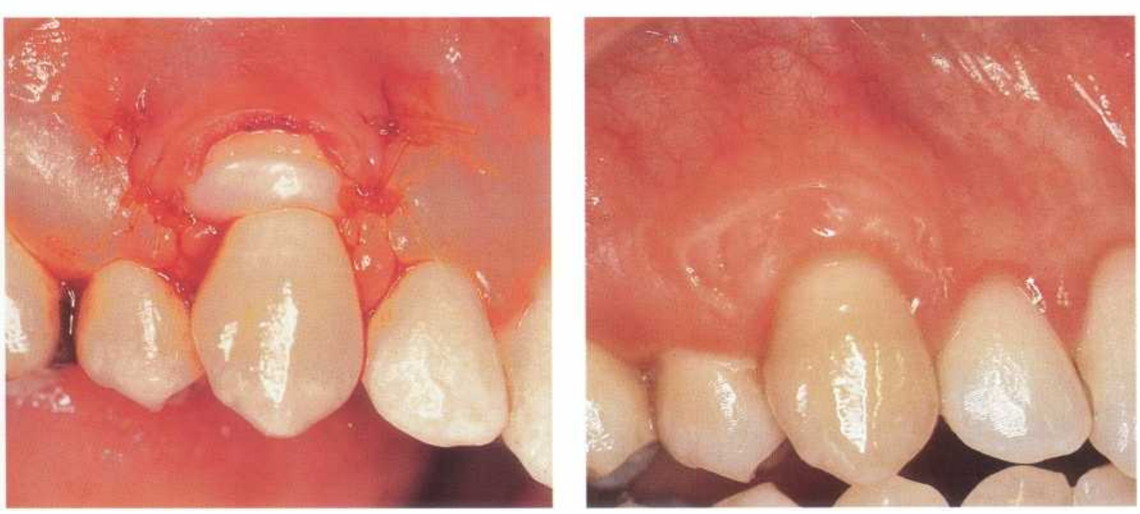
117 Free connective tissue graft combined with a coronally repositioned flap
Left. Gingival recession at a prominent upper cuspid.

Right: The recipient bed is prepared after the root surface has been planed and conditioned. A horizontal incision extends along the cemento-enamel junction approx. 3 mm into the neighboring papilla. A vertical incision extends over the mucogingival junction. A split thickness flap is mobilized by means of a sharp dissection.



118 Attaching the graft
Left. The connective tissue graft, with a small epithelial part that is located coronally, is trimmed to the right size for the recipient bed and adapted.

Right: The connective tissue transplant is attached coronally to the papillae and apical to the periosteum with a resorbable suture (size 5).



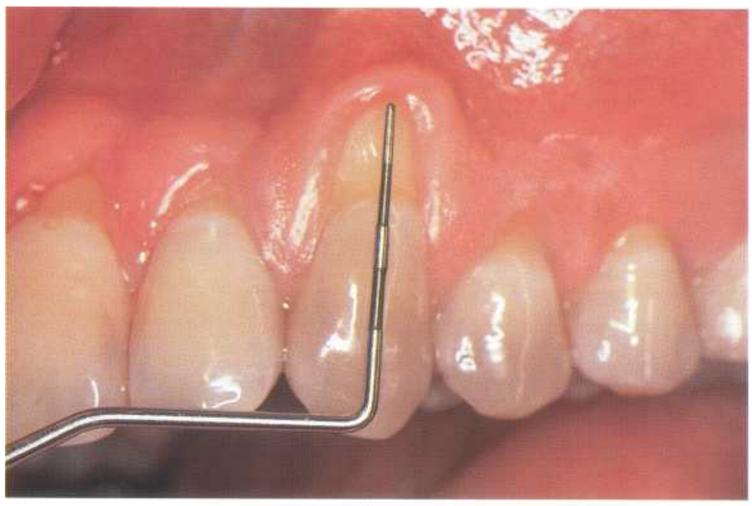
119 Sutures and postoperative result
Left: The flap is repositioned over the graft and sutured to the papillae. The vertical incisions are also sutured. These sutures do not penetrate the connective tissue graft.

Right: Two and a half years after the surgical intervention, a solid zone of gingiva covers the cuspid root surface that was exposed before.

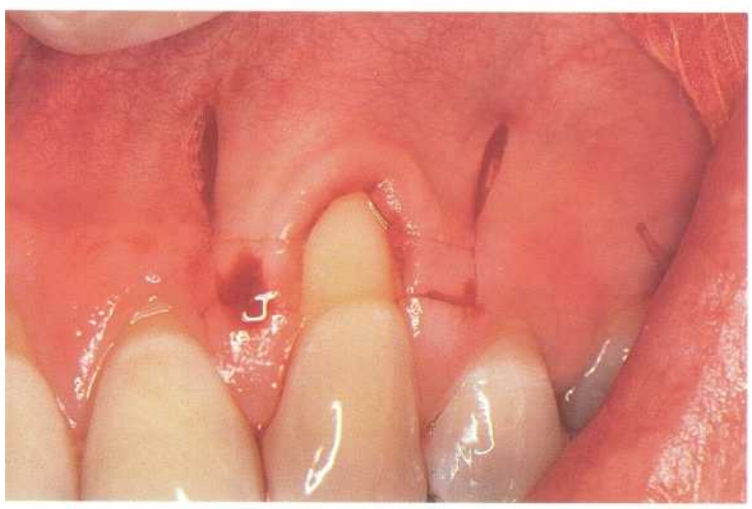
Combination Techniques

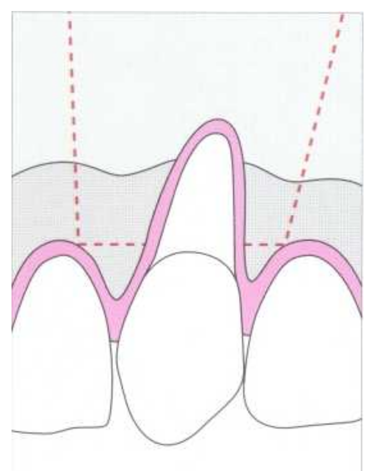
Bernimoulin et al. (1975) described a treatment that requires two sessions. First a sufficiently wide piece of attached gingiva is created by means of a free gingival graft. In another surgical session, a coronally repositioned flap is placed over the recession. This technique is no longer used today, since one-session techniques give sufficiently good results.

A connective tissue graft combined with a coronally repositioned flap is the method of choice since it leads to more aesthetically favorable result. The palate wound is minimal and the intervention is completed in one session.



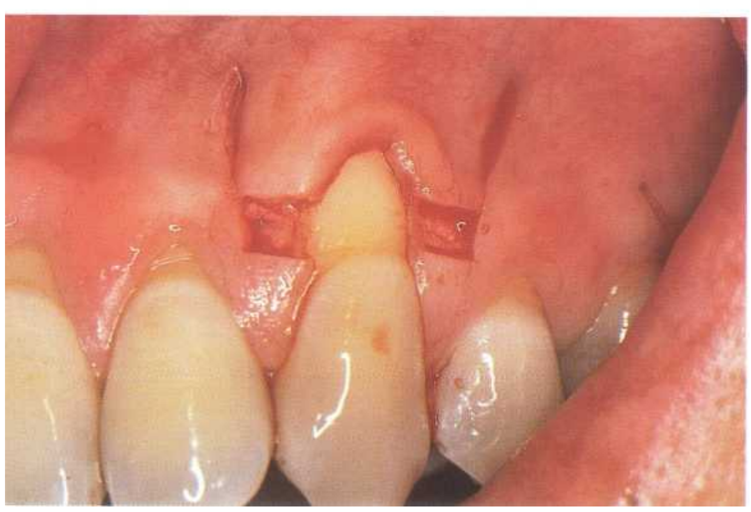
120 subepithelial connective tissue graft combined with a coronally repositioned flap
An upper left cuspid with a 4.5-mm-wide gingival recession lacking attached gingiva.

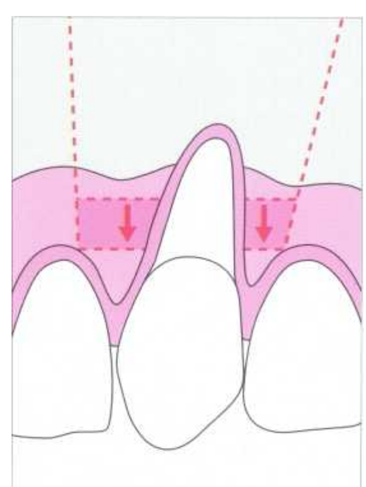




121 Incision for the recipient bed
Left: Vertical and first horizontal incisions are made at the cemento-enamel junction. The trapezoid shape is chosen to avoid damaging the papillae.

Right: Note the second horizontal incision.





122 Mobilizing the coronally repositioned flap
Left: After a sharp dissection, the gingiva is removed between the two horizontal incisions and repositioned coronally.

Right. After the gingiva has been removed between the two incisions, the flap is coronally repositioned.

Connective Tissue Graft Combined with a Coronally Repositioned Flap

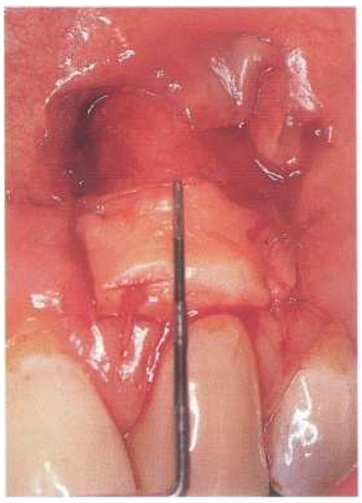
1. The recipient bed is prepared. A horizontal incision is first positioned at the basis of the papilla at the level of the cemento-enamel junction. The bed should be at least 3 mm wide and should have a sufficient blood supply to support the graft.

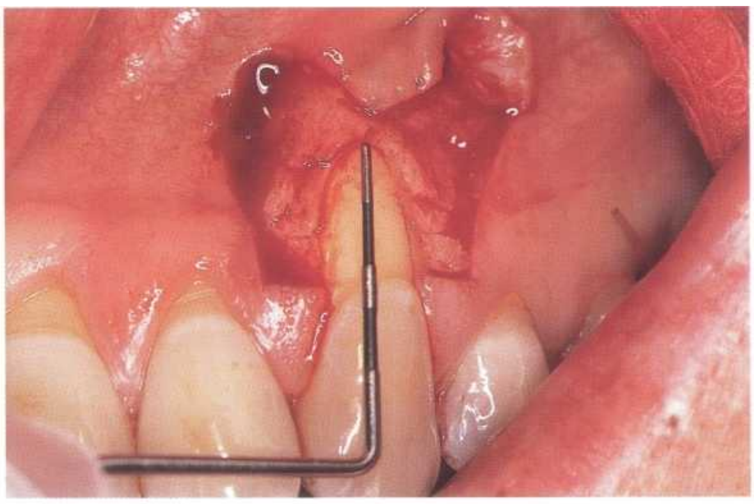
2. A lateral, vertical incision is made on both sides of the recession and extended into the mucosa.

3. The supraperiostal flap is elevated.

4. The coronal edges must be slightly shortened.

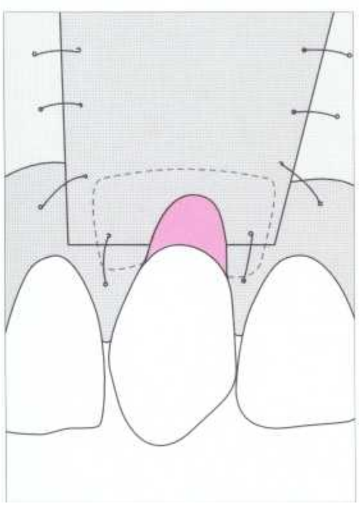
5. The flap is then positioned coronally so that a maximum of 3 mm of the graft is exposed.

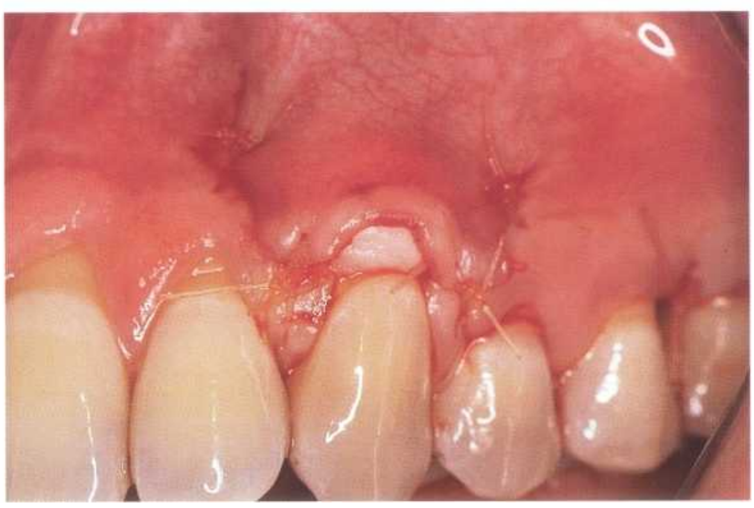




123 Attaching the graft
The flap is elevated to expose the entire recession. The root surface is planed and, if necessary, leveled off.

Left: The connective tissue graft is harvested, trimmed to the right shape and attached using resorbable sutures. The small amount of remaining epithelium is placed coronally. The graft is placed so that it stretches up to the cemento-enamel junction.





124 Postoperative view
Right: The flap is repositioned coronally and sutured. The coronally repositioned flap will better supply the graft and, since it is a small graft, it will also be better retained.

Left: Graphic representation of the graft.

125 Result after 18 months
One and a half years after the surgical intervention the root surface is completely covered by a thick layer of keratinized gingiva.

Connective Tissue Graft Combined with a Partial Thickness Double Pedicle Graft

1. Mobilization is similar to that used in the case of a coronally repositioned flap.

2. The double papillary graft is sutured.

3. The connective tissue graft is attached.

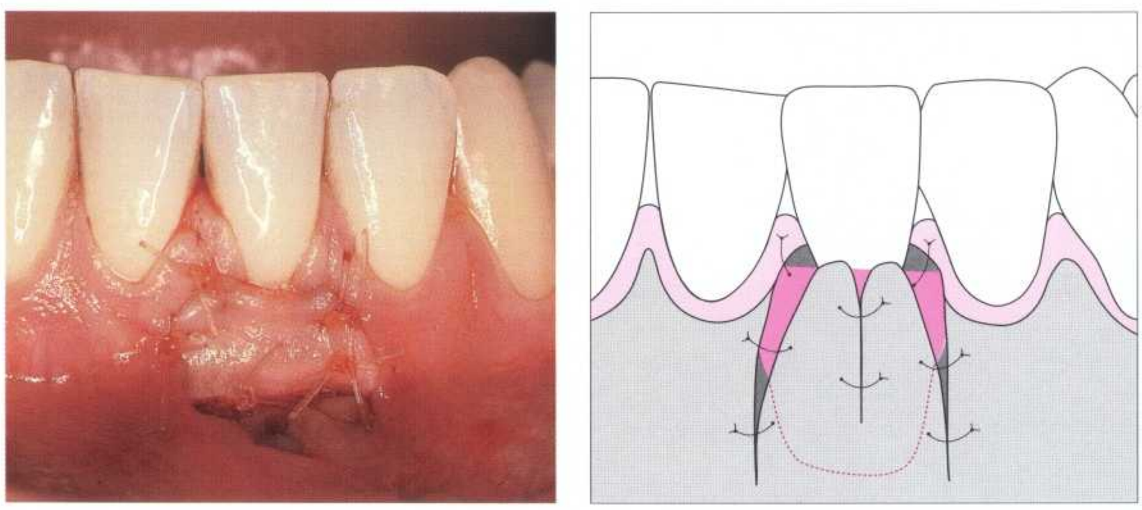
4. The pedicle graft is secured over the connective tissue graft with an embracing suture. The lateral graft parts remain exposed.

Advantages
-aesthetic results and high success rate
-only one surgical intervention is necessary
-minimal wound on the palate
-can be used when several teeth need to be treated
-good blood supply to the graft

Disadvantages
-technically difficult surgical technique
-complicated suture technique
-palatal bleeding

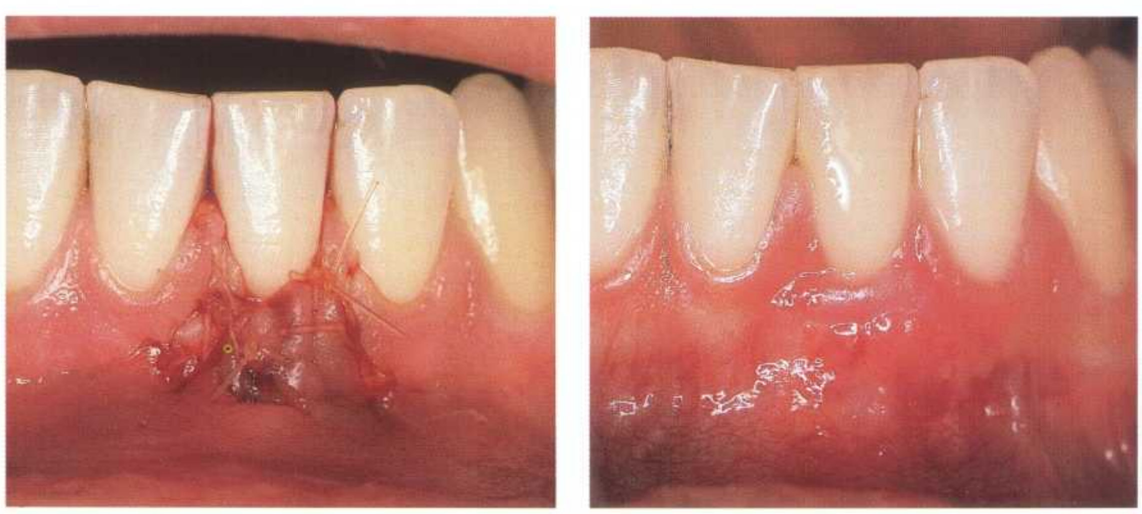
126 Connective tissue graft combined with a partial thickness double papillary graft (Harris)
Left: A 4-mm gingival recession at a lower central incisor with insufficient attached gingiva (class 2).

Right. Before the recipient bed is prepared, the root is planed and conditioned with citric acid. Note the base of the frenulum and the lack of attached gingiva. A sufficiently large recipient bed is then prepared at the site of the recession and apically.



127 Attaching the graft
Left. The epithelium-free graft is sutured to the periphery of the recipient bed. The coronal edge barely covers the cemento-enamel junction.

Right: The two parts of the detached gingiva are sutured over the graft.



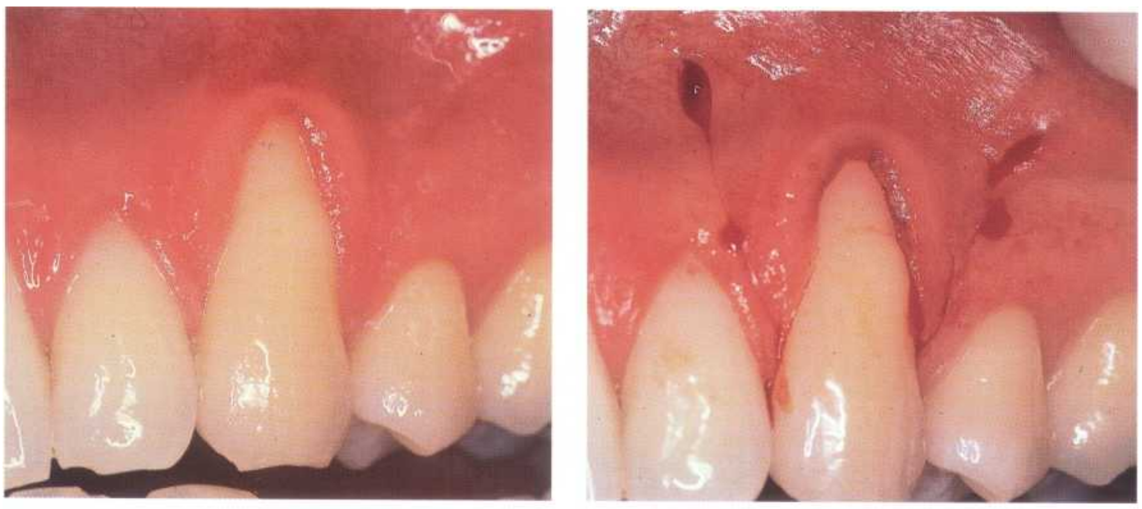
128 Fixing the double papillary graft
Left: The graft is sutured over the connective tissue graft in the area of the recession and is secured with an embracing suture around the tooth. In this way the graft covers the root segment and at the same time is protected and supplied by blood vessels from the labial side.

Right. Six months after surgical intervention, the root surface is completely covered with a sufficient zone of attached gingiva.

Guided Tissue Regeneration To Cover Recessions

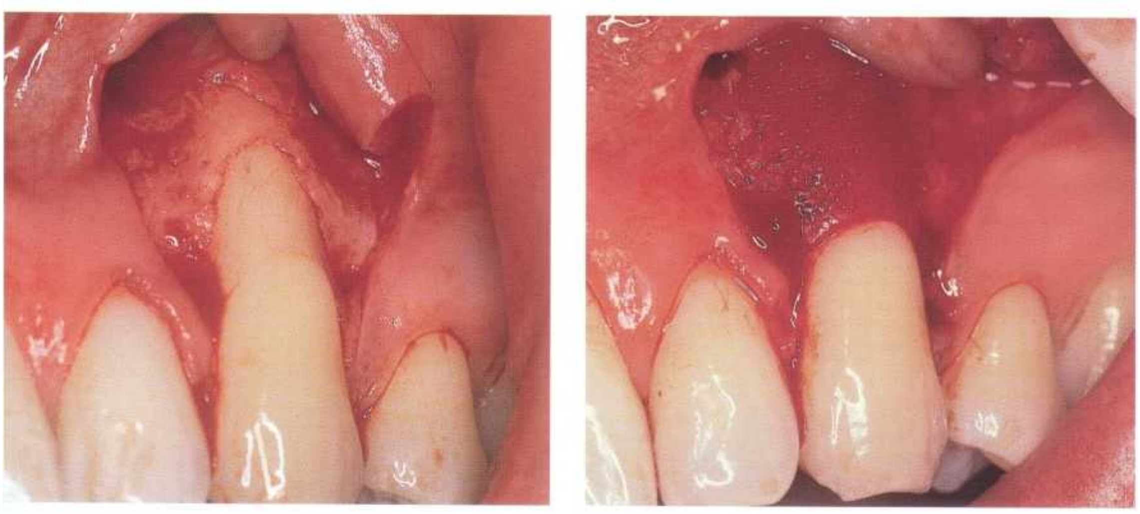
One of the newest options used to cover exposed root surfaces is guided tissue regeneration (GTR), which uses special membranes. This technique has some advantages. It simultaneously creates new attachment, including new periodontal ligament, new root cementum, and bone. If bioresorbable membranes are used, the procedure is executed in a single session.

The intervention uses a combination of full thickness flap and split thickness flap that are repositioned coronally over the membrane. However, this technique is limited to recessions with a sufficient zone of attached gingiva, because the flap must be coronally repositioned to the cemento-enamel junction.



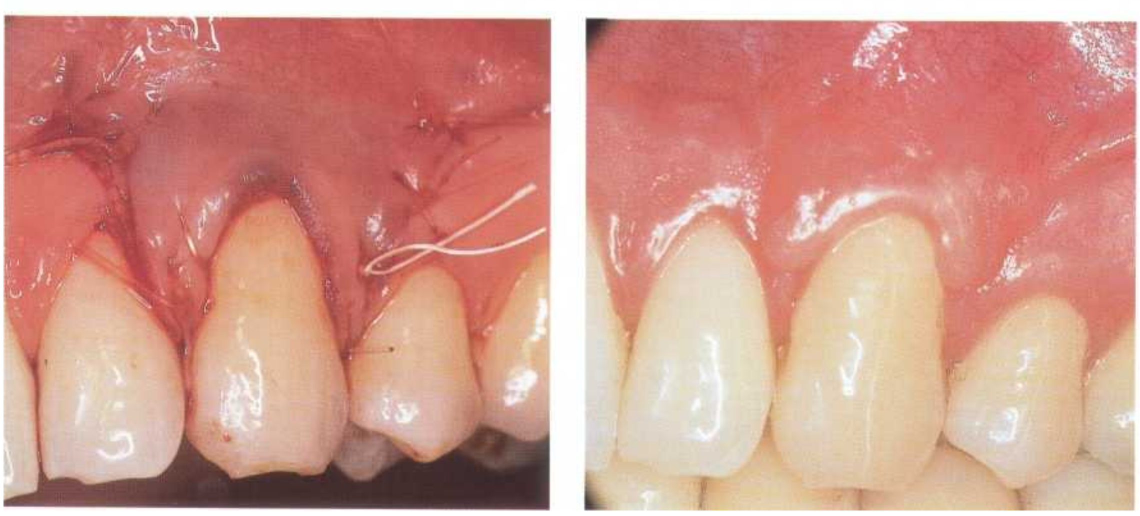
129 GTR techniques used to cover gingival recessions
Left. Class II recession on an upper cuspid.

Right: After the root surface has been planed and conditioned with citric acid, an incision is made so that the coronally repositioned flap can cover the recession and the barrier.



130 Mixing the membrane
Left. A mucoperiostal flap is elevated apical to the mucogingival junction, so that 3-4 mm of the alveolar bone is exposed. Then the periosteum is cut and the vestibulum mobilized further so that later the flap can be repositioned coronally.

Right: A resorbable membrane (Guidor) is placed and attached to the tooth with a sling suture, so that it covers approx. 2-3 mm of the adjacent alveolar bone.



131 Suturing
Left. The flap is repositioned coronally and secured to the tooth with an embracing suture. The vertical incisions are closed with single resorbable sutures. The sutures should not penetrate the membrane.

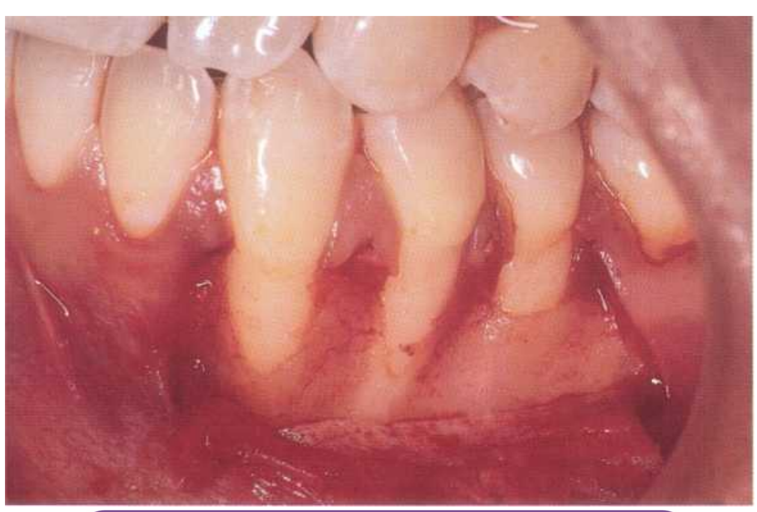
Right: Six months after the surgical intervention, the root surface is completely covered. The covering tissue is of sufficient thickness to minimize the risk of damage to the tissue during cleaning, which can cause a new recession.

Surgical Procedure

1. Before the surgical intervention begins, the root surface is planed and conditioned.
2. A trapezoid-shaped flap, very similar to the coronally repositioned flap, is elevated. However, in its coronal part it is a full thickness flap.
3. The flap is elevated approximately 3-4 mm apical to the alveolar bone margin. Here, the periosteum is carefully split.
4. The residual part of the flap is elevated like a split thickness flap. The periosteum remains on the bone. The flap has to be elevated so that it can cover the cemento-enamel junction.
5. The epithelium is removed from the remaining part of the papilla in order to create a suitable bed for the flap.
6. The membrane is trimmed so that it is large enough to cover 2-3 mm of the exposed bone and the root. It should end coronally of the periosteal incision.
7. The membrane is attached with a suture placed around the tooth to secure good adaptation.
8. The flap is repositioned coronally and attached as described for the coronally repositioned flap.

132 Covering recessions of several teeth using the GTR technique
The lower canine and premolar show class II recessions (McCall). They extend apical to the mucogingivaljunction.

133 Conditioning the root surface
The roots of all three teeth are planed and conditioned with citric acid.



134 Elevating the flap to be coronally repositioned
The membrane bed is exposed.

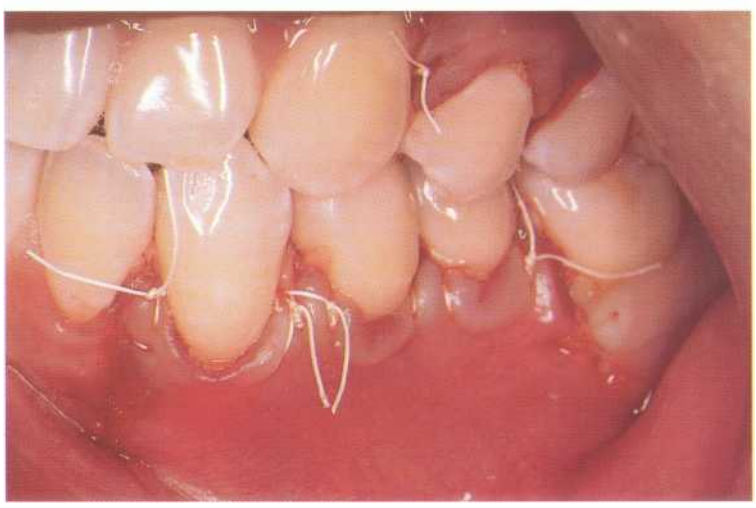
This technique can be used for single recessions and for several defects. Its advantages are: aesthetically pleasing, high success rate, regeneration of attachment, no palatal tissue removal is necessary. The first clinical studies show promising results (Roccuzzo et al. 1996).

Follow-up Care with Recession Coverage

During the first two weeks after the recession coverage, the patient must avoid traumatizing the treated site. During this time, patients should not clean their teeth, only rihse with an oral disinfectant. Also, chewing on this side should be avoided. After two weeks, all the nonresorbing sutures are removed, and the patient can proceed with oral hygiene using a soft toothbrush. However, it is not until four weeks after the intervention that the patient may touch the transplant with the toothbrush.

If the root was covered with a membrane, the patient should not brush this region for six to eight weeks. Prescribe chlorhexidine and a weekly, mild professional tooth-cleaning session.

135 **Fixing the membrane**
The resorbable barrier (Guidor) is trimmed to the desired shape and attached to each tooth with an embracing suture.



136 **Postoperative situation**
The sutures are removed two weeks after surgery. There is little inflammation and the membrane is not exposed.

137 **Outcome after seven weeks**
Seven weeks after surgery, remains of the barrier can still be recognized. The wound has almost completely healed. The membrane used has resorbed relatively slowly. After approximately four months, no more membrane remains are visible.

Corrections of the Alveolar Ridge

Some plastic-surgical interventions can be performed to Correct alveolar ridge defects (Abrams 1980; Allen et al. 1985; Buser et al. 1995; Kaldahl 1982; Langer and Calangna 1985; Seibert 1983). The alveolar bone often has to be augmented before implants can be inserted. The implants can then be placed as required for functional and aesthetic reasons (guided bone regeneration).

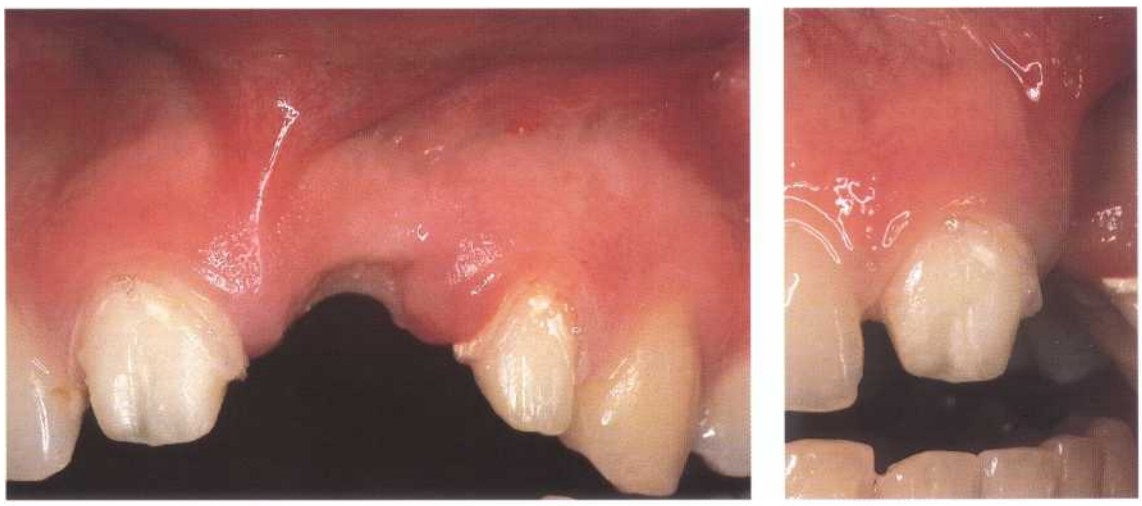
In order to achieve aesthetic success of a prosthetic reconstruction (pontic), however, ridge augmentation with soft tissue is normally sufficient.

Ridge Defects: Classification According to Seibert (1983)

Class I: Buccolingual bone loss with normal ridge height in apicocoronal direction.

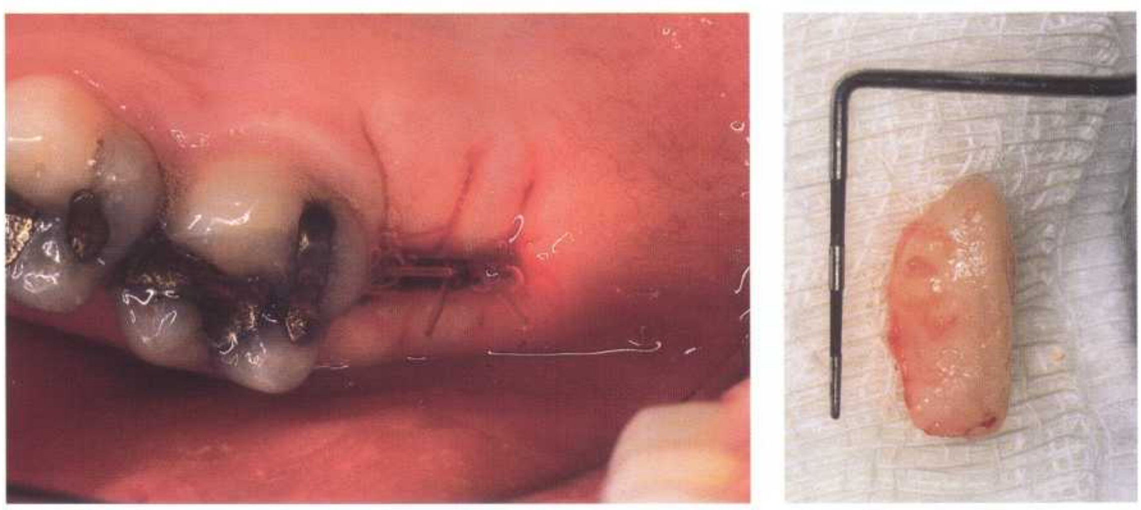
Class II: Loss of the vertical ridge height with normal ridge width in buccolingual direction.

Class III: Combination of vertical and horizontal bone loss of the alveolar ridge.



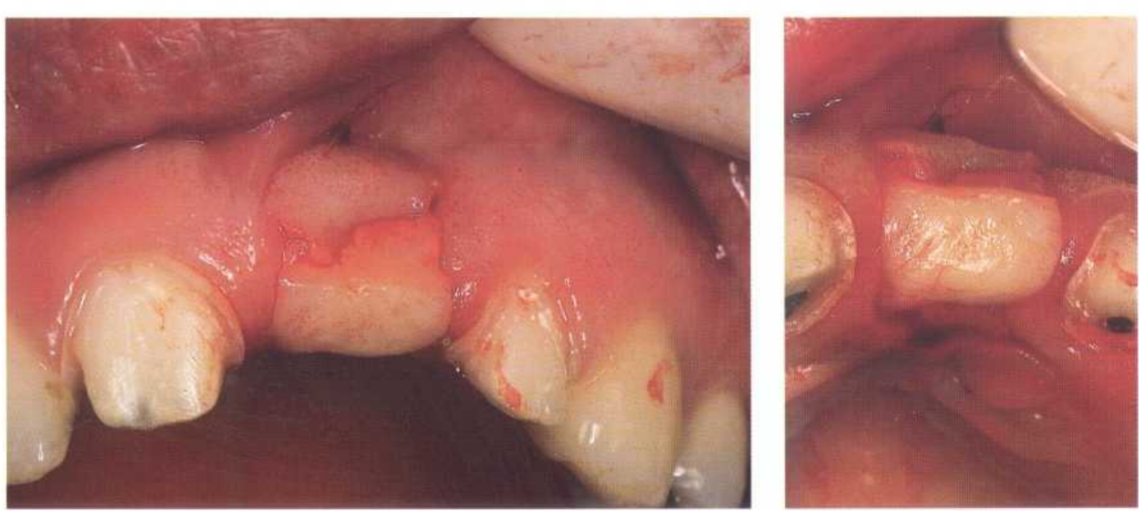
138 Defect of the alveolar ridge
A missing central incisor with extensive tissue loss in both vertical and anterior-posterior direction (Seibert class III).

Right: Ridge defect approx. 3 mm in length in buccopalatal direction.



139 Onlay graft technique
The aim is to fill the defect with a large pillow of soft tissue. A large piece of connective tissue was excised from the distal region of the upper second molar in the area of the former wisdom tooth.

Right. The graft may also contain fat tissue. The epithelium is not removed from the new alveolar ridge.



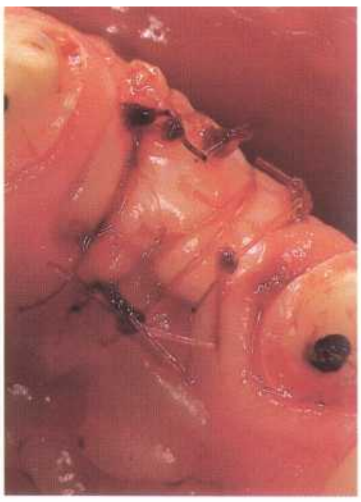
140 Grafting
After a flap has been elevated (labial and palatal), the recipient bed is freed of epithelium (to provide a blood supply) and the graft well adapted. The connective tissue graft is placed to fill the defect.

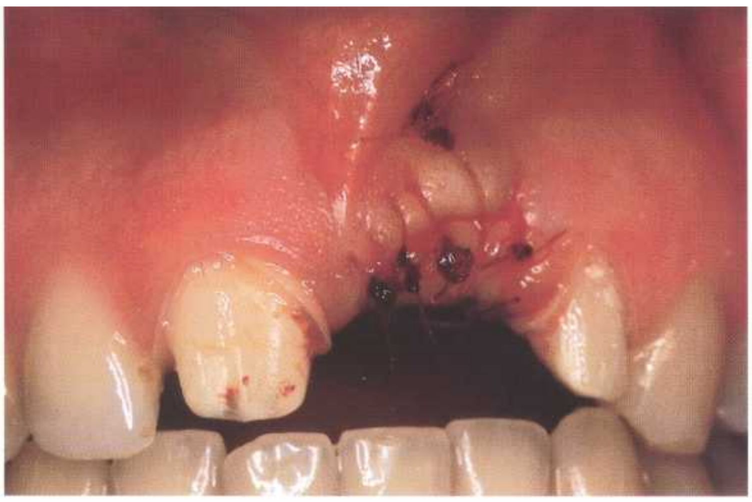
Right: Coronal view of the graft.

Surgical Procedure

Reconstruction of the alveolar ridge with soft tissue is usually carried out by means of a connective tissue graft.

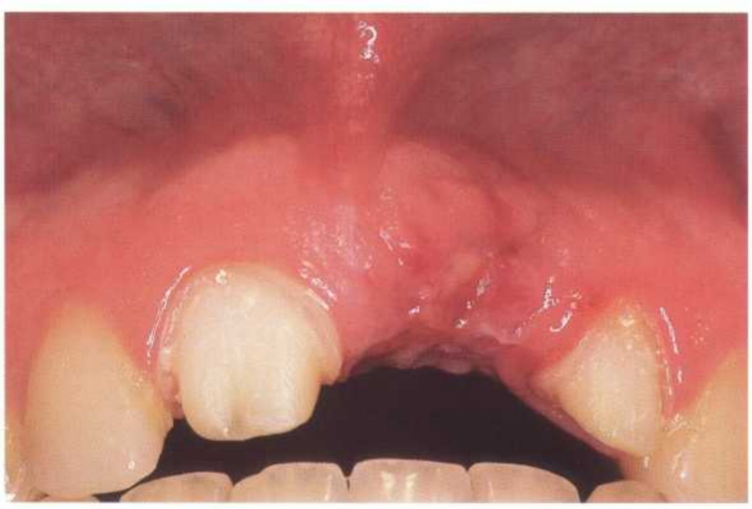
1. A horizontal alveolar ridge incision is made in the area of the defect and is extended to within approximately 2 mm of the adjacent teeth.
2. A vertical incision is made approximately 3-5 mm long. The papillae should not be involved in the vertical incision.
3. The incision creates a supraperiostal cavity on the vestibular aspect.
4. The tissue is slightly elevated on the palatal aspect as well in order to accommodate the connective tissue graft.
5. The connective tissue required is retrieved from the palate or from the maxillary retromolar area.
6. The connective tissue graft is placed under the elevated flap and is attached with resorbable sutures.
7. The palatal wound is sutured or closed with Histoacrylic alone.
8. A removable denture should not be worn. However, a temporary bridge, without contact with the surgical wound, can be placed.
9. The temporary bridge is adjusted weekly in order to generate the desired gingival contour.
10. The final reconstruction should not be initiated until three to six months following surgery.





141 Postoperative view
The graft is positioned and secured with single sutures. During this process a good blood supply to the graft must be assured. The graft is protected against mechanical irritation with a temporary bridge.

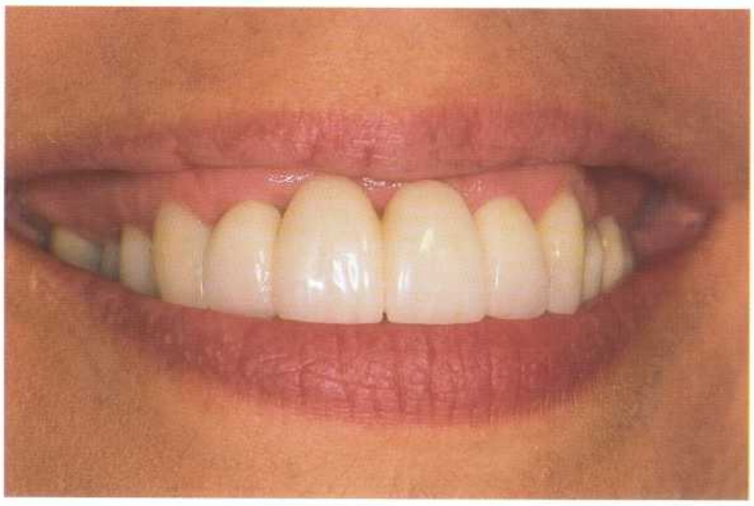
Left: Coronal view of the reconstructed alveolar ridge.



142 Result
One week after surgery, the surgical areas both at the tuber as well as in the region of the front teeth have healed well. The sutures have already been resorbed.

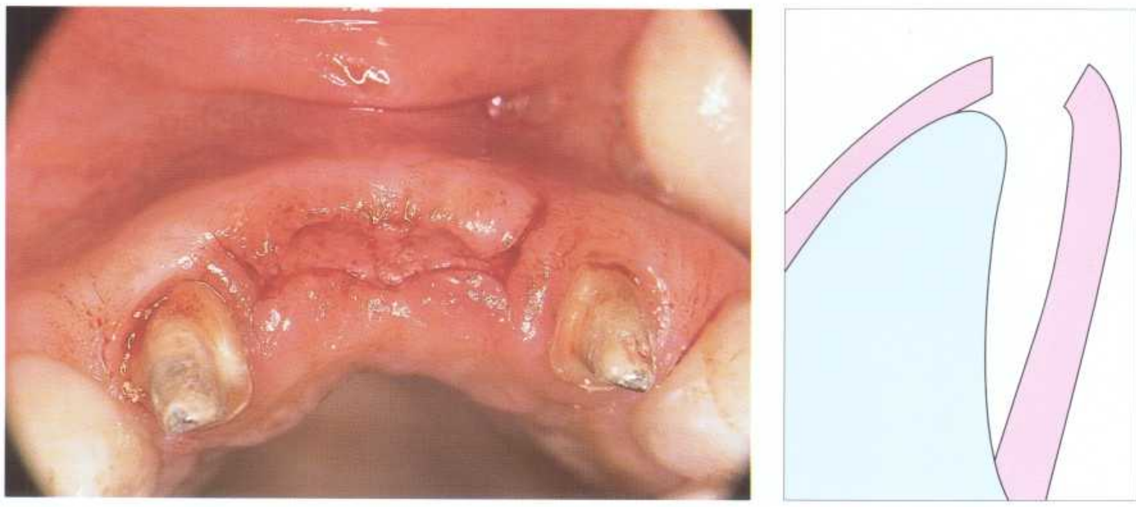
Left: The harvest site shows good healing after one week.

143 Result six months after use of a long-term temporary bridge
The final crown and bridge therapy can start six months after surgical intervention. A concave pontic tip is made at the site of the former defect. The pontic is shaped to fit the soft tissue shape (e.g., with a diamond ball). The pontic of the bridge is adapted to the soft tissue to look like a natural tooth.



144 Ridge defect-initial situation

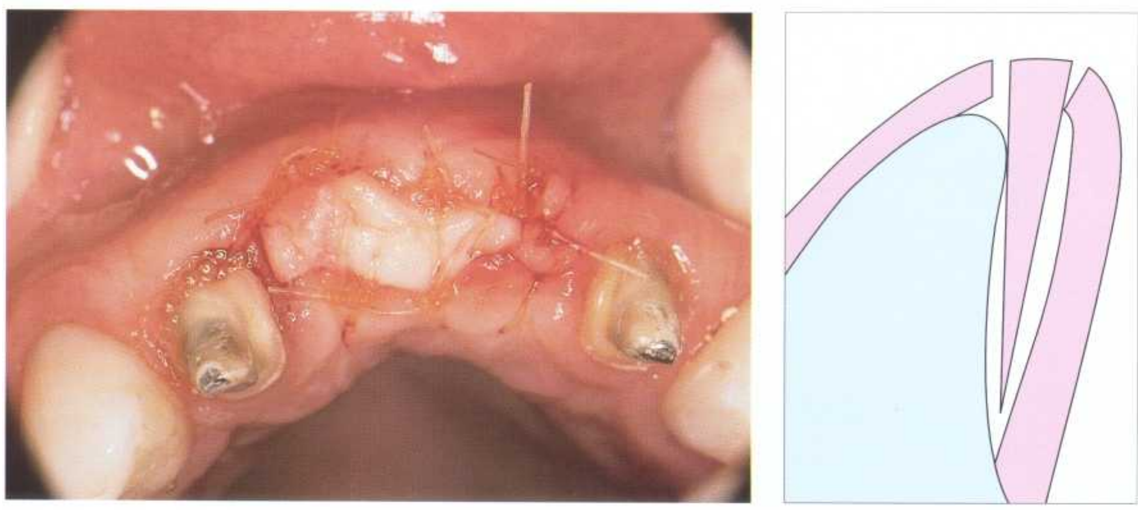
The temporary bridge-with protruding pontics-covers the ridge defect at the site of the two missing central incisors.



145 Incisions

Left. The horizontal incision begins approx. 2 mm from the papilla and continues along the entire defect. Additionally, short horizontal release incisions are made.

Right: A bed is created for the graft by means of a sharp dissection.



146 Attaching the graft

Left: The graft is now positioned and attached by means of a suture.

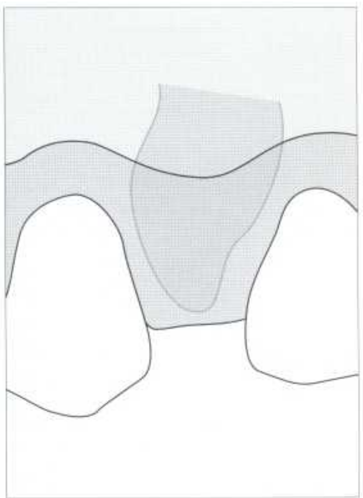
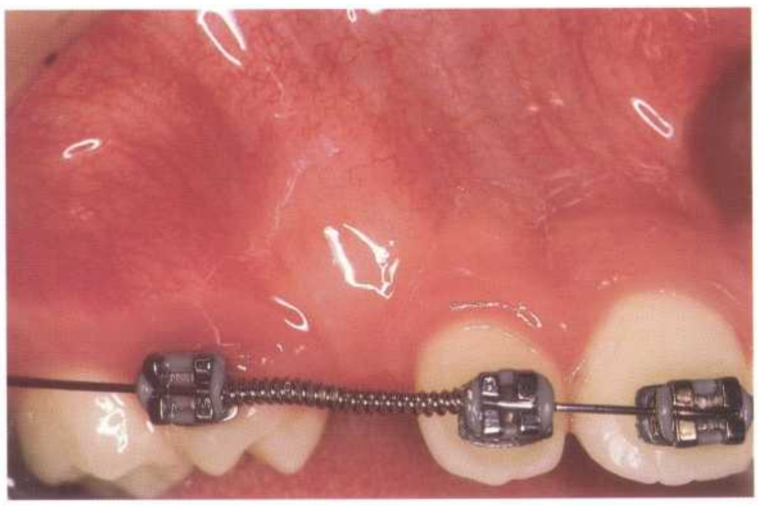
Right: Placing the connective tissue graft. The wedge-shaped graft is taken from the palate so that the epithelium is located in the exposed region.

147 Postoperative result with temporary bridge

The temporary bridge fits the alveolar ridge. The concave shape of the pontic creates the illusion of a natural tooth (emerging profile).

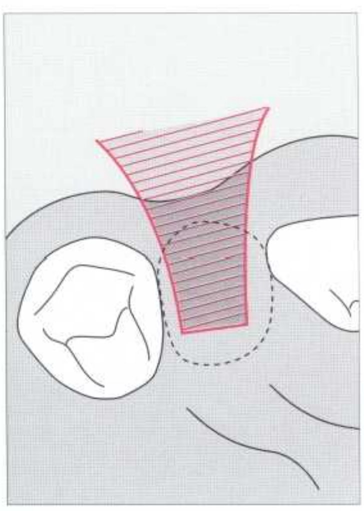
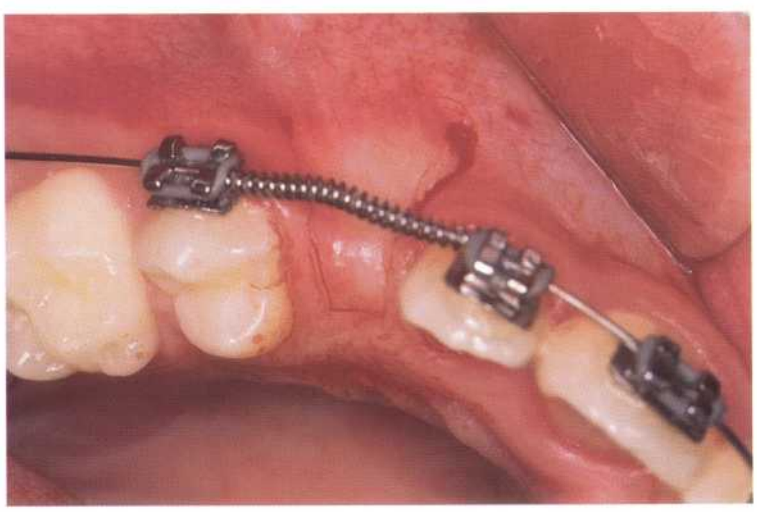
Exposing Impacted Teeth

When exposing a tooth, the orthodontist should be aware that mucogingival problems, which may occur later on, could be avoided if the surgical techniques shown on this and the following page are used. Until recently, only the tissue covering the impacted tooth was excised to produce a window for the orthodontic appliance. This is a feasible option for teeth located palatally. However, this simple technique should not be used vestibularly as the result may be insufficiently attached gingiva and, as a further consequence, recession.

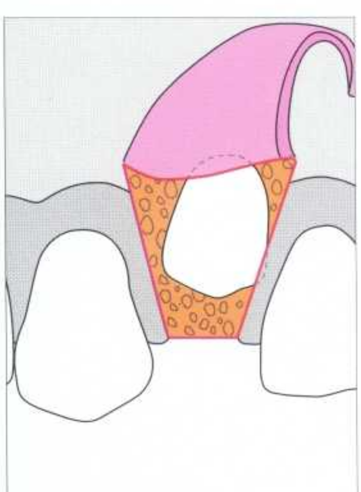
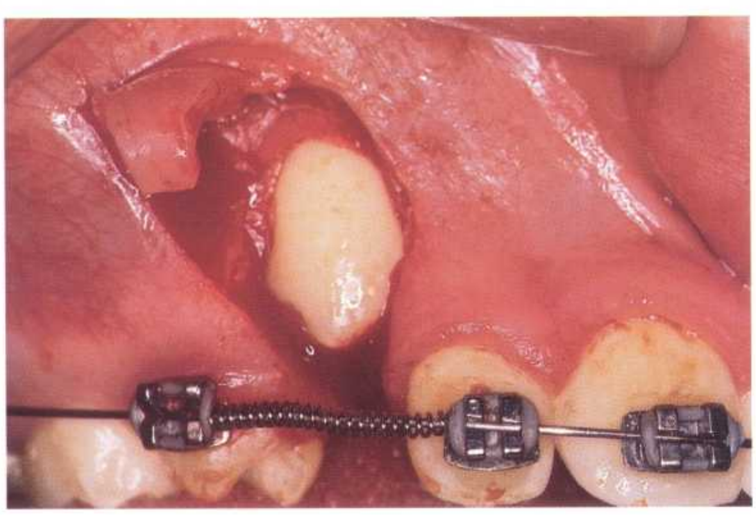
148 **Surgical exposure of an impacted tooth**
Buccally impacted upper cuspid.

Left: Schematic drawing of the tooth positions.

149 **Initial incisions**
A semilunar incision is made. The horizontal incision is placed slightly palatal to the alveolar ridge.

Left: The papillae should not be injured.

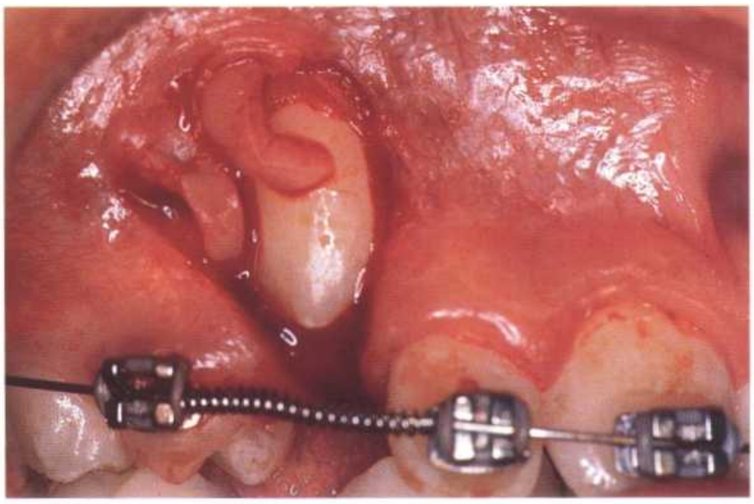



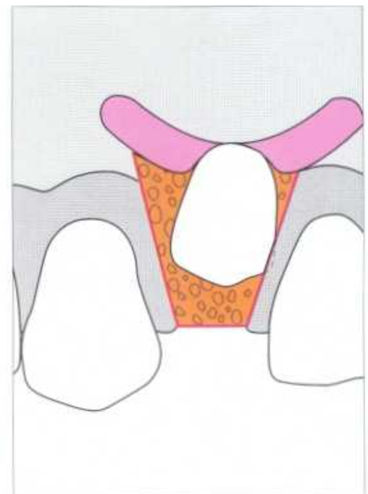
150 **Exposing the tooth**
The **flap is elevated by sharp dissection** and the impacted cuspid is exposed.

Left: After the tooth has been exposed, the flap is folded backwards.

151 Splitting the flap
The flap is split approximately up to the level of the mucogingival border.

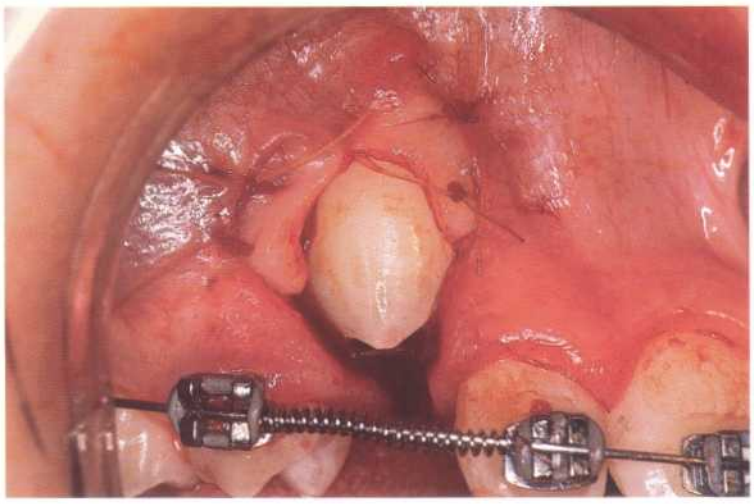
Right: The split flap will form the attached gingiva after it has been sutured.

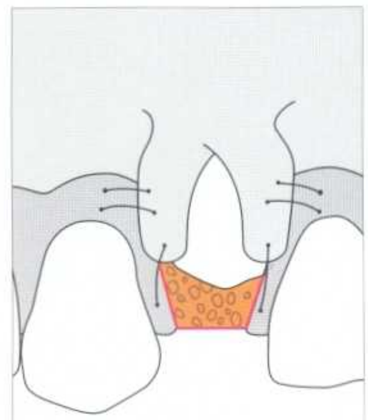




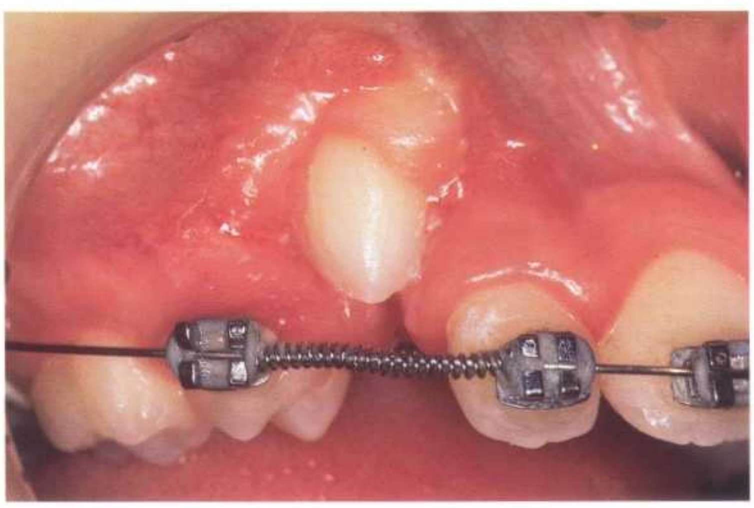
152 Attaching the flap
The split flap is attached around the exposed tooth.

Right: Attached gingival parts.

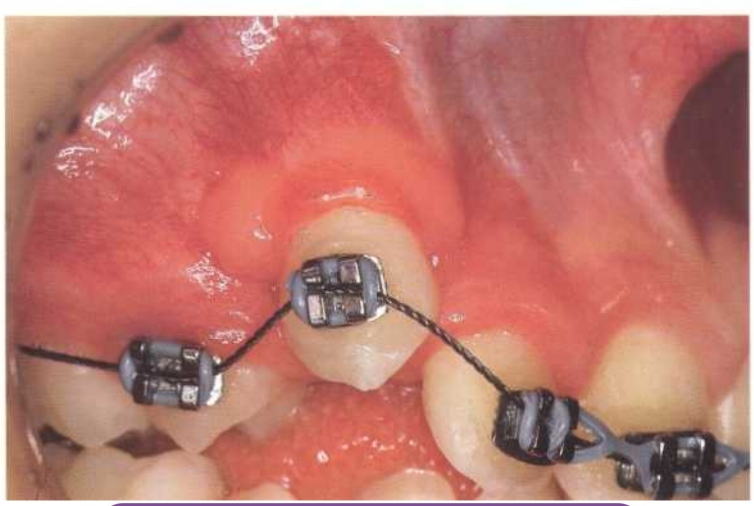




153 Situation two weeks after surgical intervention
The tooth is exposed and keratinized gingiva has been established around the tooth.



154 Postoperative situation after eight weeks
An orthodontic bracket is attached eight weeks after the surgical intervention. A sufficiently wide zone of attached gingiva is visible around the exposed tooth.



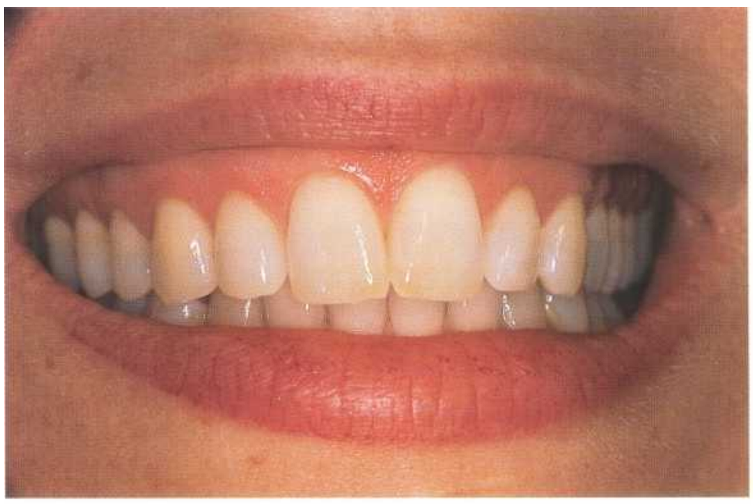
Red-White Aesthetics

Ideal Gingival Condition (Allen 1988)

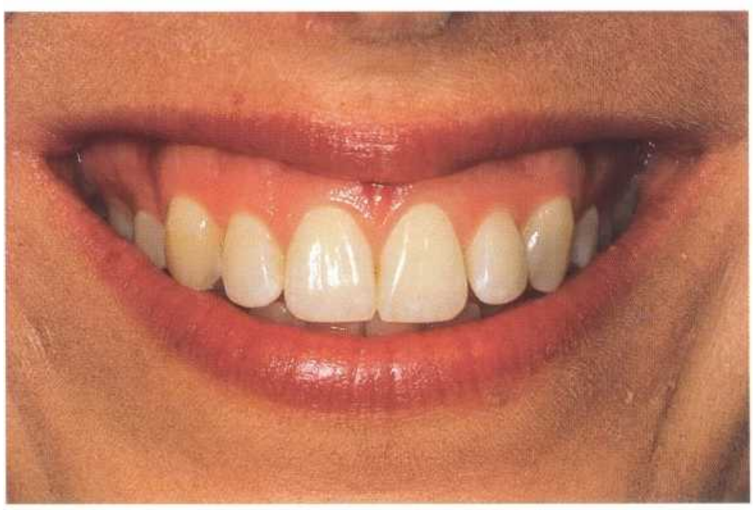
- The gingival contour on the central incisors is symmetrical and level. It is 1 mm more coronal on the lateral incisors.
- The connector of the gingival outline of the cuspids proceeds parallel to the line between the two papillae.
- Only little gingiva should be visible when the patient smiles. The gingival outline should harmonize with the smile line.
- The central incisors and the canines should be at least 12 mm long. The lateral incisors are approximately 1.5 mm shorter.

Indications for Mucogingival Intervention

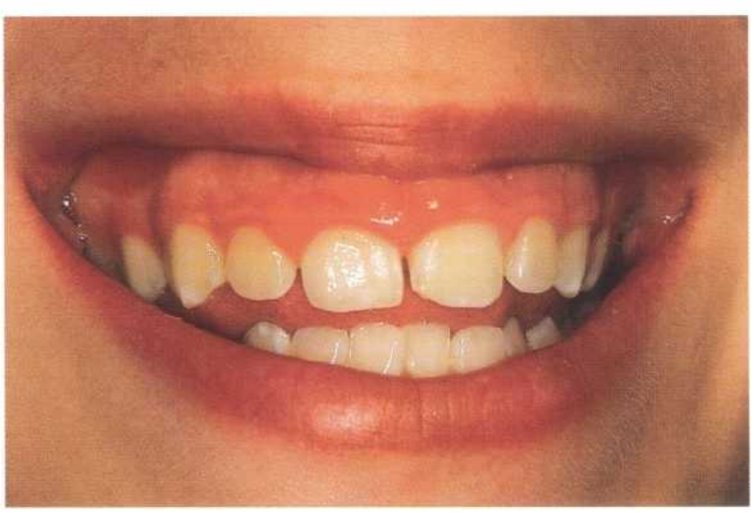
- Insufficient zone of keratinized gingiva
- Gingival recession
- Excessive gingiva
- Inadequate clinical crown length
- Asymmetrical outline of the gingiva
- Marginal gingiva outline too flat
- inadequate red-white aesthetics
- Dissonant relation between lip line and gingival outline
- Alveolar ridge defects



155 **Normal red-white aesthetics**
A normal lip line with perfect tooth shape and gingiva. The length of the clinical crown is normal and is in harmony with the upper and lower lips. Only a small part of the gingiva is visible.



156 **Higher lip line**
A high lip line shows a **lot of the attached** gingiva and a part of the alveolar mucosa. The length of the clinical crown is normal.



157 **Gummy smile**
The photo shows a normal lip shape, but a great deal of gingival tissue ("gummy smile"). The cause for this is the incomplete eruption of the anatomical crowns. Surgical crown lengthening can correct this aesthetic problem.

Surgical Crown Lengthening

In the United States too much visible gingival tissue when a patient smiles is known as a "gummy smile." The teeth then usually seem very short. If the reason for a gummy smile is clinical crowns that are too short, this can be corrected with a crown lengthening procedure.

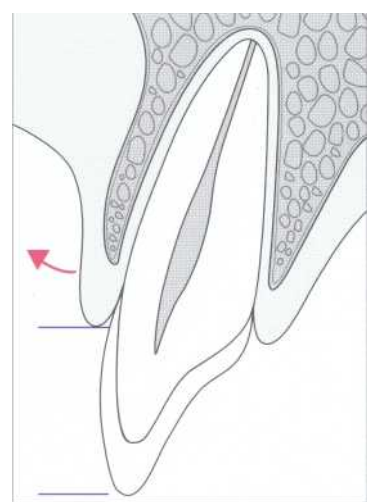
First, the length of the actual clinical crown-from the cemento-enamel junction up to the incisal edge-must be determined. If the teeth are not fully erupted, it is not only possible to elongate the crowns by means of surgical crown lengthening, but the quantity of the visible gingiva can also be reduced. This can result in a significant improvement in a person's overall appearance.

In the ideal situation, the contour of the gingiva should be symmetrical with the upper lip, and no part of the alveolar ridge should be visible. The length of the clinical crown for incisors should at least be 11 mm.

158 **Situation before surgical crown lengthening**
A high lip line is combined with very short clinical crowns. The teeth have not erupted completely.

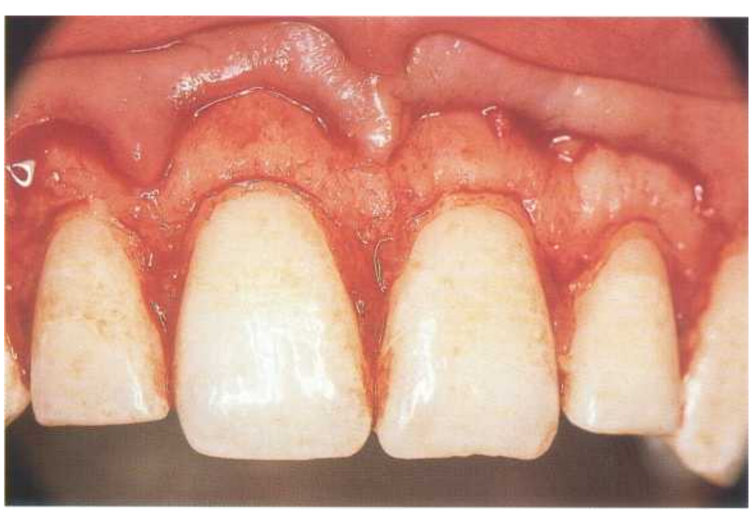
159 **Gingivectomy**
Gingivectomy around the incompletely erupted clinical crowns eliminates the aesthetic problem.

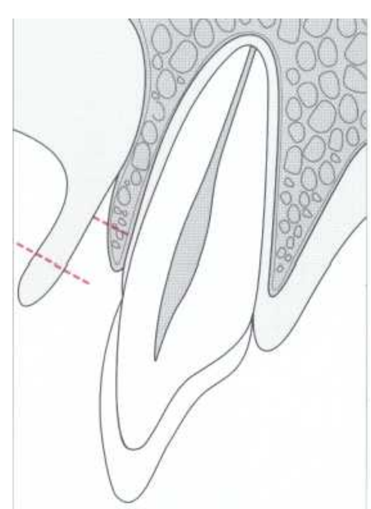
Right: The clinical crown is extended by means of gingivectomy.

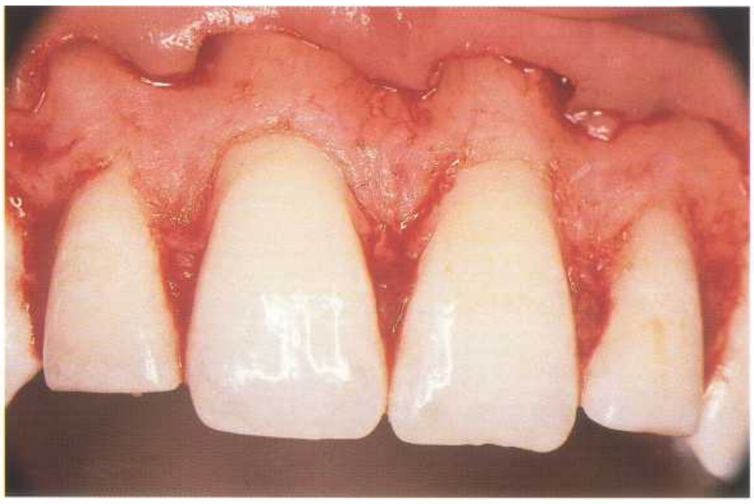


160 **Exposing the bone**
A full thickness mucoperiosteal flap is elevated. The very thick alveolar bone is exposed.

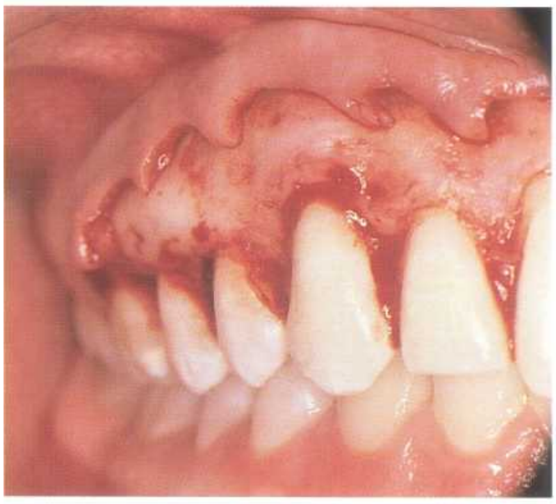
Right: The biological width is defined as the distance between the cemento-enamel junction and the edge of the alveolar bone. It should exceed 2 mm.



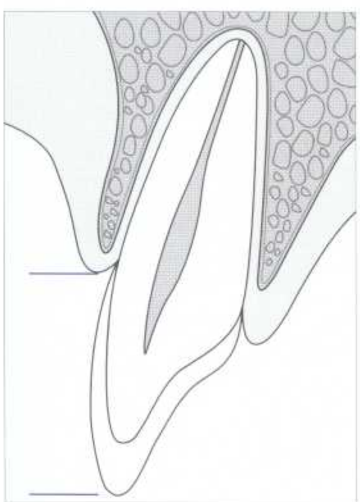




161 Biological width
The bone is trimmed carefully. The distance from the bone to the cemento-enamel-junction should be approx. 2-3 mm. This is regarded as the biological width and may be of significance for gingival health.

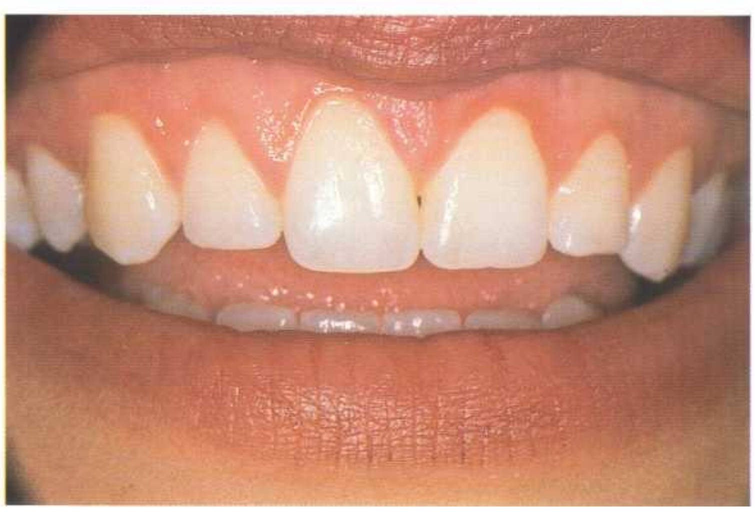


162 Contouring the bone
Hypertrophic bone is also removed in the area around the posterior teeth. During this process an even spacing of 2-3 mm between the bone and the cemento-enamel junction should be achieved.



163 Postoperative situation
The flap is repositioned and attached with resorbable, single sutures.

Left: The crown is lengthened.

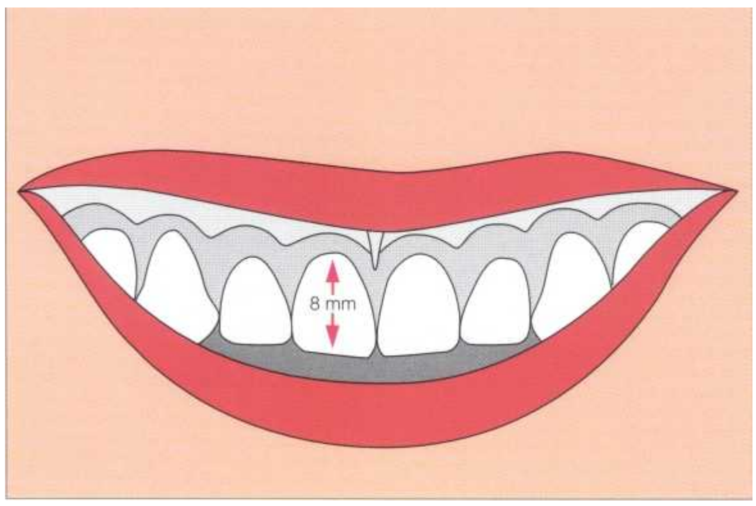


164 Result after two weeks
A perfect aesthetic result is obvious two weeks after surgical intervention.

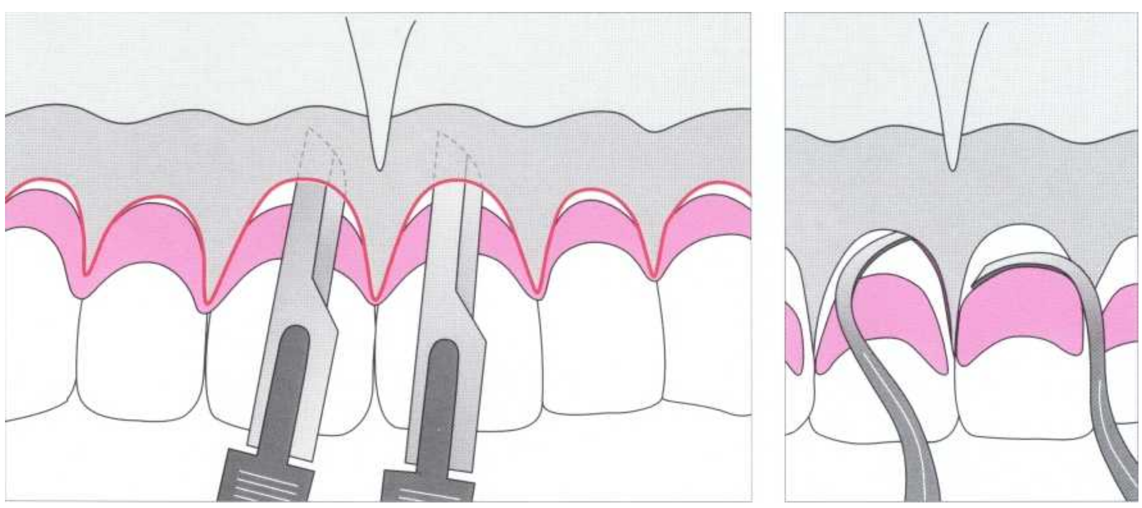
Surgical Procedure

The goal is to expose the anatomical crowns completely. Beside the gingivectomy, exposure of the bone is important in order to decide on the distance between the bone margin and the cemento-enamel junction (biological *width).* This distance should be at least 2-3 mm, which is important to secure gingival health.

1. A full thickness flap with periosteum is elevated.
2. The flap is contoured and, if necessary, thinned.
3. The flap can then be repositioned at the same place or repositioned apically. When the horizontal incision is placed, the height of the interdental papillae must be retained. Only a thin labial part of the papillae is therefore lifted up with the flap. No flap is mobilized palatinally.
4. If the bone is not resected, the gingiva may regrow to the initial level.
5. At the end the flap is secured with interdental sutures (5.0).
6. During the first two weeks after surgery, mechanical tooth cleaning of the surgical area should be avoided. A twice-daily rinse with Chlorhexidine should be prescribed.
7. Sutures can be removed after approximately four to five days.

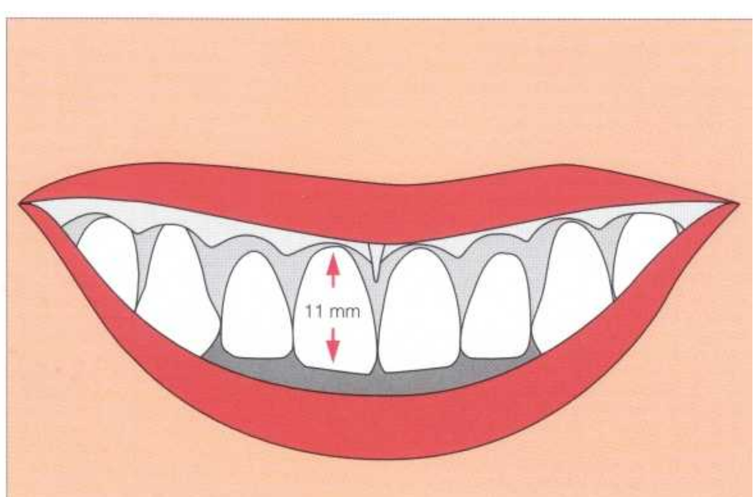


165 **Surgical procedure**
Analysis: The crowns have not erupted completely and the cemento-enamel junction is located subgingivally. Surgical crown lengthening is indicated.



166 **Crown lengthening**
Left: Crown lengthening is achieved by means of a gingivectomy. The scalpel blade should be renewed for each tooth.

Right: The gingiva is removed with a sharp curet.



167 **Result of crown lengthening**
The same case as in Fig. 165 after surgical crown lengthening. The length of the clinical crowns of the central incisors should not be less than 11 mm.

Composites-Background

One of the goals of dentistry has always been to have tooth-colored restorative material at its disposal, especially for restoring anterior teeth. During the first half of the 20th century, only various cements were available, particularly so-called silicate cement. At this time, one also believed that the low pH value of silicate cements led to pulp damage over the course of time. Therefore, one tried to eliminate the effect of the acid by placing a calcium hydroxide liner.

The development of composite materials as an alternative to silicate cements was the beginning of a new era. Dental composites contain three main components: a polymer matrix, a coupling agent, and filler particles. The polymer matrix is combined with the filler particles to form a combination material, a so-called composite material, consisting of ceramic and polymer. Through wear, polishing, and dislodging of the filler particles, the filler particles are easily removed from the composite surface. In order to prevent this, the filler particles must be bonded to the polymer matrix.

Chronological summary of the development of new composite materials in dentistry

1933	Invention of methylmethacrylates (MMA).
1942	Invention of the cold-curing method.
1949	The first cold-cured MMA-based plastic material available on the United States market.
1951	A composite based on MMA is patented.
1951	Hagger claims that resin–dentin bonding is possible.
1955	Buonocore introduces the acid etching technique for enamel bonding.
1963	Bowen obtains a patent for the first BisGMA composite material.
1973	Clinical studies show that composites used on posterior teeth wear extensively and are therefore unsuitable for posterior restorations.
1973	Ultraviolet light–cured sealants become available.
1977	Microfilled composites are introduced on the market.
1978	Visible light–cured composites are introduced on the market.
1978	Fusayama describes the total etch technique.
1980	Clinical studies show that wear is still a problem when composites are used in the posterior regions.
1990	The total etch technique is accepted as a standard treatment.

Matrix and Resin Systems

The matrix of a composite consists of several chemical components, of which resin is the most important. Other chemicals contribute to the initiation of the polymerization process, but they also prevent the resin from spontaneously polymerizing during storage. In addition, the matrix also contains components that improve the aesthetic qualities of the composite.

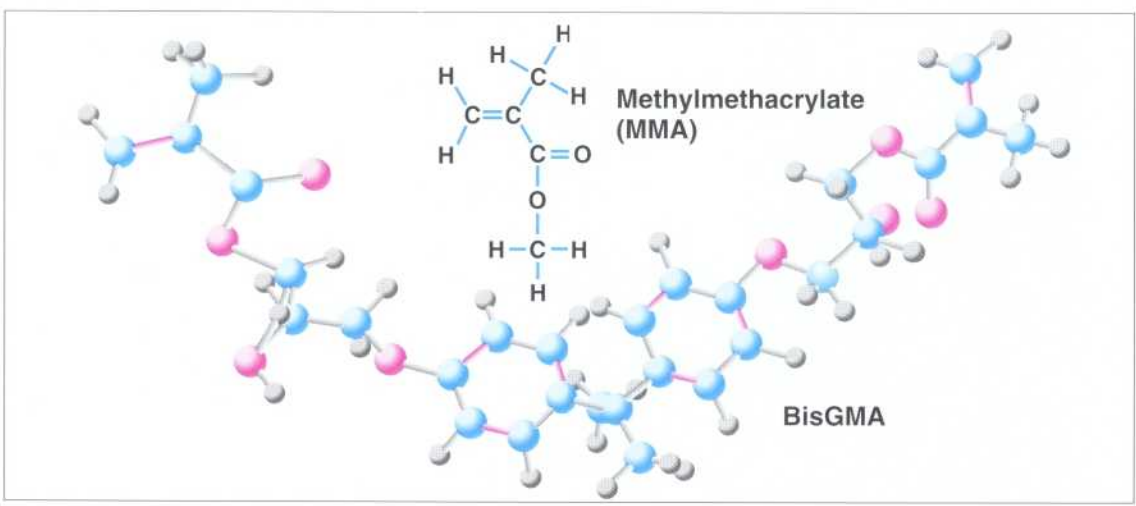
Resin Systems

Resin systems used for restorations in dentistry are primarily based on methyl methacrylate (MMA) technology. This technology was first applied in dentistry in the 1940s. Problems such as low wear resistance, marginal leakage, and a tendency to discoloration were the reasons why this technology was further developed, resulting in improved materials. In 1951, Al_2O_3 filler particles were, for the first time, mixed with methyl methacrylate resin in order to reduce the polymerization shrinkage of the resin-based restorative material. Unfortunately, these materials did not fulfill all expectations.

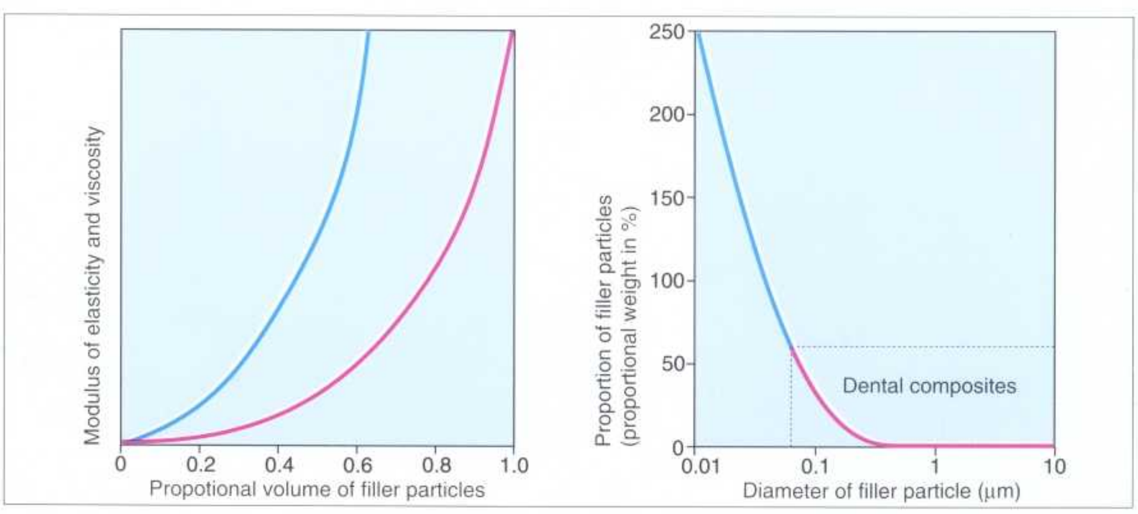
BisGMA

As a substitute for MMA, a resin based on epoxy was tested. However, because the epoxy resin tested did not cure well in a moist environment, it was not suitable for clinical use. To solve the problem, Bowen (1963) joined each end of a bisphenol-A molecule with a glycidyl methacrylate molecule. This synthesis made it possible to utilize both the reliable hardening mechanism of methyl methacrylate and the rigidity of the bisphenol-A molecule. Another advantage of the monomer molecule, named BisGMA, was that it had two separate methacrylate groups at each end of the molecule which formed a cross-linked structure during polymerization. The BisGMA molecule is also bigger than the MMA molecule. Because the BisGMA molecule is substantially larger in size, the number of double bonds per milliliter BisGMA monomer is lower than that of MMA. The reduced number of double bonds per milliliter results in a smaller polymerization shrinkage of the BisGMA-based resin than of the MMA-based resin.

The BisGMA molecule has two OH groups and two central benzene rings (Fig. 168).



168 Chemical formulas of methyl methacrylate (MMA) and bisphenol-A-diglycidyl-methacrylate (BisGMA)
The blue atoms are carbon atoms, the red ones oxygen atoms, and the gray ones hydrogen atoms. The red bonds represent carbon double bonds. Those that are at the end of the molecule react during polymerization.



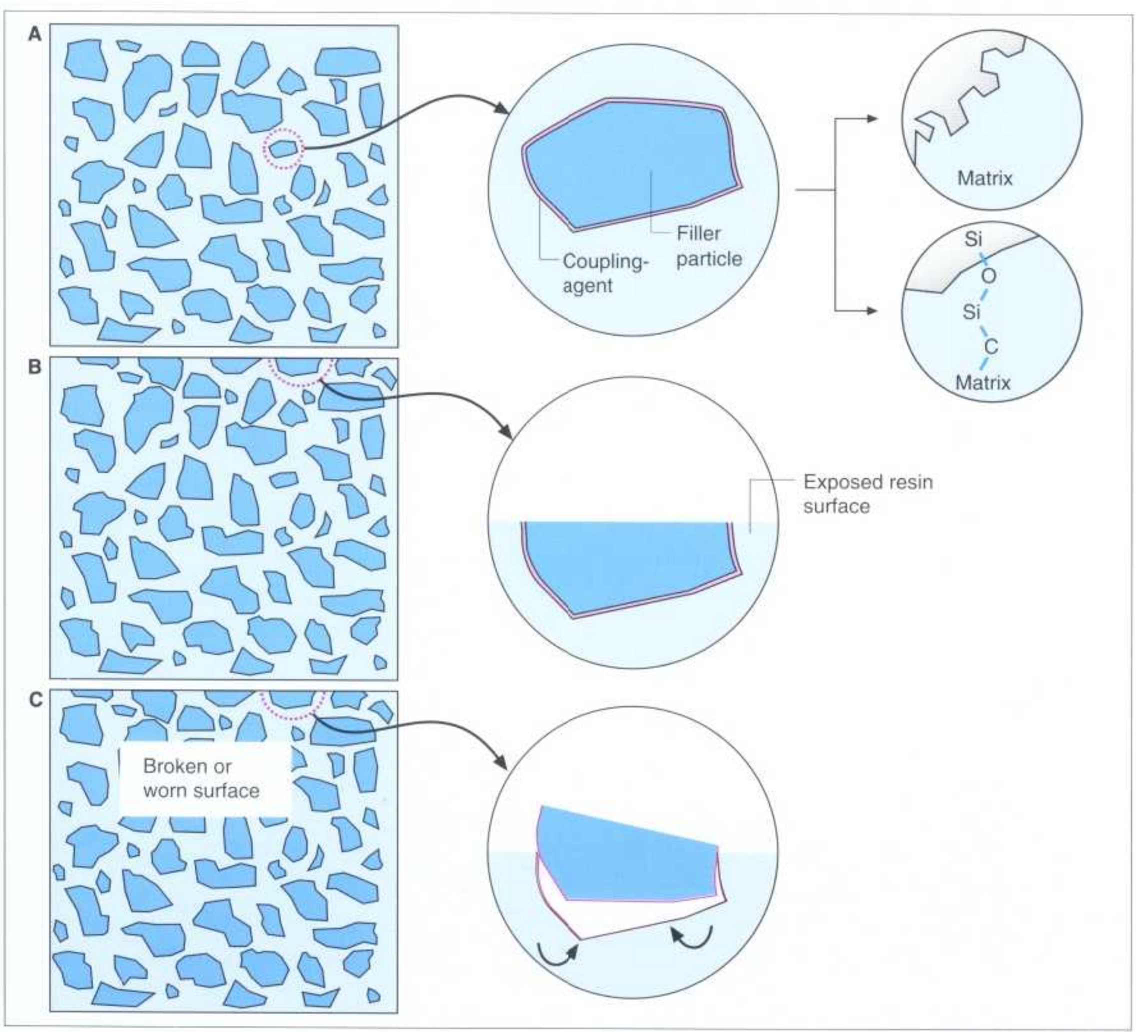
169 Physical properties and filler volumes
Left: Modulus of elasticity (blue curve) and viscosity (red curve) increase exponentially with increased proportional volume of filler particles.

Right: If one reduces the size of the filler particles, the total surface area of the filler particles increases per volume unit of filler. Dental composites use particle sizes shown as the part of the curve marked in red.

The benzene rings stiffen the middle part of the molecule, while the OH groups form hydrogen bridges with OH groups of adjacent BisGMA molecules. Because of these features, the BisGMA monomer becomes a highly viscous monomer. The high viscosity delays the sedimentation of the filler particles, but at the same time it decreases the amount of filler that can be incorporated into the monomer. Since the addition of filler particles increases the viscosity of the resin even further, mixing it with a low viscous monomer must reduce the viscosity of the BisGMA monomer. One monomer that is frequently used for this purpose is triethylene glycoldimethacrylate (TEGDMA).

TEGDMA

The TEGDMA molecule also has a methacrylate group at each end of the molecule and can therefore cross-link. It consists of a flexible chain and has no OH groups. The high flexibility of the TEGDMA molecule reduces its viscosity and increases the likelihood of its double bonds being able to rotate and find another methyl methacrylate group to react with during polymerization. The higher double bond density of TEGDMA per milliliter and its greater ability to participate in the polymerization process result in more pronounced shrinkage, but also in improved mechanical properties of the BisGMA/TEGDMA matrix. By diluting the matrix with TEGDMA, there is an increased risk that filler sedimentation may occur as the monomer becomes less viscous. Increasing the filler fraction, which will also decrease the polymerization shrinkage, can increase the viscosity of the composite. The addition of more filler essentially improves the properties of the composite.



170 **Schematic overview of the resin system**

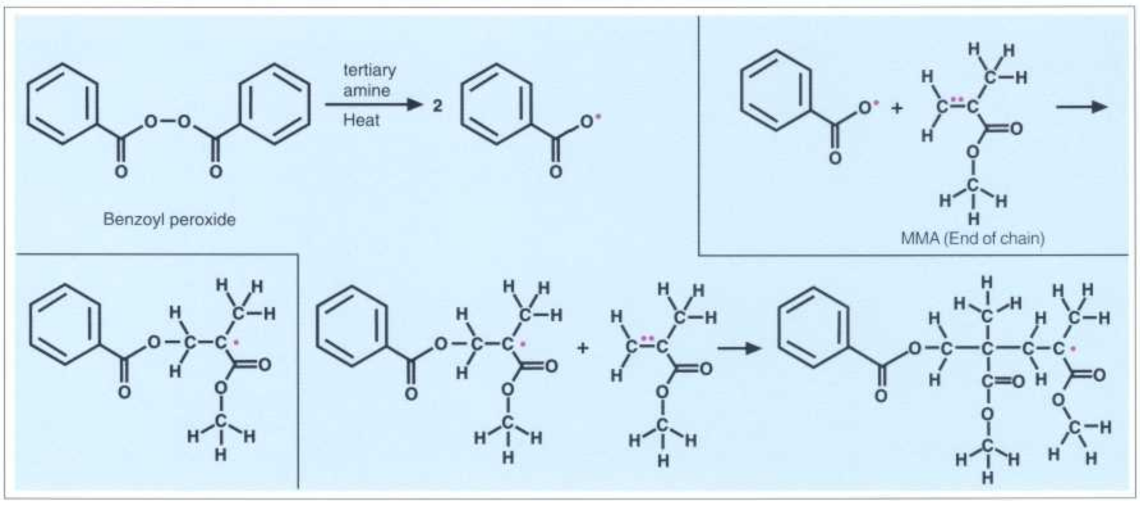
A The diameter of a filler particle varies from 20-40 nm (microfilled composites) up to a few microns (macrofilled composites). The filler particles adhere to the matrix through chemical and/or mechanical bonding.

B During finishing and polishing the silane layer is removed from the exposed filler surface.

C The filler particles can become dislodged from the surface of the composite during chewing.

Activator-Initiator Systems

Composites can consist of two pastes which, when mixed together, start the polymerization process. The two pastes contain silane-treated filler particles and the monomer system. One of the pastes contains the *activator,* frequently a tertiary amine, the other paste the *initiator,* such as benzoyl peroxide. When mixed together, the tertiary amine interacts with the benzoyl peroxide and causes the latter to split and form two free radicals. Each split molecule segment has a highly reactive single electron (free radical) that is able to pair with an electron of another molecule. By bringing such a free radical closer to a methyl methacrylate molecule, the free radical attracts one of the four electrons present in the C=C double bond, which results in a transformation of the C=C double bond into a C-0 bond between the two reacting components (Fig. 171). The remaining unpaired electron, present at the other C atom of the double bond, forms a new free radical that can attack another methyl methacrylate double bond in the same way as the free radical of the split benzoyl molecule attacked the first C=C double bond. When this occurs the chain of molecules starts growing. Accordingly, after initiation this polymerization process can, at least theoretically, continue until all double bonds have been consumed and a single large polymethyl methacrylate molecule has formed.

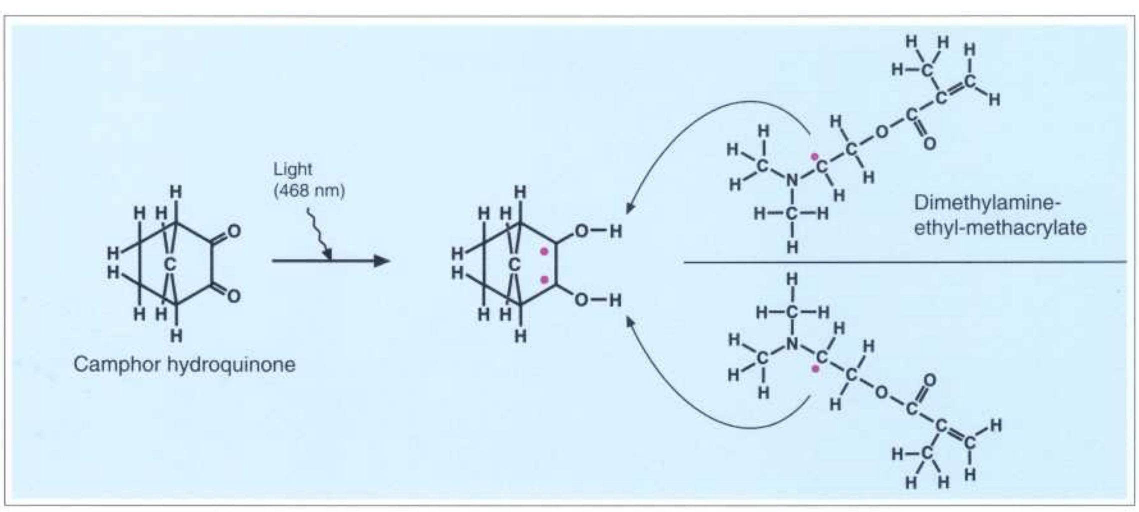


171 Activator initiator system and the polymerization reaction
A tertiary amine and heat can activate benzoyl peroxide by splitting it into two free radicals at the central oxygen atoms (initiators). The initiator and its unpaired electron break the C=C double bond of the MMA and form a new C-0 bond between the initiator and the MMA molecule. During this reaction a new unpaired electron forms a free radical that can react with another MMA monomer molecule. A chain polymer starts forming.

The biggest disadvantage of chemically cured composites is that they must be mixed, and consequently when they are mixed air bubbles are trapped. Thus, the quality of the final product depends on the mixing technique. Another disadvantage is that the reaction starts the moment the two components mixed. Thus, the reaction has already started when the cavity is filled with the composite, making it almost impossible for the filler material mixed to be of a consistent quality.

Therefore, in an attempt to overcome some disadvantages of the mixed composites, so-called *light-cured composites* were developed in the 1970s. The first light-cured composites were cured with ultraviolet light, while modern composites are cured with light within the visible part of the spectrum.

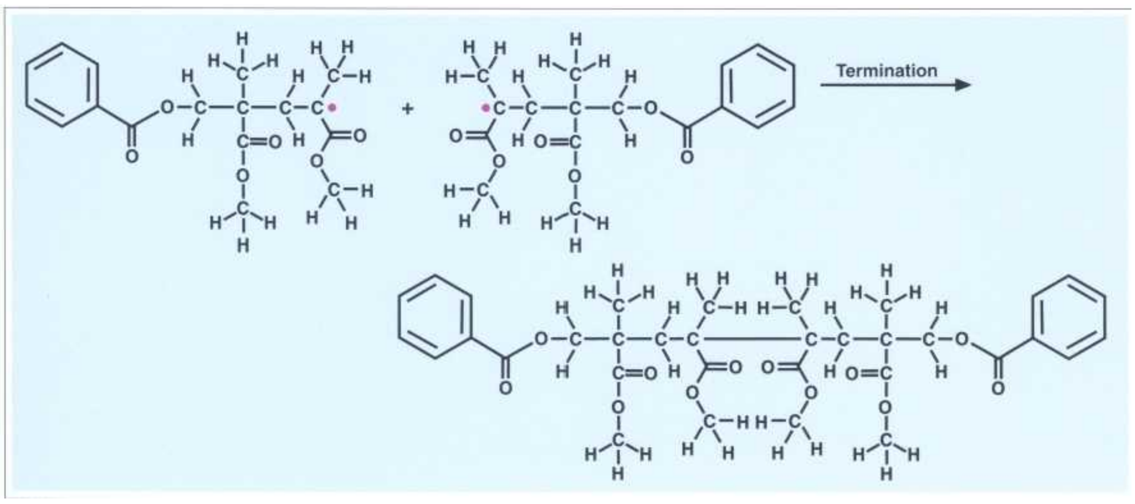
Activation begins when a photosensitive chemical (e.g., camphoroquinone) absorbs radiation of a specific wavelength. The keton group of the camphoroquinone molecule is activated by light of a 468 nm wavelength. It subsequently reacts with another component present in the monomer (e.g., dimethylaminoethyl-methacrylat). An H atom is transferred from the dimethylaminoethyl-methacrylate to the oxygen of the light-activated keton group, which changes into a hydroxy group.



172 Light curing with the help of camphoroquinone
Camphoroquinone and light activate and initiate the polymerization process of light-curable composites. Light promotes the C-atom of the ketone group of the camphoroquinone to the energy-rich triplet level, enabling the camphoroquinone to interact with two dimethylamine-ethyl-methacrylate molecules. Two hydrogen atoms are transferred to the camphoroquinone, free radicals are formed, and the polymerization reaction can start.

The remaining electron of the dimethylaminoethyl-methacrylate molecule (free radical) as well as the free radical left on the camphoroquinone starts the polymerization. The formation of free radicals in light-curable composites takes place more quickly than in cold curing materials. Light exposure can be delayed until the filler material has been inserted and shaped. Consequently, the dentist has better control of the curing process when using light-curable composites.

Despite the advantages of light-curing materials, some problems may arise. The polymerization process can be induced by the light in the operating theater. A slightly defective polymerization lamp can cause incomplete curing. Since light intensity decreases with increasing distance, activation first takes place at the point closest to the light source. Therefore, composites shrink toward the light source, which often leads to parts of the material being torn away from the margins located further away from the light source. In addition, there can be large differences regarding polymerization depth. These differences are dependent on the intensity of the light source and the light transmittance of the composite.

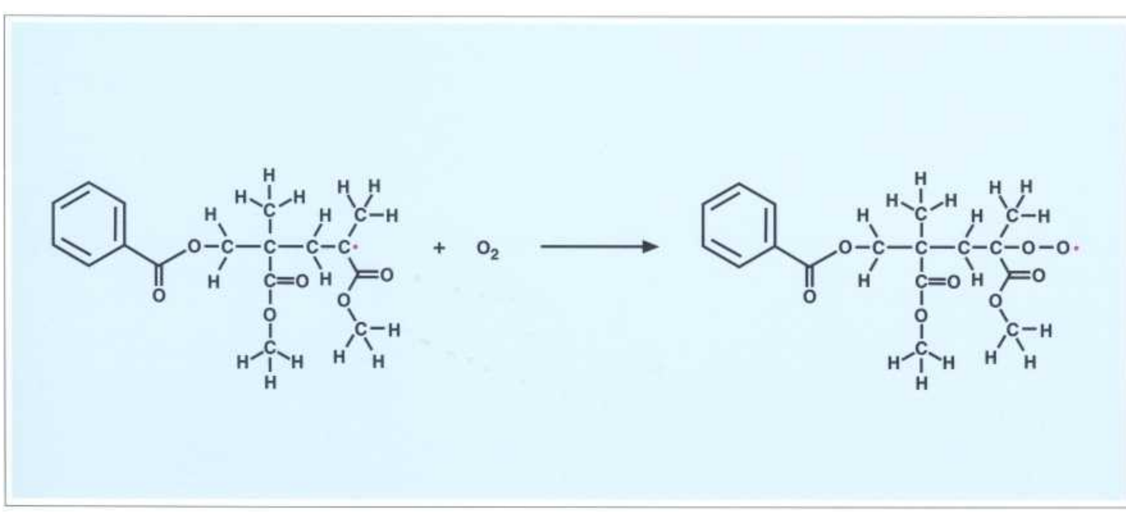


173 **Termination of reaction**
The polymerization reaction ends when two reactive chains interact with each other and their available electrons react with each other to form a stable bond and an unreactive chain

Inhibition Systems

Free radicals form spontaneously in all composites during storage. To prevent spontaneous polymerization, the monomer contains small quantities of an inhibitor. The inhibitor reacts with free radicals and neutralizes them as soon as they have been formed. Therefore, the chain only grows following depletion of all inhibitor molecules. The processing time of composites can be controlled very accurately by the concentration of the inhibitor present in the monomer.

Various *hydroquinones* are frequently used as inhibitors. *Oxygen is* another inhibitor, transferred from the air surrounding the composite. Oxygen inhibition certainly has its advantages in specific situations. It allows a new composite layer to be added on a recently cured composite surface and excellent bonding between the two layers when the new layer is light-cured.

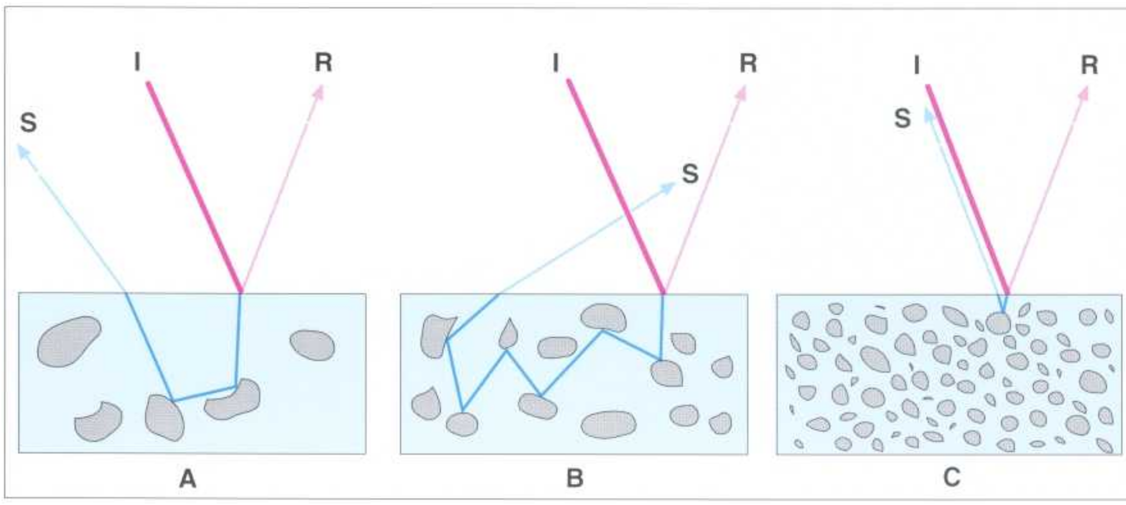


174 **Polymerization inhibition through oxygen**
If oxygen is present during the polymerization, it reacts with the growing chains and forms new radicals which are not as reactive as the free radicals of the original monomer molecule. As a result, polymerization occurs more slowly when oxygen is present and will ultimately stop.

Aesthetic Qualities of Composites

Chemical components such as ultraviolet light absorbers, different pigments, and opaquers are added to the matrix in small quantities to improve the aesthetic property of composites.

Compounds such as 2-hydroxy-methoxybenzophenone, 2-(2'-hydroxy-5'-methylphenyl) benzotriazole and phenyl salicylate are *ultraviolet light absorbers* which absorb ultraviolet light that could otherwise cause changes in the color of the resin. To give the material a particular color, inorganic *pigments* are added to the composite. The pigments are usually metal oxides. Certain *fluorescent agents* (usually rare earth metal compounds) are added in order to give the material a natural-looking, tooth-like structure. In some cases, it is necessary to prevent the color of the remaining tooth structure from shining through the composite. Traumatized teeth, for example, can be strongly discolored and the discoloration can be seen through the composite. In such cases, the composite must be opaque to prevent the dark color from shining through. To achieve this, metal oxides such as titanium oxide are added to the composite.

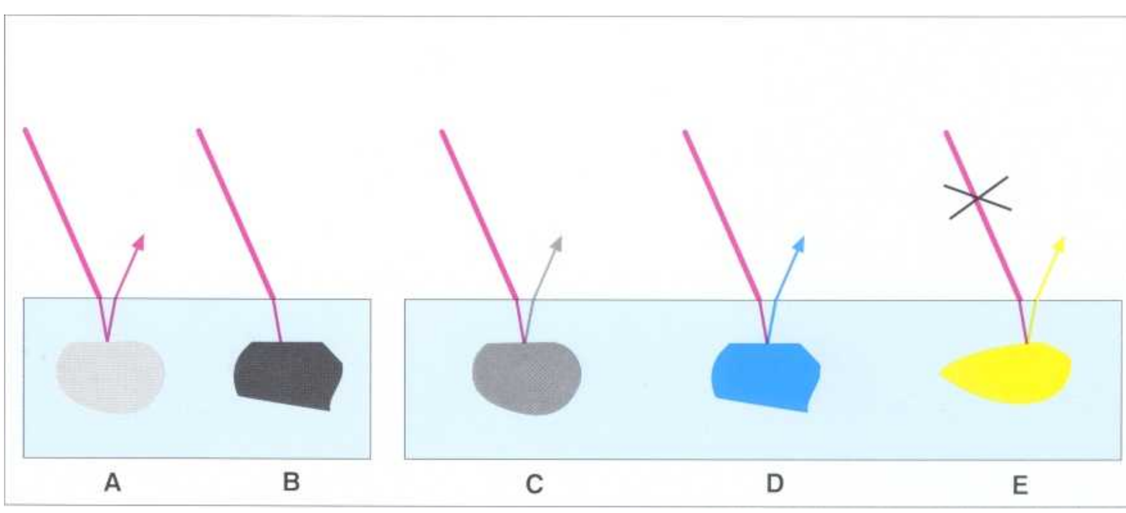


175 Optical properties of composites
If a ray of light interacts with the composite surface, some of the light may be partly reflected and some partly refracted. The density of the filler determines how strongly the light is scattered within the material. The low filler proportion regions (A and B) show lower scattering than a denser filler region C.

I incident light
R reflection
S scatter

Darker pigments absorb more light, which means that when darker shades are used, thinner layers of the light-curing composite must be placed to secure a complete cure. The same is true if opaquers are used, because they prevent the light from penetrating deeply into the composite.

The refraction indices of human dentin and enamel are approximately 1.56 and 1.65, respectively. The enamel layer is relatively thin and transparent. Therefore, it is better to use the refractive index value of dentin (1.56) as a guide, because otherwise optical variations become visible. Most composites use filler particles and resins with refractive indices between 1.45 and 1.55. Consequently, a perfect transition from enamel to dentin is hardly achievable with a composite. However, even more important than a perfect match of the refractive index of the natural tooth and restoration is the match of the refractive indices of the matrix, coupling agent, and filler particles. If the indices of the different components vary too much, light scattering occurs at the resin-filler interface, resulting in a material that looks opaque and has a reduced transparency for light.



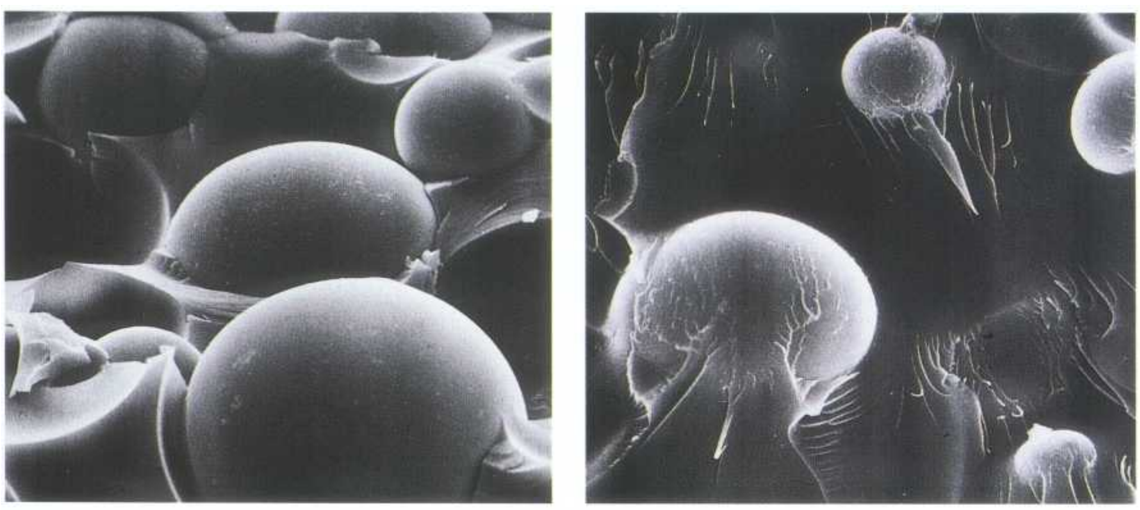
176 Color intensity and brightness
Dark pigments (B) absorb more light (A). Therefore, lighter materials are easier to cure with light. The pigments absorb specific wavelengths from the visible spectrum. The wavelength of the reflected light is added to the color reflected from the respective color pigment (C, D). A phosphorescent agent continues to emit light even after the light source has stopped (E). A fluorescent agent absorbs light of a certain wavelength and emits a longer wavelength.

Coupling Agent

In order to form a bond between resin and filler, the monomer must wet the filler particles and produce a chemical and/or mechanical attachment to the filler particles. These so-called coupling agents, or bonding agents, that are used to form the chemical bond usually belong to a group of chemicals called *silanes.*

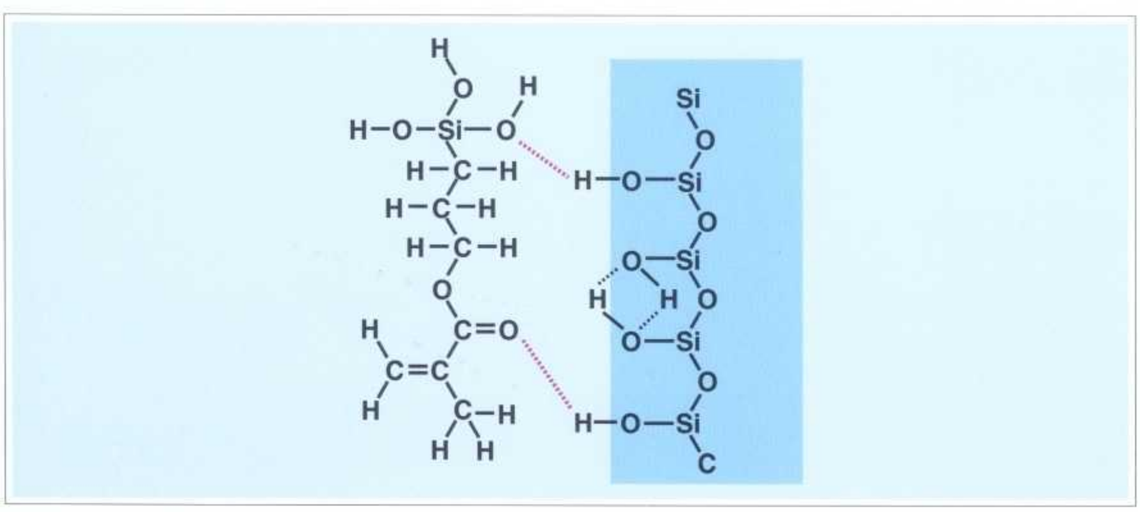
Since the main component of most filler particles is SiO_2 (silica), the bond formed between the silane molecule and the filler surface can be significant. In an aqueous solution, the filler surface consists of SiOH groups. Such an SiOH-covered surface absorbs more water from the surroundings. Since monomers such as BisGMA are hydrophobic, the BisGMA molecules will not wet the water contaminated SiOH surface efficiently. However, by treating the filler surface with hydrolyzed silane, such as a-methacryl oxypropyltrimethoxy silanol (MPS), the hydrophilic SiOH surface becomes hydrophobic and binds to the organic resin matrix. This facilitates the wetting of the filler with the monomer. Such an improved monomer wetting of the filler particles also improves the mechanical retention between resin and filler. In addition, the silane molecule forms a chemical bond with the filler surface via a condensation reaction between the *silanol* groups of both the silane and the glass surface. When the matrix material is later cured, the terminal group of the MPS molecule, which includes a methacrylate group, forms a covalent bond with the curing resin.

The above-mentioned filler-resin reactions have significant effects on some mechanical qualities, particularly on wear resistance and tensile strength. Since wear of composites, particularly on occlusal surfaces of molars and premolars represent a clinical problem, the tensile strength of a composite is an important variable to be considered when selecting a product.



177 Composite surfaces
Left: Composite with nonsilanated spherical filler particles. The resin is not bonded to the filler surface. Therefore, when the composite is stretched the resin bears all the stress.

Right: Composite with silanated spherical filler particles. The resin is bonded to the filler surface. Stress transfer occurs between resin and filler when the composite is stretched.



178 Silanization
A silane molecule (left) approaches the glass surface of the filler. Hydrogen bonds are formed between the silane and the glass surface via the hydroxyl and carbonyl groups (shown as red dots). The OH groups of the SiO_2 structure and the silane molecules react with each other, and a covalent bond is formed via a condensation reaction by means of which a water hydrogen molecule is released.

Filler Particles

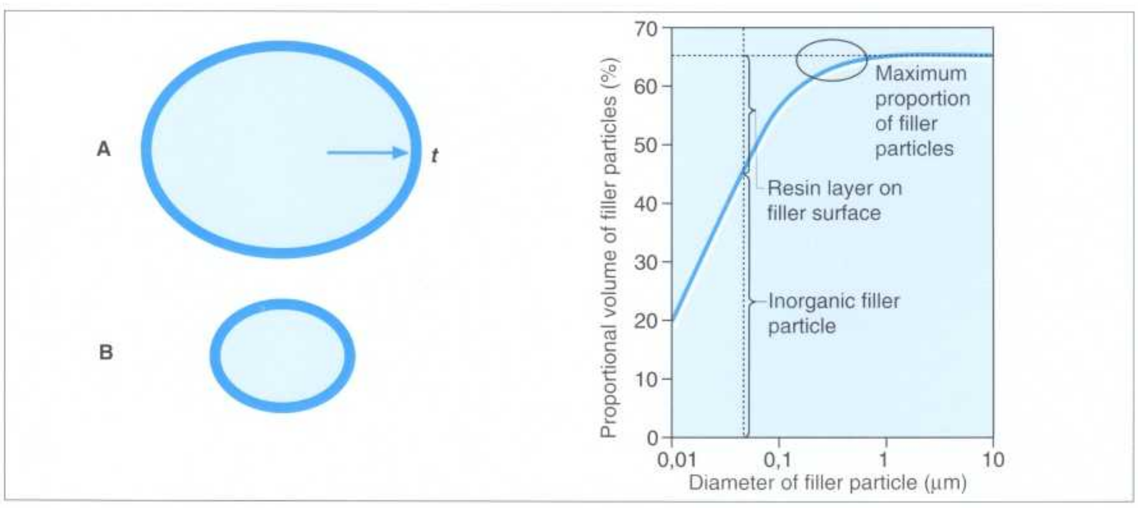
Filler particles that are used in composites are formed by grinding large quartz or glass pieces down into finer particles. It is also possible to *precipitate* particles in a liquid or burn a mixture of gases. If the particles are formed through *grinding,* the process is from bigger to finer particles, while with precipitation it is from molecular size to particle size.

The particle size used in a composite is important, since it influences properties of the material, such as wear resistance and surface roughness. As a general rule, the smaller the filler particles, the greater the total filler surface area per gram filler. Since the monomer molecules of the matrix resin stick to the filler surface, a retained monomer film surrounds each filler particle. If the thickness of such a monomer film is constant and independent of the filler size, smaller filler particles will increase the volume of the resin per gram filler because of the larger total filler surface area.

The rheologic property of a composite is strongly influenced by the unbonded monomer volume. Therefore, to produce acceptable viscosity and handling characteristics, a certain amount of free monomer is necessary. Thus, if the size of the filler particles decreases but the filler volume remains constant, more monomer is tied to the filler surface, and to retain a workable viscosity more free monomer needs to be added. Consequently, composites that contain inorganic filler particles of between 0.04 pm and 0.02 ltm (microfilled composites), contain substantially more resin than composites with particle sizes between 0.1 and 1 um (small particle-filled composites). Based on the impact of filler particle size on the qualities of composites, modern composites are grouped into three classes:

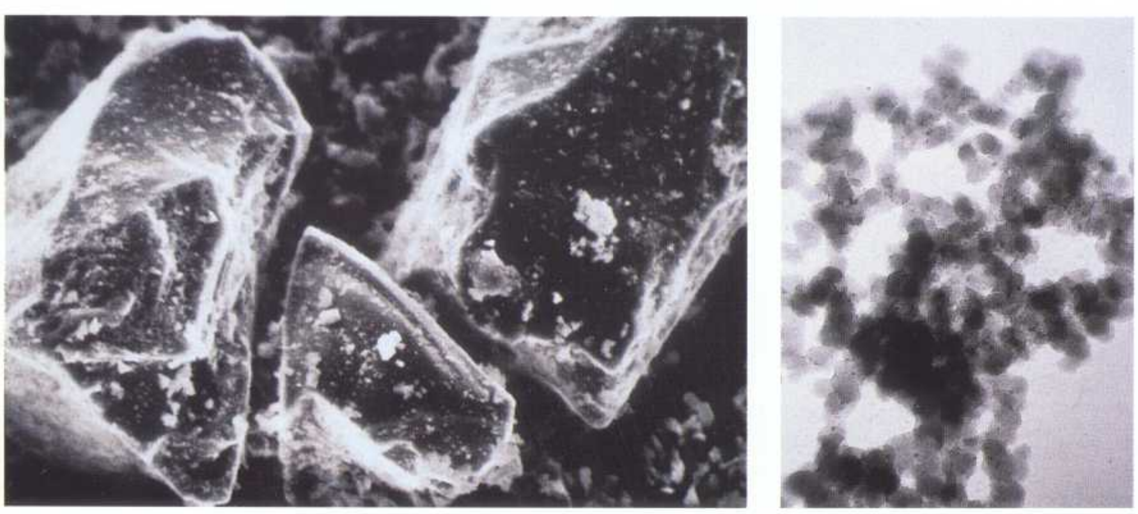
-macrofilled composites
-microfilled composites
-hybrid composites (a combination of macrofilled and microfilled composites)

These main groups can then be divided into various subgroups.



179 Interaction between filler and resin
Left: A resin layer covers the filler particles. If the filler surface area increases, the amount of filler-bonded resin also increases. Larger filler particles (A) occupy less total surface area than smaller filler particles per gram filler (B). However, the thickness of the surrounding monomer layer (t) remains constant regardless of filler size.

Right: The optimal filler volume is determined by the filler surface area.



180 Filler particles
Macrofilled and hybrid composites contain filler particles consisting of ground quartz particles, such as the one shown in the figure *(0.1-20* pm diameter).

Right: Filler particles formed by burning hydrogen, oxygen, and silicon tetrachloride ($SiCl_4$). Pyrogenic SiO_2 (of the particles *0.02-0.04* pm particle diameter) is created with this method. These particles are used in microfilled and hybrid composites.

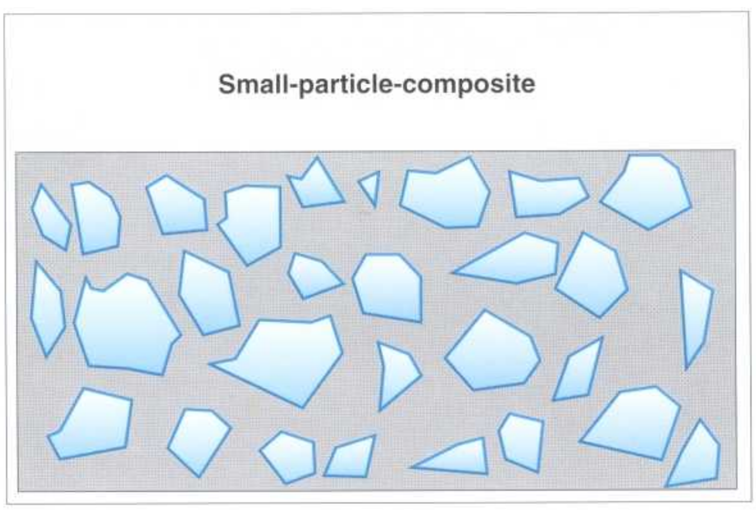
Macrofilled Composites

Most macrofilled composites available today contain a small quantity (1-7%) of microfilled particles (0.02-0.04 pm diameter). These are used in order to obtain a certain viscosity and to minimize the risk of sedimentation during storage. The remaining filler particles have an average size of less than 5 um. Since the size of the filler particles also influences the surface roughness of the composite, the particle size of currently available macrofilled composites lies between 1-3 um, and the total volume is often in the range of 60-70 volume percent. These composites are classified as small particle-filled composites. The small particle size and the large proportion of filler particles guarantee both good physical properties as well as an acceptable surface smoothness.

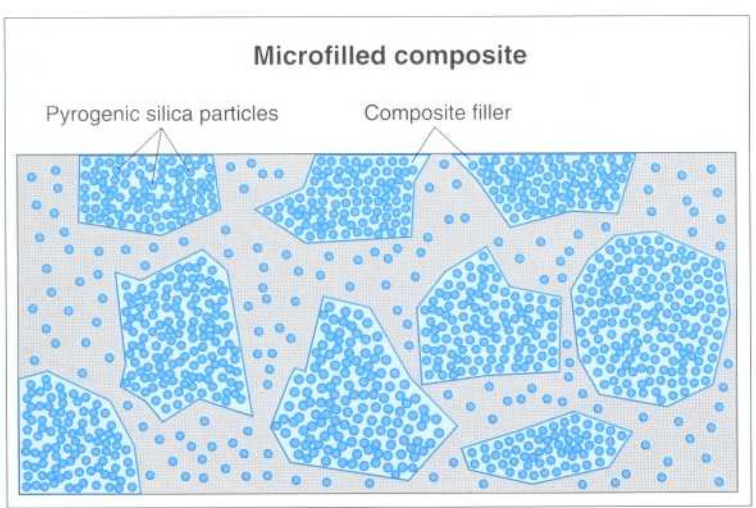
Microfilled Composites

Microfilled composites contain small inorganic filler particles (SiO_2) with an average size of 0.04 um. On the basis of their considerable surface area per gram filler, it is difficult to incorporate these particles into the monomer in high concentrations. Therefore, the microfiller particles are incorporated by the manufacturer into a low viscous monomer to produce a homogeneous microfilled composite that the manufacturer then heat cures. After the curing, the homogeneous microfilled composite is splintered into *composite filler particles.* These composite particles are then mixed with a monomer that also contains microfiller particles. The paste that is formed is the so-called heterogeneous microfilled composite (e.g., Silux).

However, what should in fact be called macrofilled composites are also sold as microfilled composites. Other composites consist of spherical filler particles or are made of microfiller-sized particles that have been agglomerated to larger 3-5 pm particles. Through this procedure, it is possible to produce composites that are actually macrofilled composites, but since they originate from microfiller particles, they are still labeled, at least by some manufacturers, as microfilled composites. The advantages of these materials are that they are easier to work with during polishing, and during wear the larger agglomerated particles can break down into smaller particles on the surface.



181 **Macrofilled composites** Small particle-filled composites belong to this group. The size of the filler particles ranges from 0.1-5 pm.



182 **Microfilled composites** **Microfilled composites** with inorganic filler particles. This material is a mixture of prepolymerized composite blocks mixed with a monomer containing pyrogenic silica filler particles. The prepolymerized composite particles are 50-150 pm in diameter, while the much smaller pyrogenic silica particles are in the range 0.02-0.04 lam.

Left. Splintered filler particle of a microfilled composite. Diameter about 50-150 pm.

Hybrid Composites

These materials consist of a combination of macrofilled and microfilled particles. Hybrid composites contain large quantities of microfiller particles or agglomerated, spherical microfiller particles (15-20 weight-%), which, as the second filler, are mixed with the macrofiller particles and the monomer.

Filler Share and Size

Composites with the best properties are highly filled small particle composites (particle size > 0.2 um). The addition of true microfiller particles binds too much monomer, which explains why real hybrid composites contain less filler particles than small particle-filled composites. Some products, which should actually be called small particle-filled composites, are marketed as hybrid composites. As the share of filler increases and filler size decreases, the interparticle spacing decreases. This is only possible if the particle size lies between 0.2 and 2 um. The composite thereby acquires the optimal qualities, namely least possible polymerization contraction and maximum wear resistance.

Beside the size of the particles, the *particle shape* also exerts an influence on the amount of resin that is bonded to each particle. Spherical particles of a particular volume have a smaller total surface area than irregularly shaped particles of the same volume. In addition, *friction is* lower between spherical particles than between irregular particles. Therefore, the monomer fraction of a composite can be reduced by the use of spherical particles, while the composite still retains a workable rheology. The disadvantage of spherical particles is that they do not offer the resin as good a mechanical retention as irregular particles do. In order to control the problem, *porous spherical particles* are at present being used in some composites. The size of these particles is often between tenths of a micron up to approximately 1 um. The advantage of these filler particles is improved filler-resin retention and improved handling. The particle size enables the composite to contain a sufficiently large proportion of filler. If equally large spherical particles are poured into a vessel, they occupy 60 volume percent of the vessel volume at most. If the spherical particles are replaced with irregular particles of the same size, the proportional volume of the filler will decrease even further.

Filler particles which are used in dental composites are neither equal in size nor ideally distributed. The different *particle sizes* makes it possible, at least to some extent, to place the smaller particles between the larger particles, which can increase the proportional volume to over 60%. However, it is very difficult for the manufacturers of dental composites to reach or exceed this value.

Another complication is that the smaller particles bind more monomer, making it more difficult to increase the share of filler. In order to increase the proportional volume of the filler in these composites, the attempt has been made to fill the space between the small particles with microparticles. On the basis of the larger surface area of microparticles, more monomer is required, which means that an increase in filler share is not obtained. Therefore, it is not rare for hybrid composites to contain a lower proportional volume of filler than small particle-filled composites.

A raised *filler volume proportion* decreases the polymerization shrinkage and increases the composite's elasticity modulus. Thus, the proportional volume of the filler should always be considered when selecting a composite in accordance with the clinical requirements, and not the heavily density-dependent filler:weight proportion. Restorations that are exposed to direct occlusal forces (e.g., class I and class II restorations), for example, should not deform significantly. The pressure-induced deformation of such a restoration leads to gap formation and to cusp fracture. Therefore a highly filled composite should be used under such conditions (small particle-filled or hybrid composites).

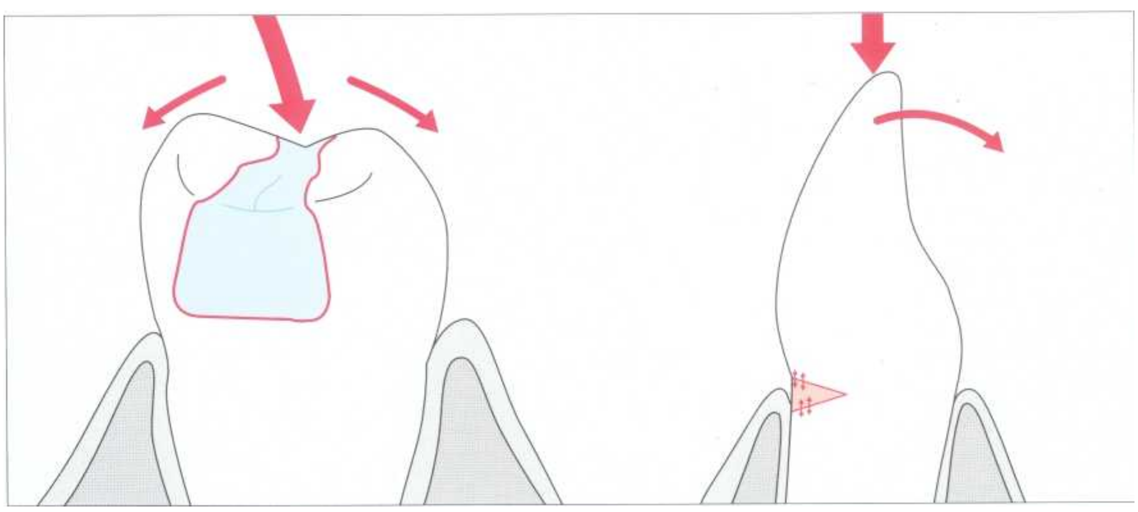
In the case of a larger class V restoration on a cuspid, the occlusal force can cause a deflection of the tooth. This increases the stress at the edges of the restoration. If stiff composite materials are used in such a case, the greatest deformation occurs in the areas with the lowest modulus of elasticity. These are the regions where the unfilled bonding agent surrounds the margins of the composite restoration. The increased deformation at the bonding agent/composite interface leads to increased stress in this region, increasing the risk that *debonding* and *gap formation will* occur. Under these circumstances, it would be better to use a low filled composite material (e.g., microfilled composites) with a lower modulus of elasticity: Such a material will distribute the stress and strain better within the entire restoration.

Examples of Dental Composites

From the above examples one can conclude that the use of a small particle or hybrid composite is not suitable in all cases. In addition to microfilled composites having a lower modulus of elasticity, the surface of these materials is also smoother. The surface texture is an important consideration, since it affects plaque retention and acceptance by the patient. Another advantage of microfilled composites is that they do not abrade the antagonists and their restorations as much as composites with coarser filler particles. The wear resistances of microfilled composites are comparable to those of hybrid or small particle-filled composites. Considering the surface properties, the wear resistance and the low modulus of elasticity of microfilled composites make them suitable for class III and class V restorations. Microfilled composites are just as suitable for direct veneers and for veneering class IV restorations that have been built up with hybrid or small particle-filled composites. The aim is to obtain a smoother surface.

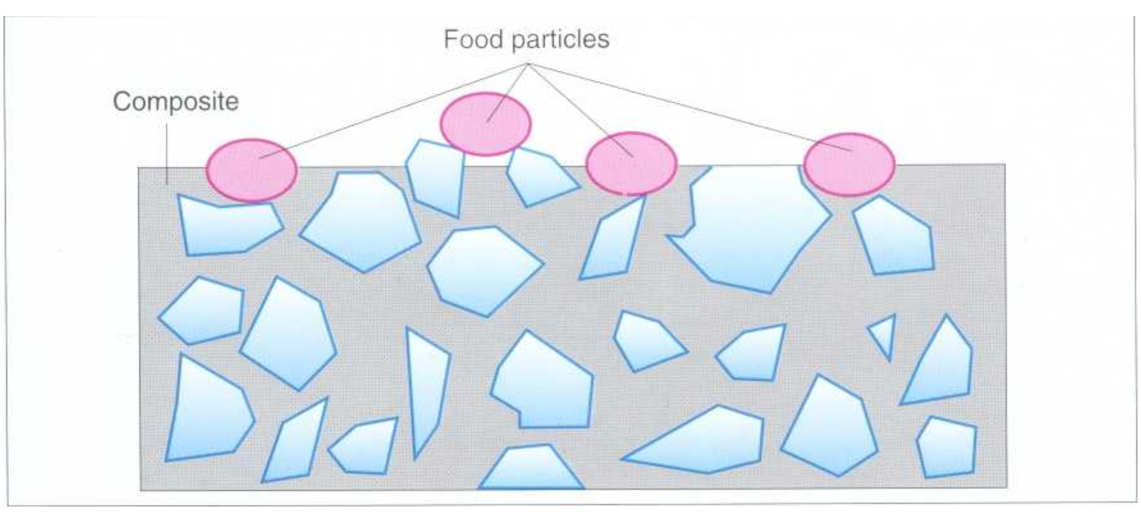
	Small Particle Composites	Microfilled Composites
Filler proportion (wt. %)	80–85	35–55
Filler proportion (vol. %)	55–65	25–35
Linear contraction (%)	0.1–0.2	0.2–0.6
Thermal expansion (ppm/°C)	30	45–70
Water absorption (wt. %)	1	3
Modulus of elasticity (GPa)	14	4–5
Tensile strength (MPa)	50–60	30–50
Compressive strength (MPa)	300	220–280

183 Comparisons of different composites.
Although the mechanical properties of microfilled composites are inferior to those of hybrid and small particle-filled composites, they have some important advantages. Microfilled composites are unsuitable for class I and class II restorations since because they have lower modulus of elasticity and often a higher tendency to chip.



184 Filler loading and clinical success
Left: The high filler proportion of modern composites leads to high modulus of elasticity and low wear rate. This is important for occlusal restorations that are exposed to high forces.

Right. The smaller filler proportion of microfilled composites results in a low modulus of elasticity, which can distribute forces better around a class V restoration, thus decreasing the risk of debonding and leakage.

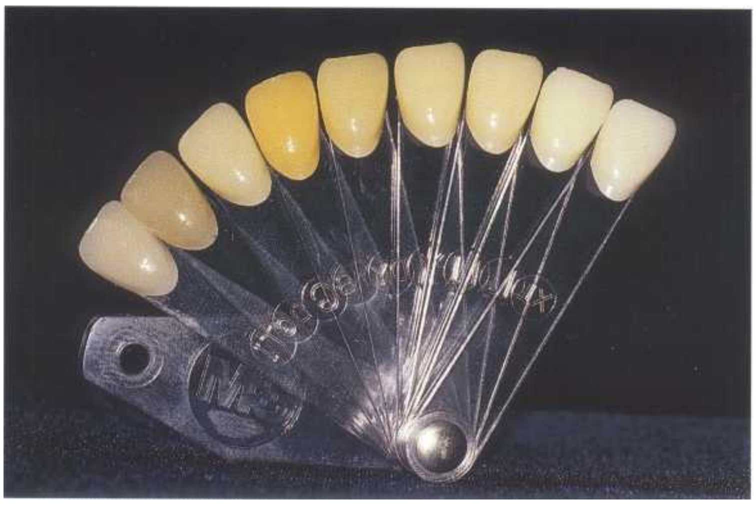


185 Size of the filler particles
The smaller the filler particles, the shorter the spacing between filler particles becomes. The shorter the inter-particle spacing, the better the filler protects the matrix. This explains why composites with a particle size below 1 -2 frm become quite wear resistant.

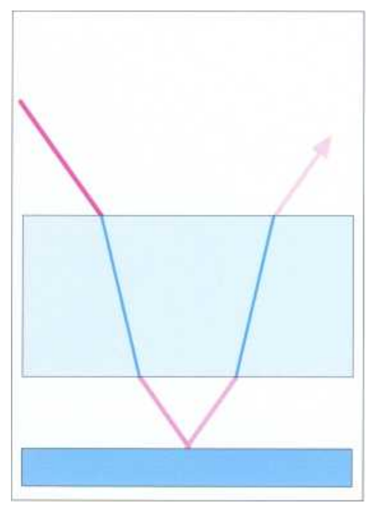
Color and Color Determination

The success of a composite restoration is also judged by the color of the restoration. Its color should be as close as possible to that of the natural tooth. This aspect may not be quite as important in the posterior region as it is in the case of front teeth. In fact, a slight deviation in color can be useful in the posterior teeth, since the margins are recognized more easily, which makes it easier to remove any overhangs. The color should be selected when the treatment starts. The principles of color selection are the same as in the case of crowns and bridges. However, the dentist should be aware of some particular aspects when selecting colors of composites:

- Dehydrated teeth become white-opaque and it takes about twenty-four hours for the color to return to normal. Therefore, color should be selected before the rubber dam is put in place.
- Molars and premolars also include an occlusal surface and the color of the enamel-rich occlusal surface deviates from the color of the facial surface of the tooth.
- Color transitions, especially on facial surfaces, are critical.



186 Shade guide
The shade guide shown is only useful for vital teeth. It should not be used to select composite colors because composites have a specific color and color gradient that is affected by the thickness of the material.

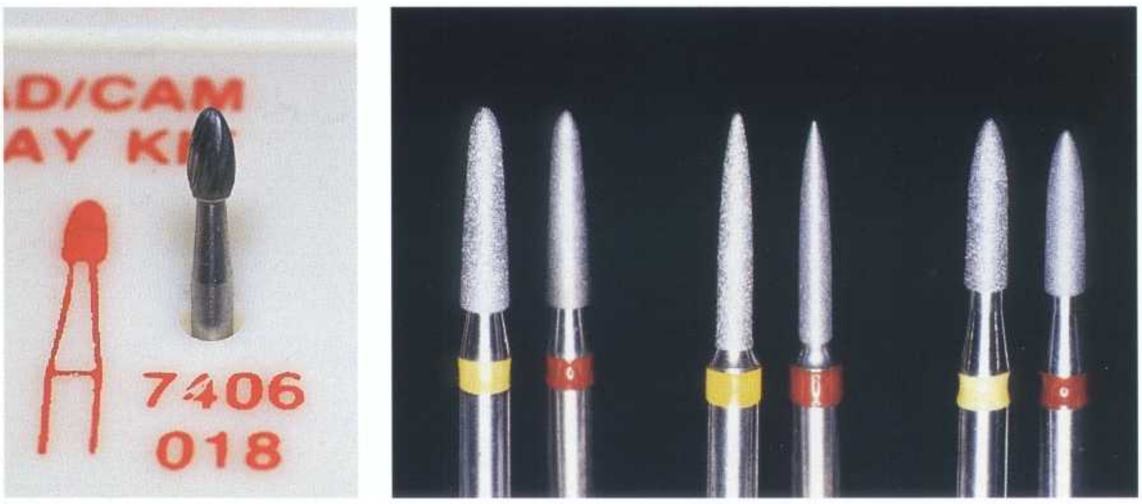


187 Light effects
A special shade guide shows the interrelationship between material thickness and translucence.

Right: Light is only partly absorbed by a composite. Light that passes through a composite layer and reaches the underlying surface is partially absorbed and partially reflected. Therefore, the transparency and the depth of the color of the underlying surface also have a significant effect on the resulting color.

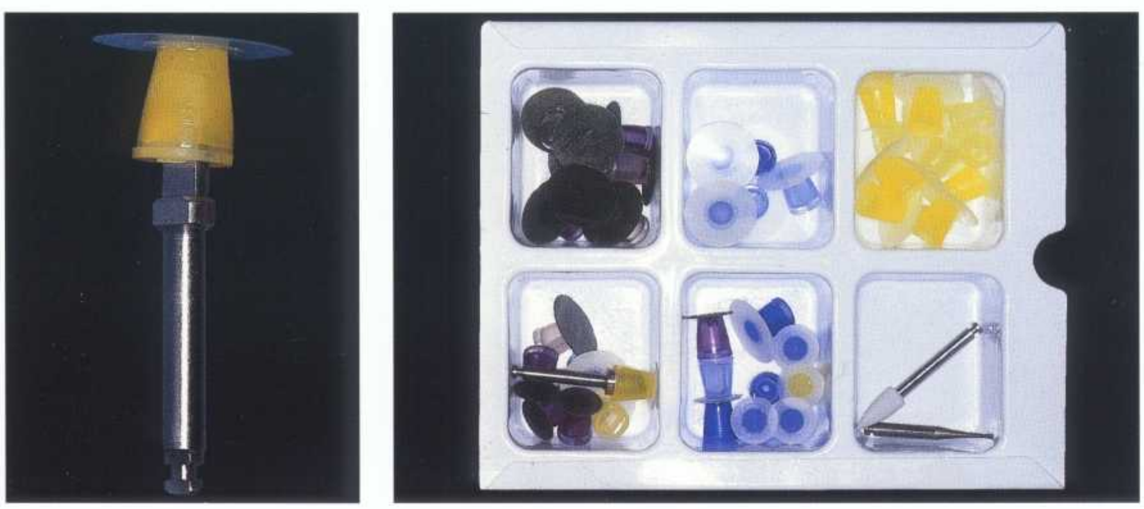
188 Color evaluation
Selected shades can be placed directly on the tooth surface. At the composite-tooth interface the color changes through light scattering.

- The shade guides used must be made from the same material. If an inlay or any other indirect restorative technique is used, the dentist and the technician should use the same shade guide.
- During color selection of inlays, water should be placed between the inlay and the tooth in order to achieve exact contact between the two surfaces. In the absence of such a contact, the intervening air can change perception of the color, leading to the selection of a color that does not match as well.
- Correct lighting must be used during the selecting procedure. It is also a good idea to seek a third opinion.
- Light-curing composites become slightly lighter when they are cured. That means that a selection based on uncured composites can lead to the wrong end result.



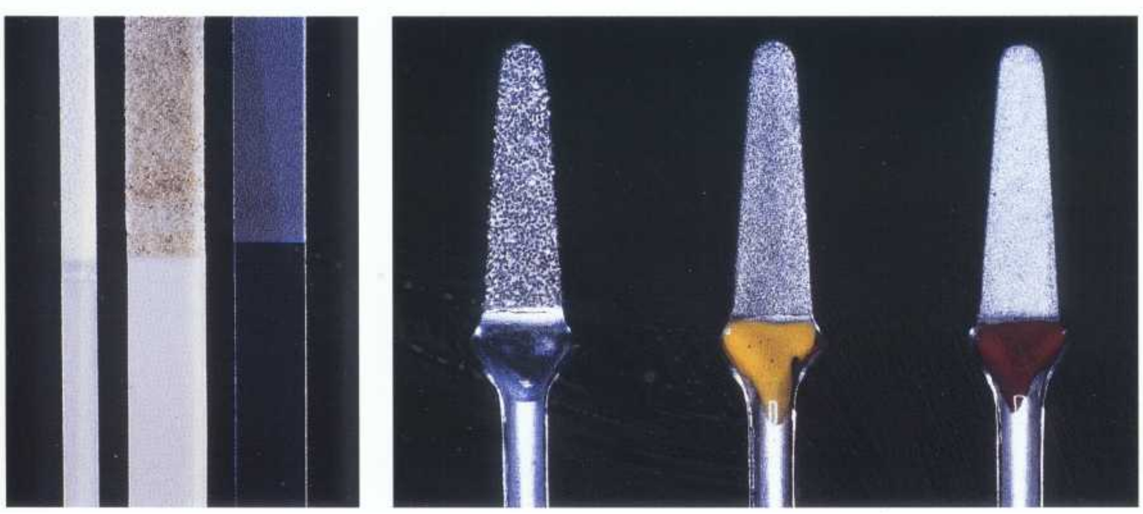
189 Finishing
Grinding and polishing diamonds should be used to trim microfilled composites. Coarse grinding tools leave behind grooves. Fine and extra fine diamonds are suitable forfinishing.

Left: Hard metal burs should be used for trimming small particle-filled composites and hybrid composites.



190 Finishing with disks
The composite surface is best fin¡shed with Shofu's Super Snap Disc or 3M's So-Flex Disc system.

Left: Attached polishing disk.



191 Proximal Finishing system
Diamond-coated metal wedges are available for the Eva handpiece which can be used to remove proximal overhangs.

Left: Finishing strips that can be useful for proximal surfaces.

Finishing and Polishing Composite Restorations

Various instruments are used during *finishing* to give the composite restoration its final shape. The finishing procedure leaves very small defects on the composite surface and at the same time the oxygen-inhibiting surface layer is removed.

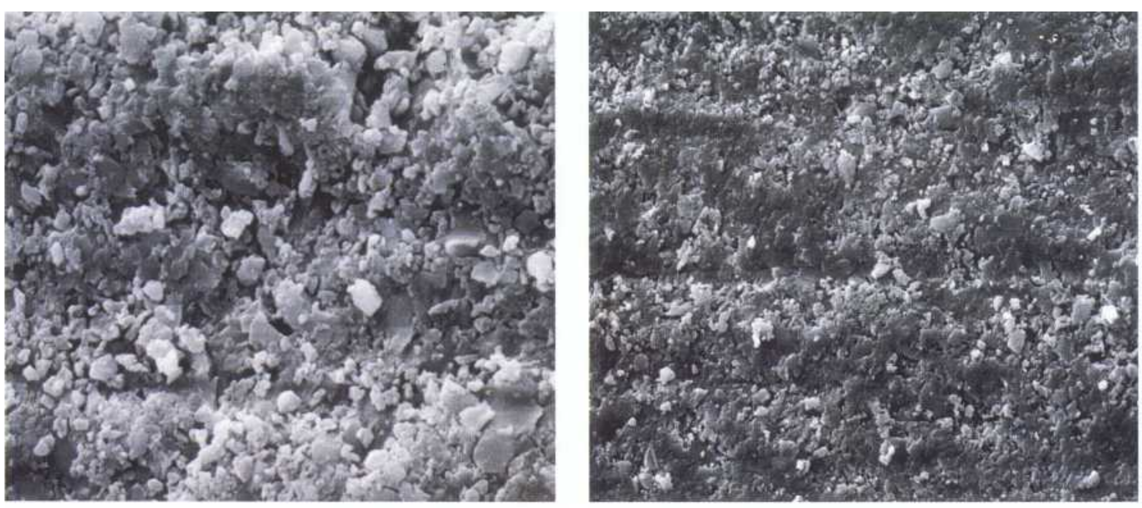
Polishing of the surface follows the finishing process. Polishing involves eliminating very small scratches and irregularities that originated during finishing. Different instruments are used, depending on the material. Small particle-filled composites and hybrid composites are ground with 12-fluted hard metal finishing burs, leaving the composite smooth after the cutting process. An oval finishing bur is suitable for a coarse occlusal adjustment. Normal diamonds should not be used for finishing, since they leave a rough surface and also cause damage to the tooth surface. Microfine diamonds (Composhape 15 µm) are ideally used in connection with the hard metal finishing bur, since they produce smooth surfaces. In the marginal areas, too much pressure should not be used with a rotating instrument. High pressure, combined with rotating or pushing in a direction toward the composites can debond the composite and produce a white line between the restoration and the tooth.

A needle-shaped finishing bur can be used to remove overhangs from proximal-cervical regions. However, such a removal is difficult to perform and can easily lead to damage to the root-cement layer.

After final contouring, smoothing of the cut surfaces takes place *with disks or strips.* So-Flex disks or strips of 3M are ideal for this purpose and are available in different grain sizes.

In addition to treating the proximal surfaces with strips, these surfaces can also be ground and polished with an Eva handpiece with the corresponding grinding instrument.

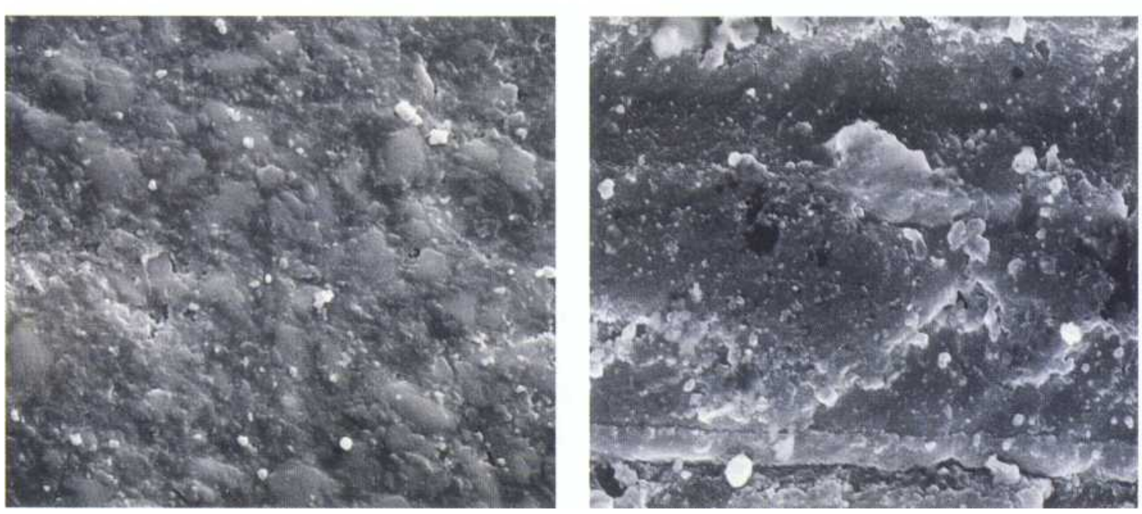
Polishing takes place after finishing. This can be done with a carborundum rubber wheel (e.g., Identoflex) and water. Cone-based silicone (Enhance) can be used as can rubber cups and polishing pastes.



192 **Differently polished hybrid composite surfaces**
Left: Hybrid composite polished with coarse Super snap disk.

Right: Hybrid composite polished with a medium-fine Super snap disk.

SEM, magnification x 1600



193 **Differently polished composite surfaces**
Left: Hybrid composite polished with fine Super snap disk.

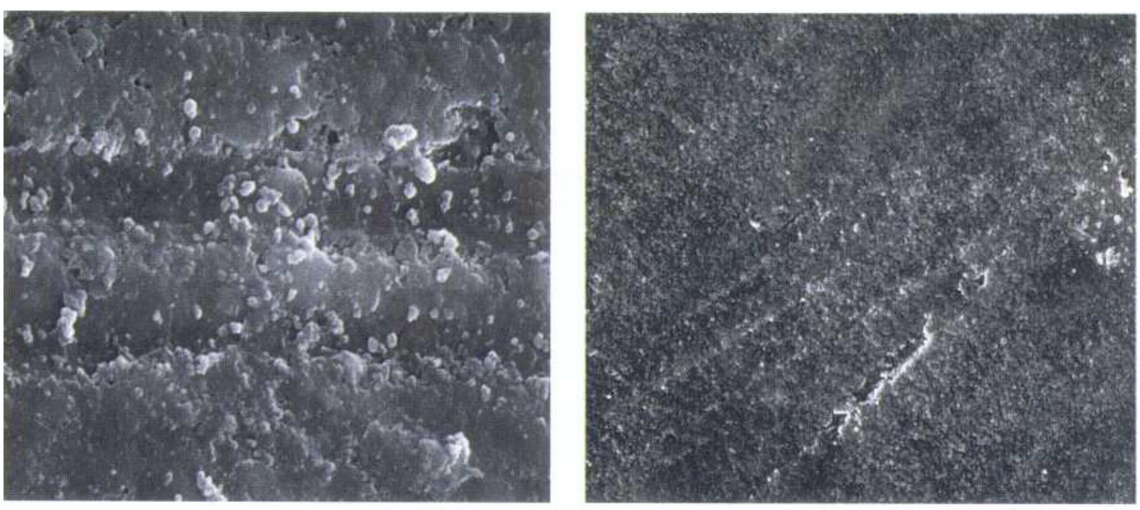
Right: Microfilled composite polished with coarse Super snap disks

SEM, magnification x 1600

Applying a paste leads to a somewhat shinier surface than is possible with disks or cones. The shine originates because the abrasive paste rounds off the prominent filler particles. However, these particles still protrude from the surrounding surface. Therefore, a surface processed with a polishing paste is not flatter than a surface processed with a disk. In fact, the surface polished with a disk is often smoother.

In the preceding section, the grinding and polishing of small particle-filled composites was discussed. In contrast to these, the *microfilled and hybrid composites* are essentially more difficult to handle. The rather poorly bonded prepolymerized filler particles may facilitate chipping if the surface is cut with fluted burs. Therefore, microfilled composites require the use of finer to superfine grinding diamonds for finishing. These should be used with water cooling and should not touch the surface of the tooth. After excess has been superficially removed, the same disks are used as in the case of small particle-filled composites.

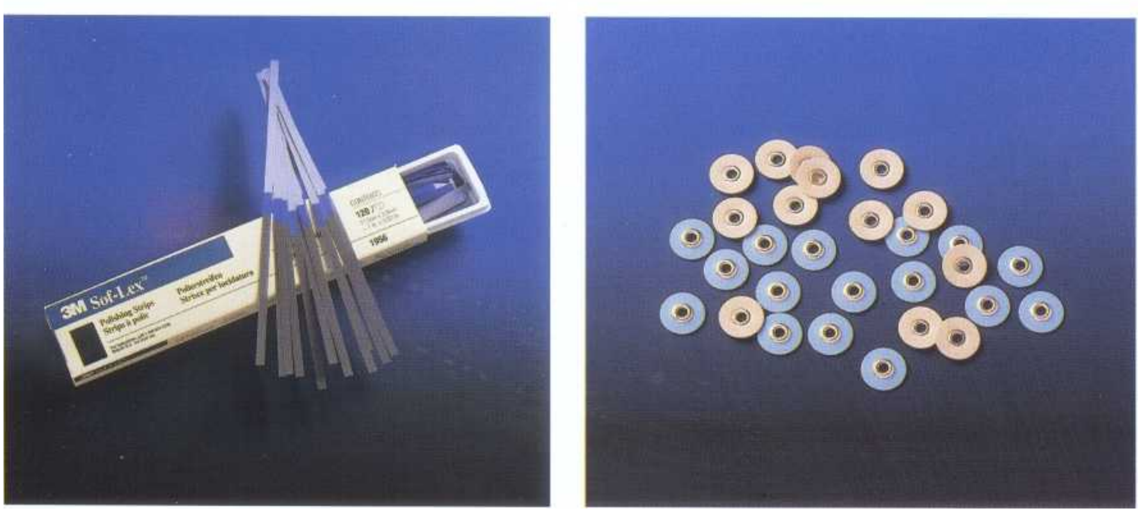
It is questionable whether the use of a polishing paste is sensible; a composite surface that has been cut with fine disks and cones produces at least as smooth a surface as those polished with a polishing paste. In addition, the surface sooner or later assumes a roughness that is related to the size of the filler particles. For long-term surface structure, the filler particle size is therefore more crucial than the polishing process.



194 Differently polished surfaces of microfilled composites
Left: Microfilled composite polished with medium-fine Super snap disk.

Right: Microfilled composite polished with fine Super snap disk.

SEM, magnification x 1600



195 Finishing strips and polishing disks
Left: Sof-Lex finishing strip made from a tear resistant, flexible plastic strip coated with aluminum oxide.

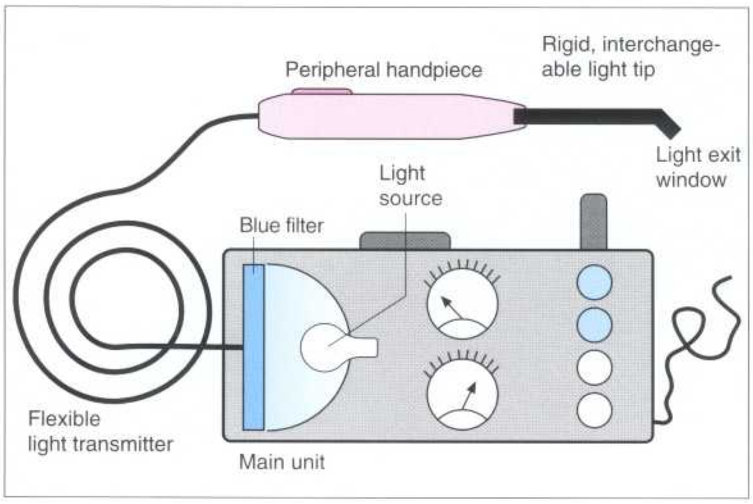
Right: Sof-Lex-polishing disks coated with aluminum oxide layer and used to polish composites, gold, porcelain, and amalgam. Both the finishing strips and the disks allow polishing of areas which are difficult to access, e.g., proximal and gingival regions.

Basics of Polymerization

The success of a composite restoration or a bonded restoration depends on how well the composite has been polymerized. Visible light polymerization utilizes the transfer of light energy, which is dependent on *light intensity* and *light exposure time*.

Light Intensity

Light intensity crucially depends on the polymerization unit. There are two types of light polymerization units: *Direct appliances* and *fiberoptic appliances* (Lutz et al. 1992). Fiberoptic appliances normally produce less intense light than direct appliances. A light intensity of at least 280 mW/cm2 is necessary to polymerize a 2-mm-thick universal color composite layer within one minute. Since the light intensity of a polymerization appliance constantly decreases, it must be checked regularly with a light measuring instrument (e.g., Model 100, Demetron Research Corp.). Commercially available polymerization units have light intensities of between 300 and 800 mW/cm2. A study by Friedman (1989) showed that 78% of the polymerization units used in dental practices have lost between 45-89% of their initial light intensity.

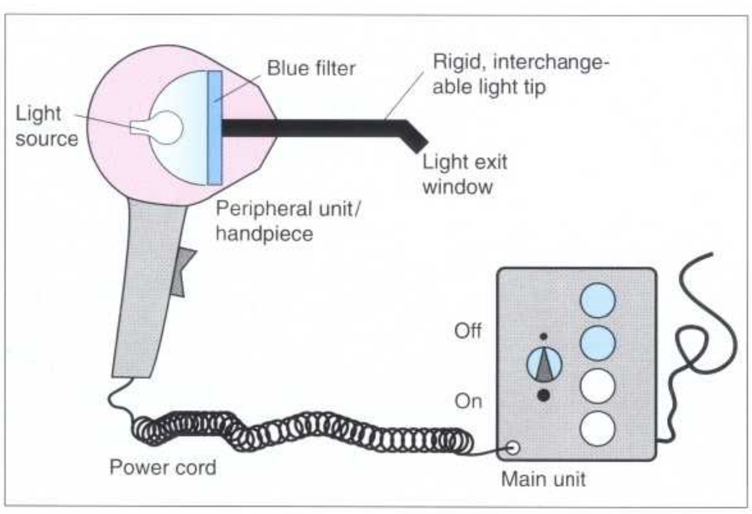


196 Schematic drawing of a light-curing unit with a fiberoptic cord
The equipment consists of the main appliance with light source and cooling fan, the flexible fiberoptic cord, and the handpiece with a rigid light-transmitting tip.

(Adapted from Lutz et al., 1992)

197 Advantages and disadvantages of light-transmitting fiberoptic cords and direct appliances

Advantages	Disadvantages
Light transmitting fiberoptic cord units	
• Small handpiece: good overview of the surgical area • Large cooling capacity: max. 150–250 W possible • Patient-friendly: no noise and heat emissions • Polyfunctional: polymerization and diagnostics • Simple disinfection of handpiece	• Restricted handpiece mobility • Long, inconvenient fiberoptic cord • Vulnerable and aging fiberoptic cord • Large loss of light • Difficult to store
Direct appliances (Pistol type/pen type)	
• High light intensity • Short, simple light transmitting unit • Good handpiece mobility • Easy to store	• Voluminous handpiece: restricts overview over the surgical area • Additional peripheral unit • Limited cooling capacity: maximum 100(–150) W • Cooling is patient-unfriendly: noise and heat emissions • Monofunctional: only for polymerization • Complex handpiece disinfection



198 Schematic drawing of a direct light unit
The system consists of a main unit, a power cord, and the peripheral appliance, including Light source, fan cooler and a rigid fiberoptic light tip.

(Adapted from Lutz et al., 1992)

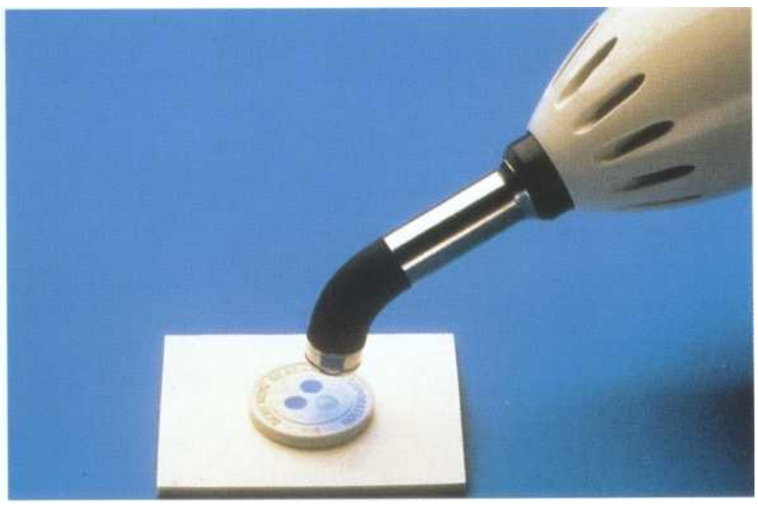
The most frequent reason for loss of light intensity is due to the light bulb:

- As soon as a black coating can be seen on the bulb, the light intensity decreases by about 74%, in the case of gray coating the decrease is about 45%, a blue coating results in a drop of about 62%;
- Reflector clouding: 65% reduction;
- Contaminated fiberoptic;
- Filter contamination.

Check the light intensity of your polymerization unit weekly and replace the bulb, fiberoptic, and filter once a year. Write down the light intensity and the date on the rear of your new or overhauled appliance.

Curing Efficiency

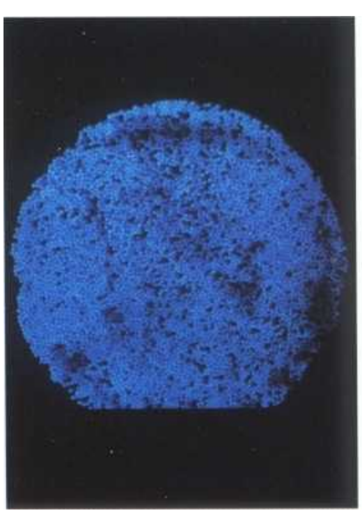
A 2-mm-thick composite layer of universal color takes 60 seconds to polymerize. In the case of darker colors, the layer should not be thicker than 1 mm and each layer must be polymerized for at least 40 seconds (Schwartz et al. 1991).

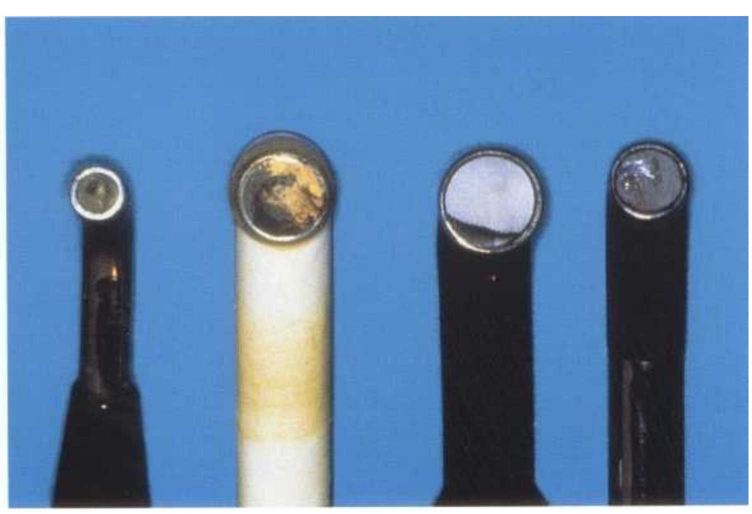


199 Testing the luminosity of the polymerization unit
Polymerization units must be checked regularly for their luminosity, which should not fall below 400 mW/cm^2. To test luminosity, a small silicone block (2 mm thick) with holes can be filled with composite and light-cured from one side. The success is checked on the opposite side by scratching the composite surface.

Left. As an alternative, a light measuring instrument can be used.

200 Bulbs get progressively weaker lead to a decrease in light intensity, requiring an extended polymerization time
The two polymerization lamps emit light the intensity of which has already been reduced by 60-80% as measured at the tip of the fiberoptic rod.





201 Contamination and partial destruction of the fiber optic tip
According to a study carried out by Clinical Research Associates, contamination can cause a reduction in light intensity of up to 60%.

Left: Fiberoptic cords can break. The result is a very large reduction in light intensity at the tip of the polymerization unit.

Durability of Composites

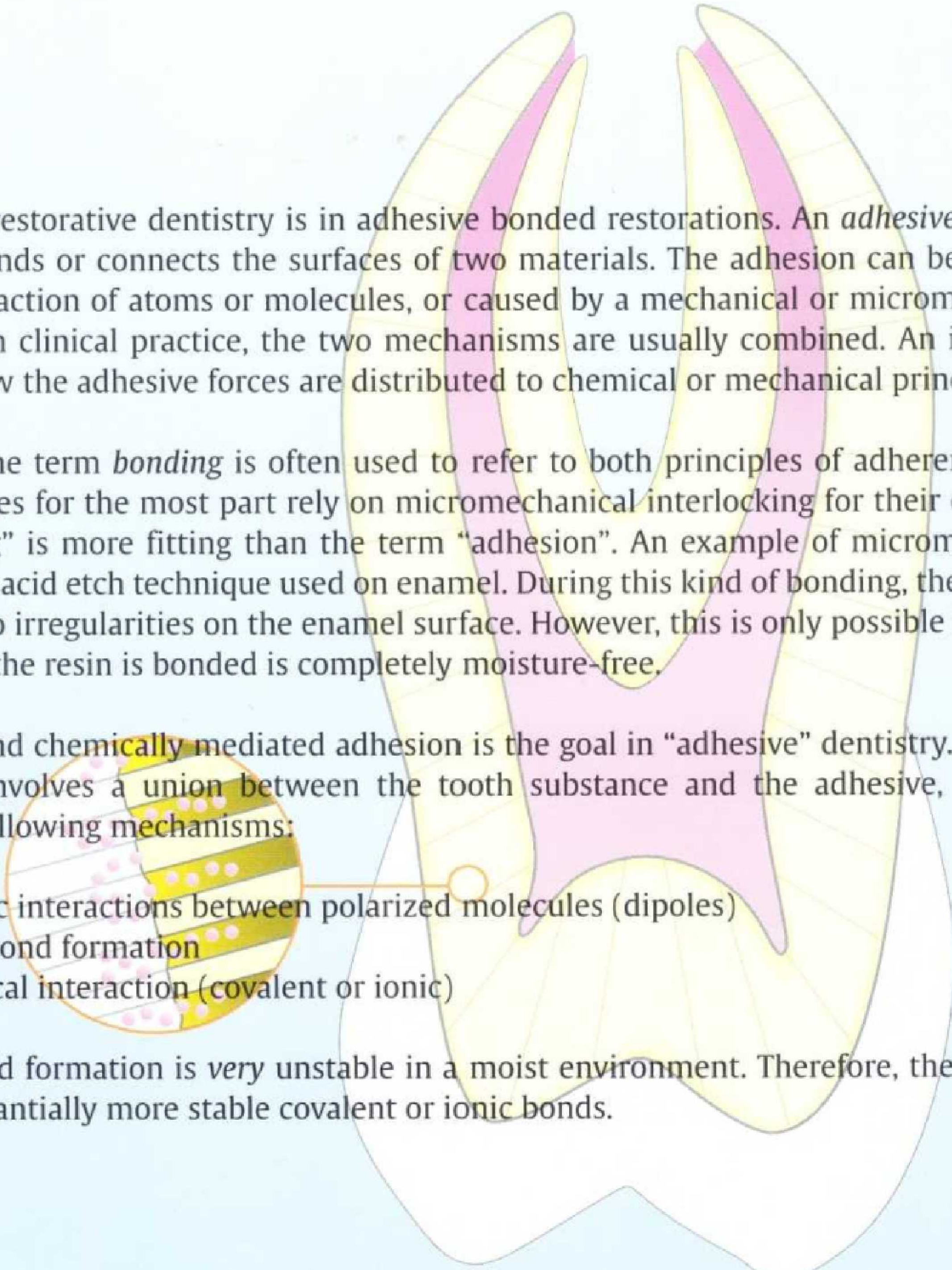
Polymerization shrinkage and wear restrict the life span of composites. The *shrinkage* can cause the formation of marginal gaps, which can lead to elevated tooth sensitivity and recurrent caries. Fortunately, important advances have been made in the field of dentin bonding. It has not yet been proved that these bonds remain strong for a long time. However, the improved bonding should decrease the development of secondary caries lesions.

The *wear resistance* of composites placed in molars and premolars is still a problem. The reason for this is large individual differences in wear among patients. For the best posterior composites, for example, a wear of 100 um/year can occur in one patient, while the same composite in the average oral environment wears by only 10 um/year. Even if the latter value appears low, this wear can still cause clinical problems over time due to elongations of teeth or a reduction of the occlusal vertical dimensions.

Teeth with low stress have the lowest wear rate and also the best bonding stability. Therefore, the first lower premolars have the best prognosis when treated with composites, followed by the first upper premolars. That means that the most visible teeth, where aesthetics plays the biggest role, normally also have the best prognosis. In the case of premolars and molars, one should try to obtain occlusal support on enamel in order to minimize the risk of wear and elongation. If these points are taken into consideration, composites should be introduced in posterior teeth for conservative reasons rather than be used as a substitute for old and large amalgam restorations.

For posterior teeth, the following golden rule can be applied: materials with minimal shrinkage, high wear resistance, and optimal surface properties should be selected. In order to fulfill the first two requirements, high filler proportion is needed. The filler particles should not be too small, since such particles normally bind too much monomer. However, at the same time surface roughness increases the larger the particles are. Thus, particles should not be larger than 1 pm and the proportional volume of the filler should be 65 volume percent or more.

Bonding



The future of restorative dentistry is in adhesive bonded restorations. An *adhesive* is a substance that bonds or connects the surfaces of two materials. The adhesion can be due to a chemical interaction of atoms or molecules, or caused by a mechanical or micromechanical interlocking. In clinical practice, the two mechanisms are usually combined. An important question is how the adhesive forces are distributed to chemical or mechanical principles.

In dentistry, the term *bonding* is often used to refer to both principles of adherence. Since most techniques for the most part rely on micromechanical interlocking for their effect, the term "bonding" is more fitting than the term "adhesion". An example of micromechanical bonding is the acid etch technique used on enamel. During this kind of bonding, the adhesive penetrates into irregularities on the enamel surface. However, this is only possible if the surface to which the resin is bonded is completely moisture-free.

A physically and chemically mediated adhesion is the goal in "adhesive" dentistry. This type of adhesion involves a union between the tooth substance and the adhesive, mediated through the following mechanisms:

1. Electrostatic interactions between polarized molecules (dipoles)
2. Hydrogen bond formation
3. Real chemical interaction (covalent or ionic)

Hydrogen bond formation is *very* unstable in a moist environment. Therefore, the goal is to produce substantially more stable covalent or ionic bonds.

Bonding: Resin Bonded to Enamel

Bounocore introduced the acid etch technique in 1955. However, it took almost 20 years for it to be generally accepted in dentistry. The technique revolutionized dentistry and created the foundation for adhesive dentistry.

Structure of Enamel

Enamel is a porous, nonvital substance. It consists of 96 (weight)% inorganic hydroxyapatite and 4% matrix containing proteins and water. Enamel is the hardest tissue in the human body and has a crystalline structure. The crystals form so-called *enamel rods* (Schroeder 1987).

In the outer structure, the enamel rods can be 10-15 pm long. In this region the crystals are arranged in parallel, perpendicular to the rods. This zone is also called the *aprismatic zone*. A *pellicle* consisting of a protein-fat-carbohydrate complex is found on the enamel surface. When the enamel is cut, the pellicle forms an organic smear layer. The structure of the enamel surface is thus rather complex. Therefore, the enamel surface should be conditioned before each adhesion (Gwinnett 1994).

When bonding to enamel, the enamel surface must be treated with an acid. A 15-40% phosphoric acid is used for this purpose. Etching should be done for more than 15 seconds. This procedure leads to adhesion with a tensile strength exceeding 20 MPa. This strength is sufficient to resist the stresses induced by the polymerization shrinkage.

202 Enamel Structure
The SEM shows the direction of the enamel crystals within a single enamel rod.

203 **Aprismatic layer**
The aprismatic enamel layer proceeds parallel to the surface of the tooth and perpendicular to the underlying prismatic layer.

Checklist—Enamel Etching

1. Cleaning
- Clean the surface with a glycerinfree paste.

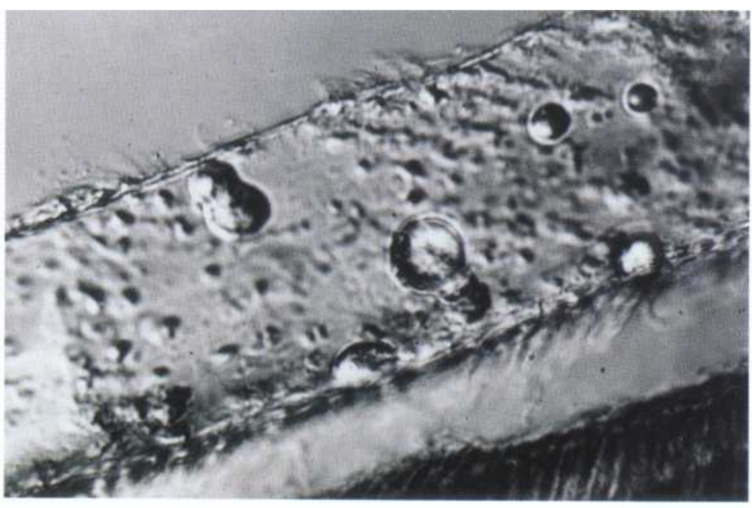
2. Drying
- Isolate the teeth with rubber dam.
- If this is not possible, place dry cotton rolls and use an efficient suction system.

3. Etching
- Dry the teeth and place the phosphoric acid (30–35 %) using an applicator.
- The acid should remain on the enamel for 15–60 seconds, on prepared enamel for more than 15 seconds.
- In orthodontics or during fissure sealing, cut enamel is not etched and acid should then be allowed to act for more than 30 seconds.
- The acid should be applied over the prepared margins.
- The action of the acid can be enhanced by means of light brush strokes.
  This leads to a smoother etching pattern.

4. Rinsing
- Rinse with a water spray for 20 seconds and dry with pressurized air.
- The etched surface should now have a frosty appearance.

5. Secure dryness
- The dried surface must remain dry.
- If the etched surface is contaminated with saliva, it must be reetched for another 15 seconds.

Place the bonding agent with an applicator and polymerize the resin.
The composite can then be placed and polymerized.



204 **Pellicle**
On the uncleaned enamel surface there is a pellicle consisting of organic material, to which no bonding is possible. This layer must be removed before bonding.

205 **Etching the enamel**
Conditioning the enamel surface with phosphoric acid usually dissolves inorganic components. The ends of the enamel prisms form a typical etch pattern.

Left. To etch the enamel use a 30-35% phosphoric acid. Lower phosphoric acid concentrations should not be used.

Photomicrographs
(Fig. 202-205) A.]. *Gwinnett*

Bonding: Resin Bonded to Dentin

Structure of Dentin

Dentin is a mineralized hard tissue, consisting of:

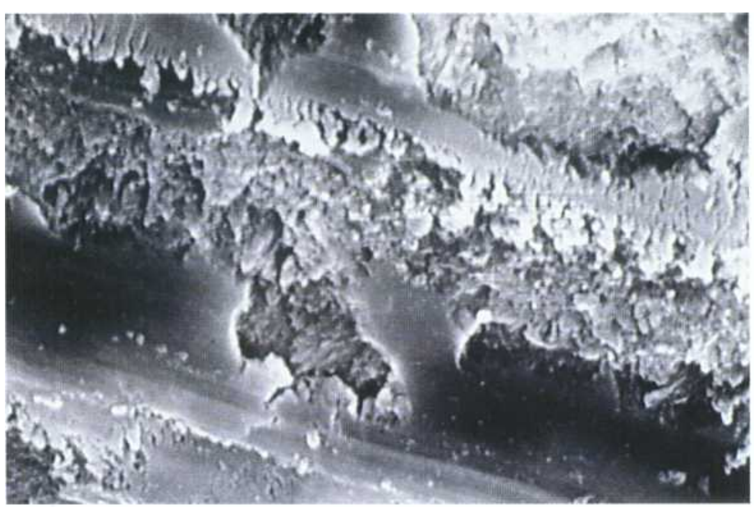
-peritubular dentin with a high mineral content
-intertubular (collagen-rich) dentin
-mantel dentin
-dentin canals or tubules, containing
-odontoblastic processes and tubular fluid (dentin liquor)

Dentin consists of approximately 50 (volume)% inorganic material, 30% organic components, and 20% water. The organic matrix of the dentin consists of 91-92% collagen and 8-9% noncollagen ground substance (Schroeder 1987). The inorganic components consist mainly of hydroxylapatite crystals that are smaller than those in the enamel. During cutting, a 1-5 pm-thick *smear layer* forms, consisting of burnished components and hydroxylapatite fragments. The smear layer blocks the dentin tubules and stops the tubule fluid escaping, but also prevents the formation of a chemical and/or a micromechanical retention of the dentin bonding agent (Gwinnett 1994).

The smear layer was for a long time the weak point in adhesive dentistry. The general opinion was that the dentin and the pulp would be harmed if dentin were etched. However, since it is very difficult to etch the enamel alone without at the same time etching the dentin, Fusayama raised the question in 1977 of what would happen if one intentionally etched dentin. His goal was to develop a working adhesive system and he was the first to explore the so-called *total etch technique.*

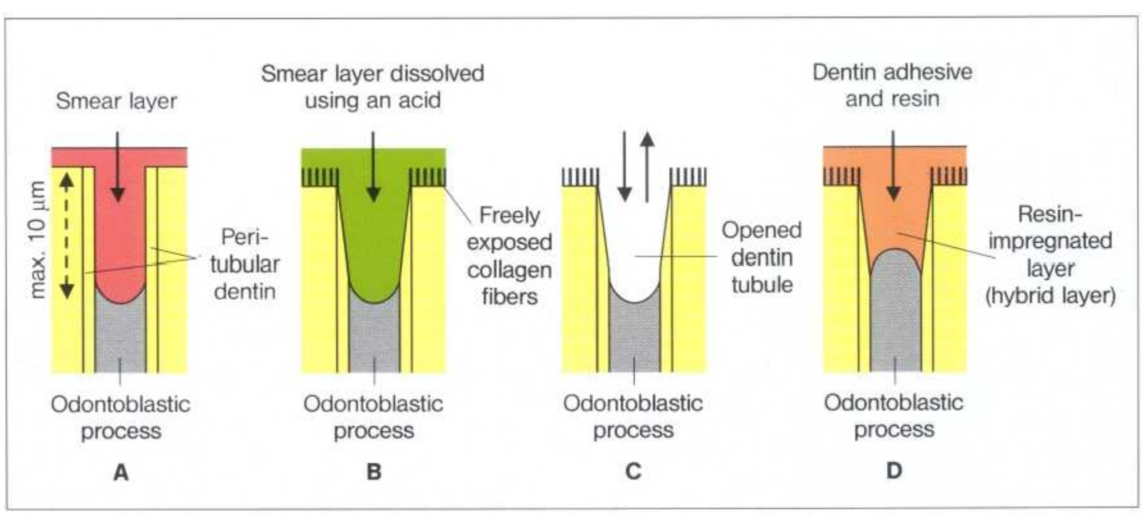
Total Etch Technique

Total etch means that enamel and dentin are etched simultaneously. The result is astonishing. Not only is the bond strength value of the materials improved, but the pulp reaction against the material is also less pronounced. Fusayama, Hieda, Inokoshi, and others showed that the total etch technique did not increase pulp reactions, but rather reduced them (Fusayama 1980): The total etch technique protects the pulp, because after removal of the smear layer with a mild acid (conditioner) the opened dentin wound was sealed with a hydrophilic resin, for example, HEMA *(primer;* see below) and a bonding agent (adhesive).



206 **Smear layer**
A smear layer that is pressed approx. 5-10 pm into the dentin tubules is formed each time a dentin surface is cut. This layer must be removed in order to enable the best possible bonding conditions for dentin bonding.

SEM picture A.] Gwinnett



207 **Effect of the total etch technique on the opening of the dentin canals**
A Prepared cavity
B The smear layer is dissovled through treatment with phosphoric acid
C The acid and the dissolved smear layer are washed away using a water-air spray
D Forming the hybrid layer with a dentin adhesive

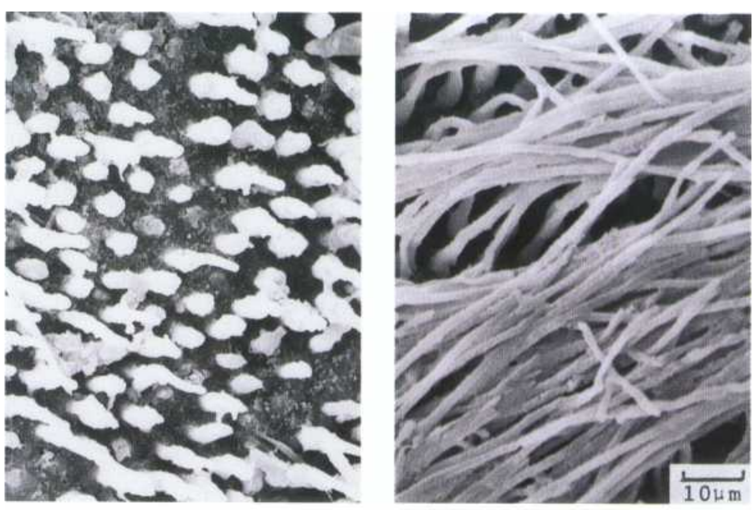
During this treatment a dentin surface impregnated with resin (hybrid layer) is formed that guarantees an optimal dentin wound closure which is acid resistant and prevents bacteria penetrating.

Etching the dentin removes the smear layer, demineralizes the dentin surface and opens the dentin tubules. Now, a filled or unfilled resin (the adhesive) can penetrate the tubules and bond to the walls of the tubules. This hermetic closure of the dentin surface serves not only to protect the pulp, but also to form a micromechanical retention with the tubules and the collagen structures, which results in high mechanical bond strength values. The resin can only penetrate up to 10 um into the tubules of vital dentin, because of the resistance of the odontoblasts, while in extracted teeth the resin can infiltrate the tubules up to 40 um. Even repeated etching of the dentin does not lead to pulp irritation. If, however, the dentin surface is etched too aggressively and over too long a period, a reduction in bond strength will occur, but it will still not cause any pulp irritation. A longitudinal study (Inolcoshi et al. 1982) showed that following treatment of 224 deep caries lesions with the total etch technique, only one pulp necrosis occurred. In another study of 213 deep caries treatments, not a single nonvital pulp was found after four years.

Method of Procedure

Phosphoric acid is applied for 15 seconds. The acid dissolves the smear layer and opens the dentin tubules up to a depth of 10 um. Using a powerful water spray, the acid and the dissolved smear layer are removed. If the cavity walls, despite use of rubber dam, are contaminated with saliva or blood, acid treatment and the rinse must be repeated.

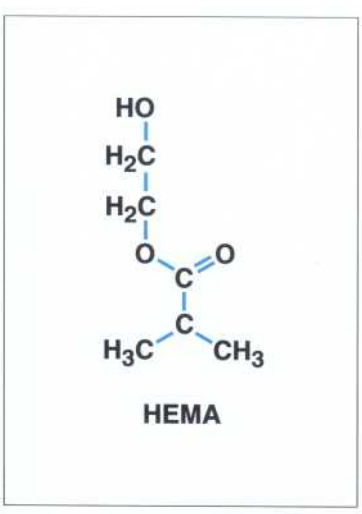
After etching and rinsing, the cavity is lightly blow-dried. Low levels of moisture increase the bond strength values of many dentin adhesives. Immediately after this, the primer, usually a hydrophilic monomer mixed with a solvent, is applied. The solvent in many dentin adhesives is an easily evaporating alcohol (usually ethanol) or acetone (e.g., All-Bond 2). It penetrates into the moist dentin surface and displaces the fluid, whereupon the solvent evaporates and leaves the hydrophilic monomer. This process is called priming. It is very important that the solvent in the primer has evaporated before the bonding agent (adhesive) is placed. Airflow accelerates this. The solvent could otherwise disturb the polymerization of the adhesive. As the last step in the formation of a hybrid layer, the adhesive is applied and polymerized.

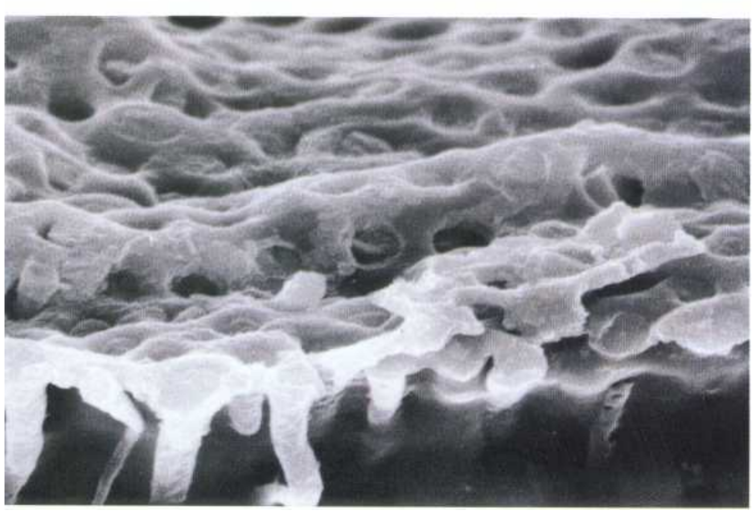


208 Resin-impregnated dentin surface
Etching the dentin removes the smear layer and produces a demineralized dentin surface. This enables the primer to penetrate into the dentin and to impregnate the collagen fibers with monomer.

Left: Resin has penetrated into the dentin tubules.

Right: The resin encloses the collagen fibers and forms a resin-impregnated dentin surface.





209 Structure of a hybrid layer
This resin-impregnated dentin layer is also known as a hybrid layer. It serves to protect the pulp. The resin penetrates approx. 10 pm into the dentin tubules.

Left: Hydroxyethyl methacrylate (HEMA) is one of the most important components of modern dentin adhesives.

SEM pictures (Figs. 208 and 209) T. Tamadi

History of Dentin Adhesives

First- and Second-Generation Dentin Adhesives

In 1951, Hagger developed one of the first bonding agents. It was a glycerophosphoric acid dimethacrylate. The product was named *Sevriton.* The bond was not very strong in a moist milieu and disintegrated over time (Nagger 1951).

In 1965, Bowen introduced the first dentin adhesive. Through copolymerization, an N-phenylglycin-glycidyl-methacrylate (NPGGMA) was to be bonded to the tooth. This is a bifunctional molecule, one end of which bonds to the dentin, while the other end bonds with the resin-based restoration. *Cervident* by S. S. White was the first commercial dentin adhesive.

Clinical performance: More than 50% of the restorations failed within six months.

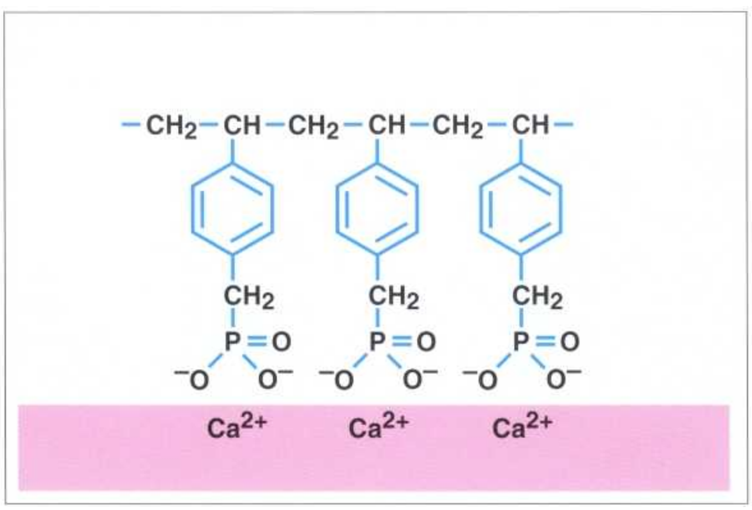
Other dentin adhesives used an improved adhesive system based on aminocarboxyl monomers (e.g., MirageBond and Tenure).

In 1978 the first *Clearfil Bond System F* came to the market (Kuraray). It contained a hydrophobic monomer (Phenyl-P = Methacryl-oyloxyethyl-phenyl-hydrogen phosphate), which reacted with a water-soluble methacrylate (HEMA = Hydroxyethyl-methacrylate), and was also marketed as a two-component system. The activator initiators needed for the polymerization reaction were placed in the two components (Fusayama et al. 1979; Fusayama 1980).

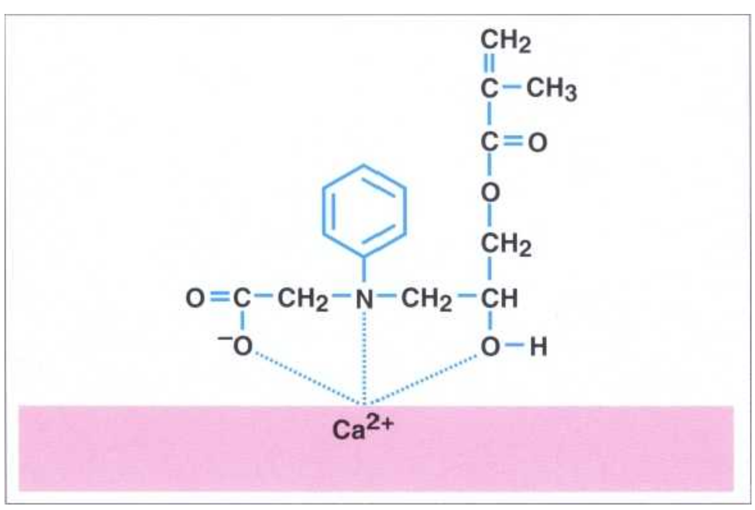
Clinical Performance: Initially, the dentin bond strength values were below 3 MPa. It was only after Fusayama used dentin etching (total etch technique) with this system that the bond strength values increased. The system was the first that produced acceptable bond strength values with both dentin and enamel (Fusayama 1980).

In 1983, *Scotchbond* appeared on the market. Scotchbond is very similar to Clearfil. Instead of phenyl-P, it contains a phosphate ester based on BisGMA. Like Clearfil, Scotchbond is a two-component system consisting of resin and liquid.

The resin consisted of 57% of the above-mentioned dichlorophosphate ester of BisGMA and 43% of a low viscous TEGDMA and the usual polymerization enhancers. The



210 **Phosphate-based dentin adhesives**
Phosphate-based dentin adhesives bond to calcium ions present in the smear layer. Even if the bond is initially very strong, it disintegrates over time in the moist environment present in the oral cavity through hydrolytic degradation (Nagger 1951).



211 NPGGMA **and its bonding ability to hard tooth surfaces**
Amino carboxyl monomeres bond to calcium ions present in the smear layer. NPGGMA, a compound formed from N-phenylglycine and glycidyl methacrylate, was developed in 1965 by Bowen (Bowen 1965).

liquid contained 95% ethanol and additional accelerator initiators (camphor quinone, sodium benzene sulfate).

Function: Although Fusayama had already proved that the total etch technique did not harm the pulp, at that time the general opinion was still that dentin should not be etched. It was expected that with the help of the phosphate groups in the adhesive it should be possible to form a chemical bond to the resin restoration via the calcium-rich part of the smear layer. Therefore, the bond strength values were not significantly better than that of the smear layer (3.5-4.0 MPa).

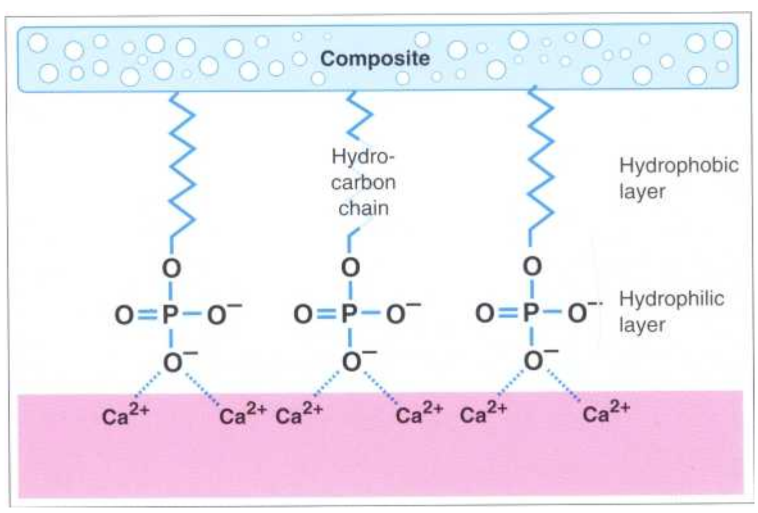
Manufacturing and distributing dentin adhesives was a lucrative business. Shortly after introduction of the phosphate-based dentin bonding agents, numerous similar products came on the market:

- Bondlite (Kerr) with a glycerol-dimethacrylate,
- Dentin Bonding Agent (Johnson & Johnson) with a phosphoric acid ester of HEMA,
- Universal Bond (Caulk) with PENTA, etc.

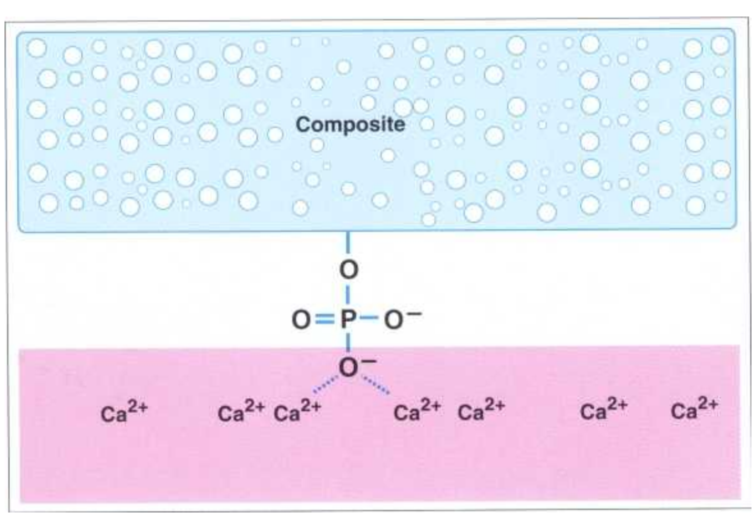
After one year in clinical service, 30% of class V restorations without enamel etching and 10% of the enamel-etched restorations exhibited loss of retention. The reason for these failures was due to the phosphate-based bonding agent dissolving or the smear layer disintegrating. Different thermal expansion coefficients led to leakage and accelerated the failure.

Bowen and Cobb (1965) proceeded in another direction. They did not target phosphate groups, but rather introduced an oxalate system. The original iron oxalate was replaced with aluminum oxalate because of tooth discolorations. The first commercial product based on this system was Tenure (Den-Mat), which was introduced in 1982.

The system was very complex and necessitated eight steps. As a consequence, this method was significantly simplified with the use of NPGGMA, a surface-active amino acid.



212 Bipolar dentin adhesives
Most dentin adhesives consist of bipolar molecules. They have a hydrophilic end, for example the phosphate group that can interact with the calcium-rich dentin, while the hydrophobic end, usually a hydrocarbon chain, bonds with the composite.



213 Bonding mechanism of Scotchbond
The first dentin adhesives were all similar in design. Scotchbond consisted of 57% phosphate-containing monomer (dichlorophosphate ester of BisGMA), monomer (TEGDMA), and a low quantity of benzoyl peroxide to accelerate the polymerization. The solution consisted of 95% ethanol in order to better cover the hydrophilic tooth surface with the hydrophobic BisGMA-resin.

Third- and Fourth-Generation Dentin Adhesives

Clinical studies of the first-generation dentin adhesives were not conducted until after they were introduced on the market. Since the results were often not satisfactory, improvements were desperately needed.

The following belong to the third-generation dentin adhesives:

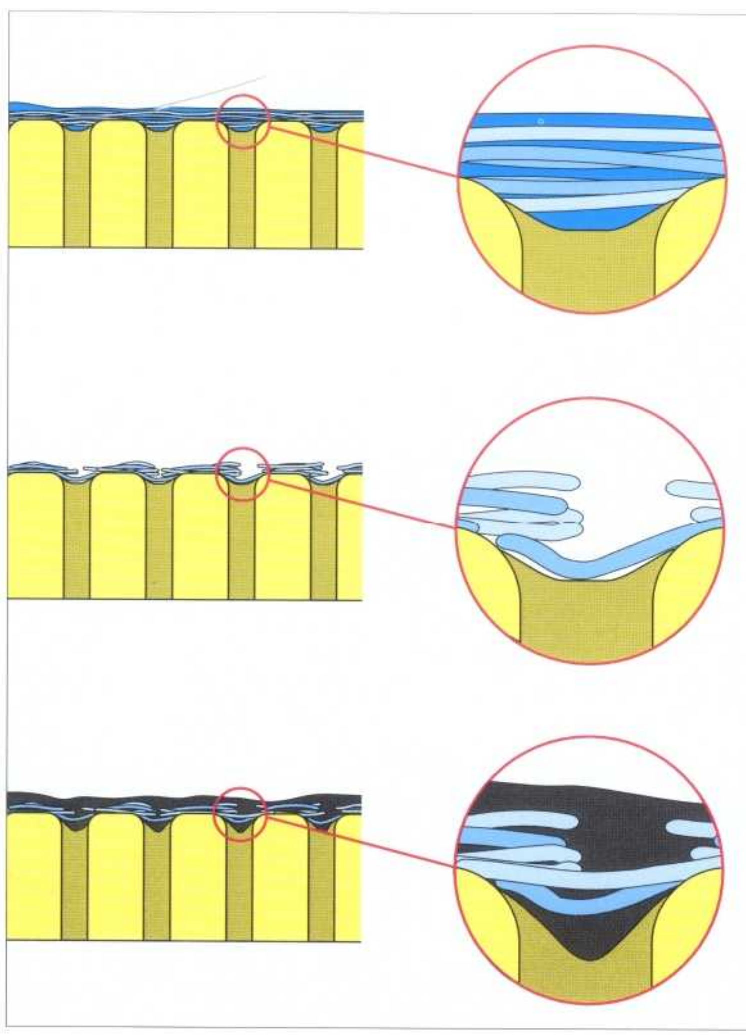
- *Tenure* (Den-Mat): A conditioner, consisting of 3.5% aluminum oxalate, 2.5% nitric acid, and 94% water, removes the smear layer, resin flows into the dentin tubules, and enables retention.

- *Mirage Bond* (Myrons) and *Restobond* (Lee), were also developed by Bowen (1988): After the smear layer has been (partially) removed using a conditioner consisting of 4% NPG, 2.5% nitric acid, and 93.5% water, a hydrophilic resin (PMDM) infiltrates the surface.

- Munksgaard and Asmussen (Munksgaard and Asmussen. 1984; Asmussen and Munksgaard 1985) developed Gluma. The enamel is etched with 37% phosphoric acid. The dentin is conditioned and the smear layer is removed with 17% EDTA. The primer consists of 5% glutaraldehyde that reacts with the collagen present in the dentin. After it has bonded to the collagen, a condensation reaction occurs between 35% HEMA (and 60% water) and the collagen-bonded glutaraldehyde. After the primer has been placed, an unfilled monomer is applied and polymerized. Gluma was the first dentin adhesive with a very high, documented success rate. Gluma 2000 is glutaraldehyde-free.

- *Scotchbond* 2 uses no separate dentin conditioner. The primer is sufficiently acidic (2.5% maleic acid, 55% HEMA, and 40% water) to condition the smear layer. The binder consists of 62.5% BisGMA and 37.5% HEMA. Because this bonding agent had a very reactive oxygen inhibition layer, a rather thick layer had to be placed. The phosphate-based bonding agent was very similar to the original Scotchbond. Scotchbond 2 was the first dentin adhesive that received provisional acceptance by the American Dental Association (ADA) (Vanherle et al. 1993).

- *XR Bond* uses a phosphate-containing primer that infiltrates the smear layer. As a result, a resin-infiltrated layer is formed to which the bonding resin is joined.



214 Infiltration of the smear layer

Above: The smear layer is only slightly infiltrated by the dentin adhesive. The smear layer prevents the dentin adhesive from penetrating into the dentin (first- and second-generation adhesives).

Middle: Mild acid treatment partially dissolves the smear layer. Most third-generation dentin adhesives contained a mild acid that fulfilled this function.

Below: By using a mild acid, a weak infiltration of the resin into the dentin occurs. Nevertheless, sufficiently high bond strength values cannot be achieved with this technique because the smear layer remains intact or partially intact.

-*Primer Universal Bond 2* works in a similar way to XR Bond. The primer consists of 6% PENTA, 30% HEMA, and 64% ethanol; it creates a resin-impregnated layer within the smear layer.

The bond strength values of the second-generation dentin adhesives lie somewhere between 10 and 12 MPa. In all cases, the dentin was etched with a weak organic acid which removed the smear layer.

Clearfil New Bond and *Clearfil Photo Bond* fall between the third and fourth generation of dentin adhesives. Although they were already introduced in 1984 and 1989, they are still quite up to date. Clearfil New Bond is a purely chemically cured adhesive, while Clearfil Photo Bond is a dual-cured material. Enamel and dentin are etched evenly with 37% phosphoric acid. A hybrid layer is created with a hydrophilic resin, which combines the effect of a conditioner and a bonding agent.

The classic dentin adhesives that are still used today consist of three components: conditioner, primer, and adhesive.

Conditioners: Acids that remove, dissolve, or change the smear layer. They demineralize the dentin and expose collagen structures. Moreover, they open the dentin tubules and enable a hybrid layer to form.

-Clearfil Liner Bond: 10% citric acid, 20% CaCl
-Optibond: 37% phosphoric acid
-Scotchbond MP: 10% maleic acid
-Scotchbond MP Plus: 35% phosphoric acid

Primer: Hydrophilic monomer that penetrates into the exposed structures (dentin tubules, exposed collagen network, and intertubular dentin) and forms a hybrid layer. The adhesive, a low-filled resin, binds with this primer.

-Clearfil Liner Bond: MDP, HEMA, glycerolphosphate dimethacrylate
-Optibond: HEMA, glycerol phosphate dimethacrylate
-Scotchbond MP: HEMA, isocyanoethyl methacrylate

Adhesive: The adhesive is a low viscous monomer (a dimethacrylate) that binds with the primer. The hybrid layer is completed after the polymerization of the adhesive.

Product	Conditioner	Primer			Resin	
		Solvent	Monomer	Adhesive	Monomer	Adhesive
Gluma (Miles/Bayer)	17 % neutral EDTA	60 % water	35 % HEMA	5 % glutaraldehyde	45 % TEGDMA 55 % BisGMA	–
Mirage Bond (Myrons Int.)	2.5 % HNO_3	96 % water	–	4 % N-phenylglycine	90 % acetone 10 % PMDM	–
Scotchbond 2 (3M)	–	40 % water	55 % HEMA	5 % maleic acid	37.5 % HEMA 62.5 % BisGMA	–
Tenure (Den-Mat)	3.5 % aluminium oxalate 2.5 % HNO_3 94 % water	95 % acetone	5 % NTGGMA	–	10 % PMDM 90 % acetone	–
Triptone (Coe Laboratories)	0.1 % polyhexamide	–	–	–	70 % TEGDMA 15 % urethane dimethacrylate	10% phosphate monomer
Universal Bond 2 (Caulk)	–	64 % ethanol	30 % HEMA	6 % phosphate ester (PENTA)	25 % TEGDMA 50 % urethane dimethacrylate	4.5 % PENTA 0.5 % glutaraldehyde
XR Bond (Kerr)	–	46 % water	50 % ethanol	3.75 % phosphate ester monomers	30 % TEGDMA 60 % urethane dimethacrylate	10 % phosphate monomer

215 **Components of dentin adhesives**
Each adhesive consists of three components: conditioner, primer, and resin. Today, the conditioner is virtually always phosphoric acid. All primers are solutions, and their solvent must be known to the dentist. If it is acetone or ethanol, the solvent will require a certain amount of time to penetrate into the deep dentin structure and evaporate. Any remaining solvent disturbs the polymerization of the bonding agent or resin that is used to coat the primed surface. The bonding resin is usually a low-filled resin that can cover the primed surface well.

The Path to Fourth-Generation Dentin Adhesives

Nakabayashi described in 1982 that the bond strength value to enamel and dentin could be improved with MMA and Tri-N-butyl-borane (MMA-TBB) (Nakabayashi 1982). His hypothesis was that the monomers must diffuse into the dentin before they can polymerize. He first worked with HNPM, phenyl-P as well as 4-META-compounds in order to increase the diffusion. In the fourth-generation bonding agents, PMDM, BPDM, MDP, and Penta-P-monomers are used to form a hybrid layer. Products that have this chemical composition are also classified as *4-meta products.*

Nakabayashi etched the dentin with 10% citric acid and 3% ferric chloride, also called 10:3 *solution.* The citric acid removes the smear layer and etches the inorganic hydroxyl apatite to expose the organic dentin matrix up to a depth of 5-10 um. The 3% ferric chloride leads to a denatured or a coagulated layer of exposed collagen fibers. Now a hydrophilic monomer, a component of the primer, can infiltrate the dentin and the collagen fibers. The 4-meta system also has an excellent bonding ability to enamel, metals, and porcelain.

All-Bond 2 by Bisco Inc. was the market leader several years ago. This system uses a 35% phosphoric acid for the conditioning process. The primer consists of acetone and biphenyl dimethacrylate (BPDM). The acetone present in the primer competes with moisture present on the dentin and pulls the monomer with it. All-Bond 2 not only has outstanding bonding ability to dentin and enamel, but also to other materials.

The bond strength values of All-Bond 2 to moist dentin are significantly higher than to dry dentin. This facilitates work on a moist dentin surface and in the moist milieu of the oral cavity. However, it is important to know that the *wet bonding,* as defined by Kanca (1992a), does not work as well with all systems.

Scotchbond Multi-Purpose (MP) is another example of a fourth-generation dentin adhesive. Instead of using phosphoric acid, the enamel and the dentin are etched with 10% maleic acid. Since enamel etching with maleic acid does not always result in an optimal etch pattern, MP Plus comes with a 35% phosphoric acid.

216 **System components and active substances of the adhesive systems and their effect on dentin**
A list of the most important substances and the current affiliated abbreviations is presented on the page opposite.

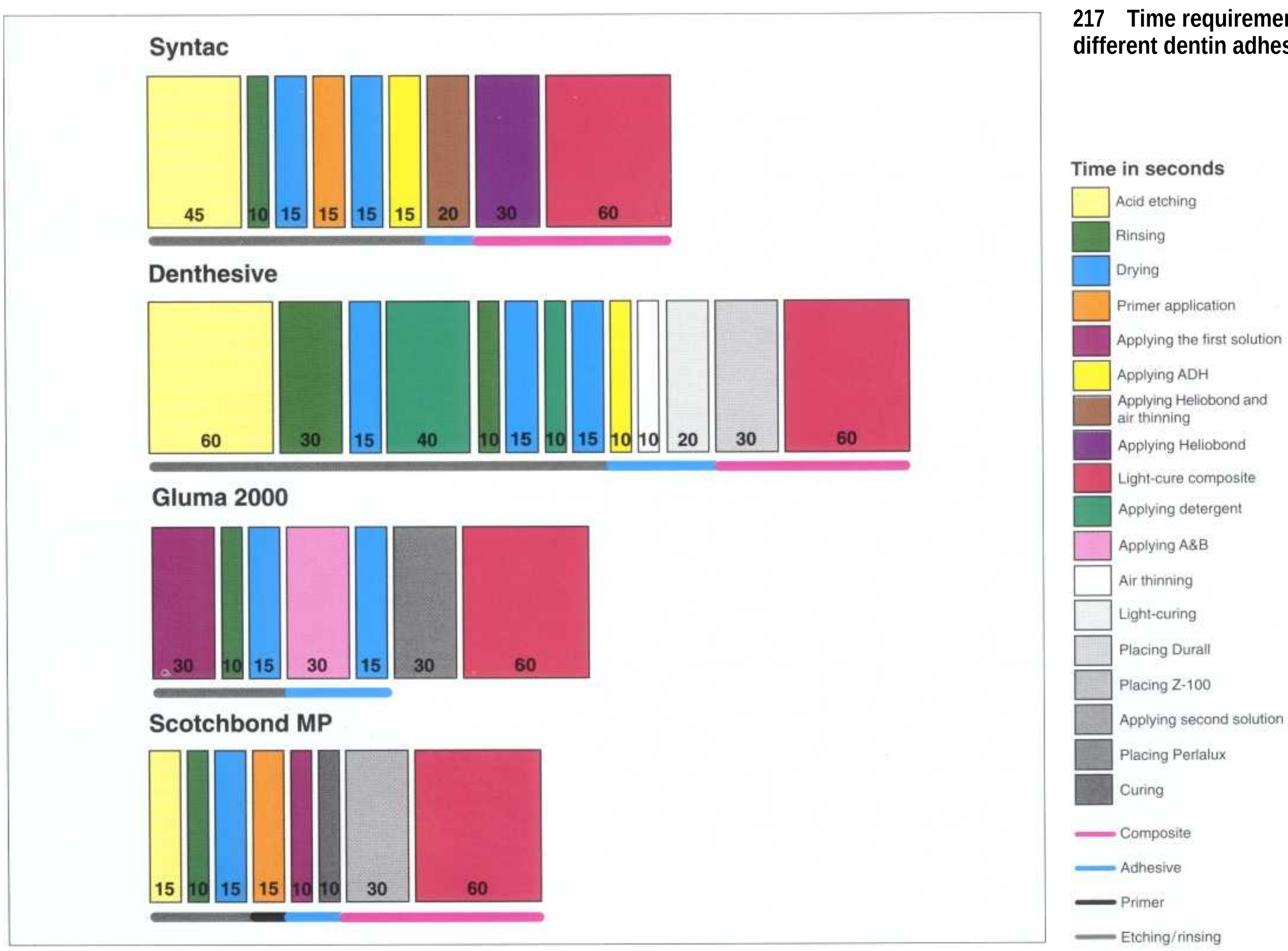
(Adapted from Lutz and Krejci 1995.)

Components	Reactive Compounds	Effects
Conditioners	• Acids: pyruvic, acetic, maleic, oxalic, phosphoric, nitric, citric acid • Metal salts: Al, Ca, Fe • Amino acids (NH_2-CHR-COOH): glycine, N-Phenyl glycine (NPG) • Chelators: EDTA	• Dissolves smear layer • Demineralization • Exposes collagen network • Open tubules • Porous, retentive intertubular dentin
Self-etching primers	• Inorganic acids • Organic acids, such as dicarbon - (COOH-R-COOH): • Succinic, glutaric, maleic acid • Metal salts: Al, Ca, Fe • Acidic monomers ($COOH_{(n)}$-R-$[COO\text{-}EMA]_{(n)}$: MES, MEP, MEM, MEC, polymethacryl oligomaleic acid • Phosphonated poly-, di-, monomethacrylate: DMEP, MDP, PENTA, phenyl-P, • Water-soluble di-, monomethacrylate ($M_{(n)}$-R-$OH_{(n)}$: HEMA, HPMA, BPDM, GM, EM, PEMA; PEGDMA • Amino acids (NH_2-CHR-COOH): glycine, NPG • Solvents: water, acetone, alcohol	• Smear layer conversion • Partial demineralization • Partially exposed collagen network • Partially open tubules • Porous, retentive intertubular dentin • $[Me^{z+}]$ ↗ • $[\text{-}NH_2]$ ↗ • [-Ma] ↗ • Hydrophobic property ↗
Primer dentin adhesive	• Water-soluble di-, monomethacrylate ($M_{(n)}$-R-$OH_{(n)}$: HEMA, GM, EM, PEMA; PEGDMA • Aldehydes: glutardialdehyde, propionaldehyde, • Amphiphilic di-, monomethacrylate: NMSA; NMENMF, NPGGMA, NTGGMA, PMDM, 4-META, • PMMA/TBBO • Phosphonated poly-, di-, monomethacrylate: DMEP, MDP, PENTA, Phenyl-P, • M-R-M: BPDM, BisGMA, TEGDMA, UDMA, UTMA, • Solvents: water, acetone, alcohol, methylenchloride, tetrahydrofuran	• Secondary chemical forces: covering, penetration, diffusion • Pegs • Tags • Stickiness • Polymerization and machanical interlocking • Modification of the surface structure • Hydrophobic properties ↗ • Polymer layer formation
Enamel adhesive	• Unfilled, slightly viscous dimethacrylates	• Copolymerization • Hydrophobic property ↗ • Polymer layer formation

Like the All-Bond 2 system, both enamel and dentin can be etched simultaneously with most of the products belonging to this group. However, there are also products that belong to this group (e.g., Syntac, Denthesive 11 and others) that condition enamel and dentin in different ways.

Current Abbreviations of Components and Active Substances of Bonding Systems

BisGMA = Bisphenol-A-diglycidyl-methacrylate
BPDM = Biphenyl-dimethacrylate
DMEP = Di-methacryloxy ethyl-phosphate
EDTA = Ethylendiaminetetraacetate
EM = Trihydroxybutyl-methacrylate
EMA = Ethyl methacrylate
4-META = 4-Methacryloxyethyl-trimellitate-anhydride
GM = Dihydroxypropyl-methacrylate
HEMA = Hydroxyethyl-methacrylate
HPMA = Hydroxypropyl-methacrylate
MA = Methacrylate
MDP = 10-Methacryloyloxy-decyl-dihydrogen-phosphate
MEC = Mono-methacryloyloxyethyl-hexahydrogen-phthalate
MEM = Mono- methacryloyloxyethyl-maleate
MEP = Mono-methacryloxyethyl-phthalate
MES = Mono-methacryloxyethyl-succinate
NMENMF = N-Methacryloyloxyethyl-N-methyl-formamide
NMSA = N-Methacryloyl-5-aminosalicylic acid
NPG = N-Phenyl-glycine
NPGGMA = N-Phenyl-glycine-glycidyl-methacrylate
NTGGMA = N-Tolylglycine-glycidyl-methacrylate
PEGDMA = Polyethylene-glycol-dimethacrylate
PEMA = 3-Hydroxy-2,2-di(hydroxymethyl) propyl-methacrylate
PENTA = Dipentaerythtritol-pentamethacrylate monophosphate
Phenyl-P = 2-Methacryloxy ethyl phenyl hydrogen phosphate
PMDM = Pyromellitic acid diethylmethacrylate
PMMA = Polymethylmethacrylate
TBBO = Tri-N-butylborane (partially oxydated)
TEGDMA = Triethylene glycol-dimethacrylate
UDMA = Urethane-dimethacrylate
UTMA = Urethane-tetramethacrylate



217 Time requirements to use different dentin adhesives

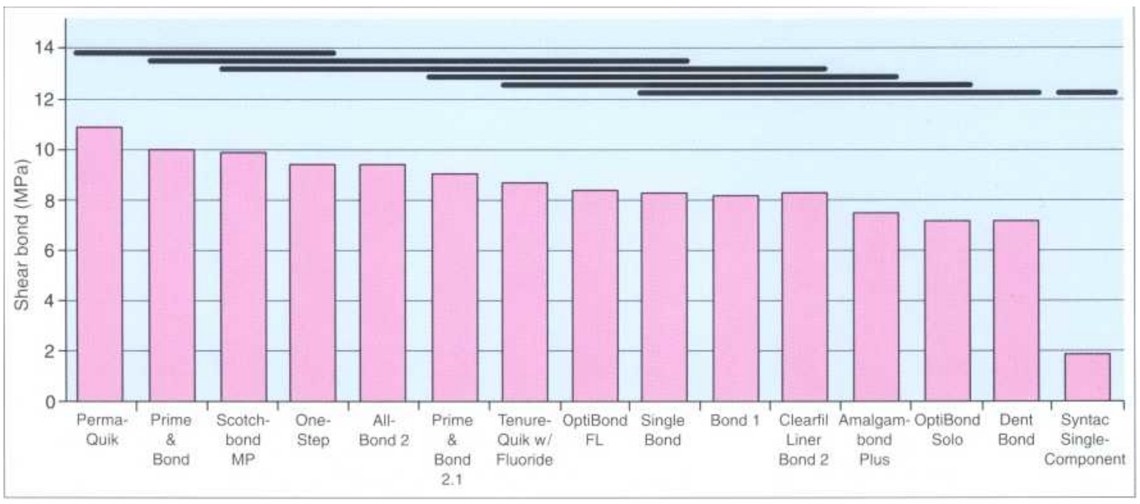
Fifth-Generation Dentin Adhesives

A possible way to simplify the application of dentin adhesives is to reduce the number of components. Even if some dentin adhesives give the impression that they contain a single component (e.g., Syntac Single Component) or a single treatment step (One-Step), all products include at least two components and two treatment steps.

However, the conditioner and the primer can be combined in a single liquid. These products are called *self-etchers* or *self-conditioning primers. Clearfil Liner Bond 2* is an example. Most manufacturers have actually moved toward combining the primer and the bonding agent. The best-known product *is Prime & Bond.* The number of treatment steps needed is not necessarily less than in the case of the three-component systems. With Prime & Bond, Syntac Single Component, One-Step, and Tenure Quick, two layers should be placed, dried, and polymerized.

218 Bond strength of the latest dentin bonding agents
The shear bond strength values of the latest dentin adhesives are comparable to those of Scotchbond MP and All-Bond 2. Exception: Syntac Single-Component.

(Adapted from CRA Newsletter, October 1997)



219 Composition of commercially available third-generation dentin adhesives

(Adapted from Van Meerbeek et al. 1993)

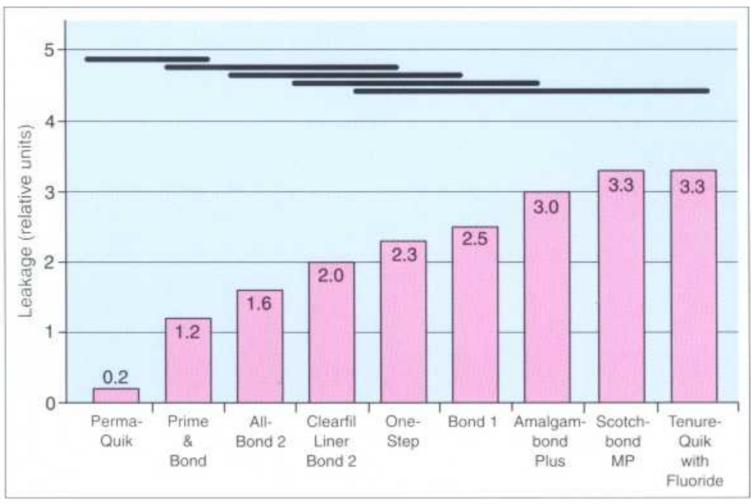
Product	Conditioner	Primer	Resin
Scotchbond	2.25 % maleic acid	–	BisGMA/HEMA
Tenure	2.5 % nitric acid	5 % NTGGMA/ 10 % PMDM	BisGMA
Scotchbond MP	10 % maleic acid	HEMA/PAA	BisGMA/HEMA
Linerbond II	10 % citric acid	3 % NMSA	MDP
All-Bond 2	10 % phosphoric acid	2 % NTGGMA/ 15 % BPDM	BisGMA/UDMA/ HEMA
Scotchbond 1	10 % phosphoric acid	HEMA	BisGMA, UDMA, GDMA

220 Comparison of new dentin adhesives: time and cost per application

Product (Manufacturer)	Time to take effect (min:s)	Cost per application (US-$)
Bond 1 (Jeneric/Pentron)	1:22	0.24
Single Bond (3 M)	1:16	0.44
One-Step (Bisco)	1:49	0.40
Scotchbond MP (3 M)	1:27	0.71
Prime & Bond (Dentsply/Caulk)	2:03	–
TenureQuik mit Fluorid (Den-Mat)	1:55	0.67
Dent Bond (Dentpac/5 star)	2:30	0.30
Clearfil-Liner Bond 2 (J. Morita)	1:51	0.79
Optibond FL (Kerr)	2:12	0.69
Prime & Bond 2.1 (Dentsply/Caulk)	2:21	0.72
Syntac Single-Component (Ivoclar)	2:15	0.82
All-Bond 2 (Bisco)	2:25	0.71
OptiBond Solo (Kerr)	1:43	1.52
PermaQuik (Ultradent)	2:40	1.36
Amalgambond Plus (Parkell)	2:40	1.47

Clinical Considerations When Using Bonding Agents

- Dentist and assistant must know the purpose of each component and must follow the instructions.
- Some products contain solvents that easily evaporate (e.g., acetone). Watch the use-by date and the consistency of these materials.
- The tooth surface must be clean in order to protect it from contamination. A rubber dam is highly recommended.
- Do not desiccate the teeth. Keep the tooth surface moist (moist cotton pellet). Dry the tooth surface just before the adhesive is placed. All products attain higher bond strength values on slightly moist dentin surfaces.
- With products that contain acetone as a solvent, take out only the quantity that is needed and use it immediately.
- The above-mentioned systems are only light-curing systems. Therefore, they should be restricted to indications that are light-curing (CRA Newsletter 6/1996).



221 **Leakage around the latest generation of dentin adhesives**
Relative leakage units:
0 no leakage,
1 leakage at the upper wall,
2 leakage up to the rear wall,
3 leakage along the rear wall,
4 Leakage into the tubules,
5 Leakage into the pulp chamber.

Left. Clearfil Liner Bond 2, suitable for deep caries treatments and for direct pulp capping.

Produce	Number of Components	Number of Steps	Steps (Time taken in s)		Total Time (s)
Prime & Bond	2	11	Etch (15), Rinse (15) First adhesive layer (7) Dry (5) Second adhesive layer (7) Dry (5) Place resin	Dry (2) Wait (20) Polymerize (10) Wait (20) Polymerize (10)	**107**
Syntac Single-Component	2	11	Etch (15), Rinse (15) First adhesive layer (7) Dry (5) Second adhesive layer (7) Dry (5) Place resin	Dry (2) Wait (20) Polymerize (20) Wait (20) Polymerize (20)	**135**
One-Step	2	11	Etch (15), Rinse (15) Place 2 adhesive layers (14) Dry (10) Place 2 more adhesive layers (14) Dry (10) Place resin	Dry (2) Polymerize (10) Polymerize (10)	**110**
TenureQuick with Fluoride	2	9+	Etch (15), Rinse (15) Place 3 adhesive layers (21) Dry (10) Place second adhesive layer (7) Dry (10) Place resin	Dry (2) Wait (15) Polymerize (15) Wait (15) Polymerize (15)	**116**
Clearfil Liner Bond 2	3	7	Mix primer (5) Place primer (7) Place adhesive (7) Place resin	Wait (20) Dry (5) Dry (2) Polymerize (20)	**111**
Scotchbond MP	3	7	Etch (15), Rinse (15) Place primer (7) Place adhesive (7) Air-thin adhesive (5) Place resin	Dry (2) Dry (5) Polymerize (10)	**87**

222 **Necessary steps and time taken for the latest dentin adhesives**
Scotchbond MP served as control.

Figs. 221 and 222 are adapted from CRA Newsletter, September 1996

Factors Influencing Dentin Bonding

Dentin

The reliability of modern dentin adhesives is strongly dependent on the quality of the dentin. Higher bond strength is achieved for younger teeth compared to the dentin of elderly patients. Bonding to sclerotic or carious dentin is poor. Also, the density of the tubules plays a role. At the cemento-enamel junction the tubule density is approximately 4 (vol.)% or 20 000 tubules per cm ^{2} and close to the pulp it is approximately 28 (vol.)% or 45 000 tubules per cm^2 (Gwinnett 1994). The bond strength values are higher in peripheral dentin than in dentin closest to the pulp because of the liquor pressure in the canals. The dentin should not be desiccated; it must be kept moist during the entire procedure. If it dries up, the collagen structure collapses. The dentin should not be etched for too long. In the case of 30-35% phosphoric acids, do not exceed 15 seconds. The reason is not that the pulp would suffer damage, but that a too strongly etched dentin surface results in impeded hybrid layer formation and produces a weaker bond strength.

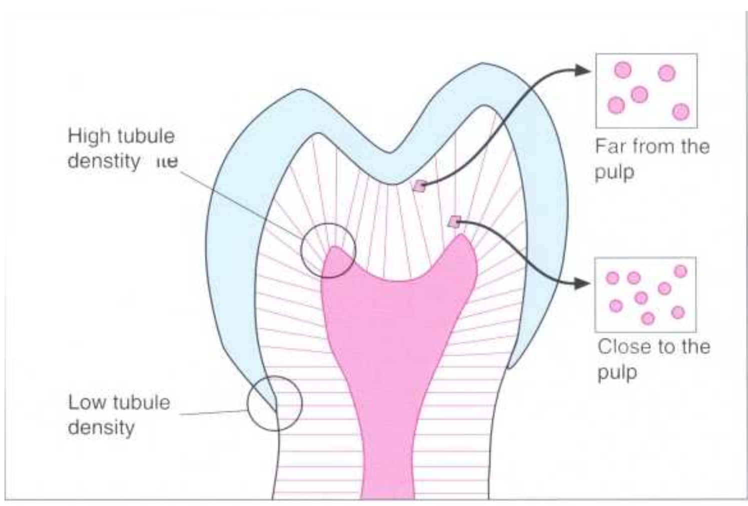
All the above factors suggest that single bond strength values are meaningless per se. Only comparative bond strength values from standardized experiments by an independent institute are meaningful. It is an internal standard that bond strength values of dentin adhesives are compared with Scotchbond MP or All-Bond 2 (Heymann and Bayne 1993).

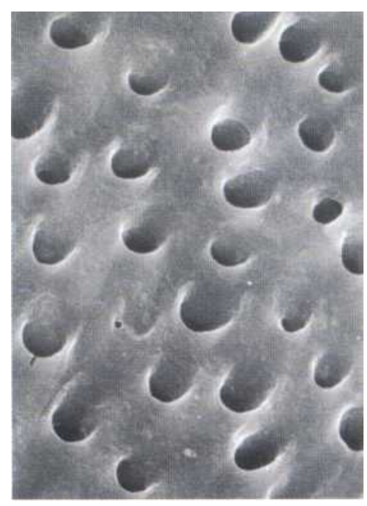
Tooth Factors

The location of the tooth, the size and form of the lesion, and the inflexion of the tooth play a role. The bonding ability in the upper jaw is generally higher than in the lower jaw. Restorations covering big wedge-shaped defects have a longer lifespan than if the erosions are flatter. This may be due to tooth inflexion. At approximately one million chewing cycles per year this leads to bond failure of dental neck fillings.

Patient Factors

The age of the patients plays a role. As consequences of caries and trauma, the dentin tubules become closed through precipitation of hydroxylapatite crystals. This process is called sclerosis. Heymann et al. (1988) and Lambrechts (1987) showed that 75% of 61-80-year-old patients lost at least one cervical filling within two years, while among 20-40-year-old patients the failure rate was only 27%.

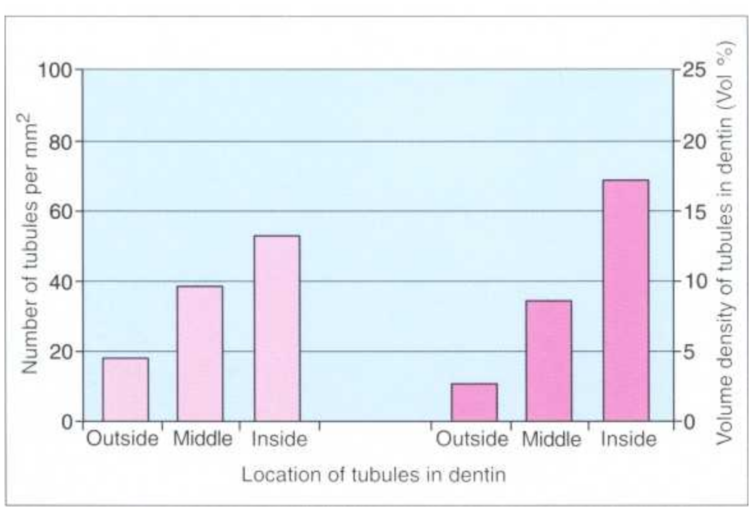




223 **Distribution of tubules in dentin**
Dentin close to the pulp shows a higher tubule density than in dentin remote from the pulp. The higher the tubule density, the lower the bond strength values of the dentin adhesives to the dentin.

Right. Openings of dentin tubules.

SEM picture *Bisco Inc.*



224 **Relative number of dentin tubules and tubule volume at different dentin levels as measured at different distances from the dentinoenamel junction**
Adapted from Heymann 1995.

Materials

Using a layering technique can reduce the stresses that are caused by the polymerization shrinkage. The modulus of elasticity of the small particle hybrid composites is higher than that of the microfilled composites. Also, a low sub-filling with low modulus (e.g., Clearfil Liner Bond 2) is to be recommended.

Different polymerization rates are just as important. If the adhesive is not completely polymerized, the polymerization forces of the composite can lead to debonding and gap formation.

Disturbing Factors

The key to dentin bonding is the hybrid layer. The following factors can disturb the formation of this resin-impregnated dentin layer:

- Dentin etching is too strong.
- Desiccation of the dentin (results in a collapse of the collagen structure and insufficient penetration of the resin).
- Contamination of the dentin with saliva or blood after etching (etching must be repeated).
- Insufficient priming time.
- Primers contain evaporating solvents, usually acetone, that can disturb polymerization. After the primer has been placed, it must be blown away with a light airflow.
- The primer thickness may change during storage because of evaporation. The bottle must be closed immediately after use.
- Blowing the adhesive too thinly. As a consequence, the resin is no longer completely polymerized because of oxygen inhibition.
- *Incomplete polymerization. To* avoid these problems, do a weekly check-up of the polymerization lamp and an annual inspection. If in doubt, in the case of adhesive cementation of inlays or crowns, use a dual-cured or chemically cured system. An incompletely polymerized adhesive leads to an incomplete hybrid layer, leakage, damage to the pulp, postoperative sensitivity, and premature failure of the restoration.
- *Mechanical stress during polishing.* The polymerization stress amounts to 2-7 MPa. Since the tensile strength of the enamel is approximately 10 MPa, no new stress factors should be introduced during grinding and polishing of the filling. The effect of such stress could be cracks formed in the enamel. If possible, grind and polish the filling at a later time, or seal it with a low viscous, hydrophilic resin.

Product Names and Manufacturers	Light Intensity (mW/cm^2)	Maximum Diameter of the Light Tip	Built-in Radiometer	Continuous Operation	Handling
Arcus 2 (Litema)	560	Standard: 10 mm; 8 and 4 mm available	No	No, switches off after approx. 9 mins	–10 mm light tip is standard –Light appliance without cord –Possibility of testing battery –Quiet –Simple bulb replacement
Coltolux 4 (Coltene/ Whaledent)	450	Standard: 8 mm; 13 mm available	Yes, digital	No, switches off after approx. 8 mins	–Simple bulb replacement –Push-button (on–off)
Optilux 500* (Kerr)	680	Standard: 11 mm; 13 mm available	Yes, digital	Yes	–Best timer –11 mm light tip is standard –Push-button (on–off) –Adjustable timer with warning tone –Indicator for the lifespan of the bulb
Prolite (Detrey Dentsply)	400	Standard: 8 mm; 13 mm available	Yes, red-yellow-green LED	No, switches off after approx. 12 mins	–Light appliance without cord –Simple bulb replacement –Quiet –Push-button (on–off) –Excellent timer with indicator built in handle
Spectrum (Detrey Dentsply	710	Standard: 8 mm; 13 mm available	Yes, red-yellow-green LED	Yes	–Best usefulness –Quiet –Push-button (on–off)
Vivalux II (Vivadent Dental)	260	Standard: 7 mm; 13 mm available	No	No, switches off after approx. 8 mins, followed by change of light appliance	–Two light appliances for continuous polymerization –Quiet –Simple bulb replacement –Push-button (on–off) –Indicator for the lifespan of the battery
XL 3000 (3M Medical)	600	Standard: 12 mm; 7 mm available	Yes, only green LED	Yes	–12 mm fiberoptic rod is standard –Quiet –Simple bulb replacement –Push-button (on–off) –Built-in replacement bulb

225 Comparison of different light-curing units
(Modified from CRA Newsletter, Junel996)

Dentin Adhesives and Pulp

Dentin Adhesives-The Ideal Therapy for Deep Caries Lesions

Studies by Brannstrom (1982), Bergenholz (1979), and Cox (1982) have shown that bacteria are responsible for inflammation of the pulp. Therefore, one of the uppermost goals in dentistry is to produce restorations that seal the dentin sufficiently so that a bacterial invasion is impossible.

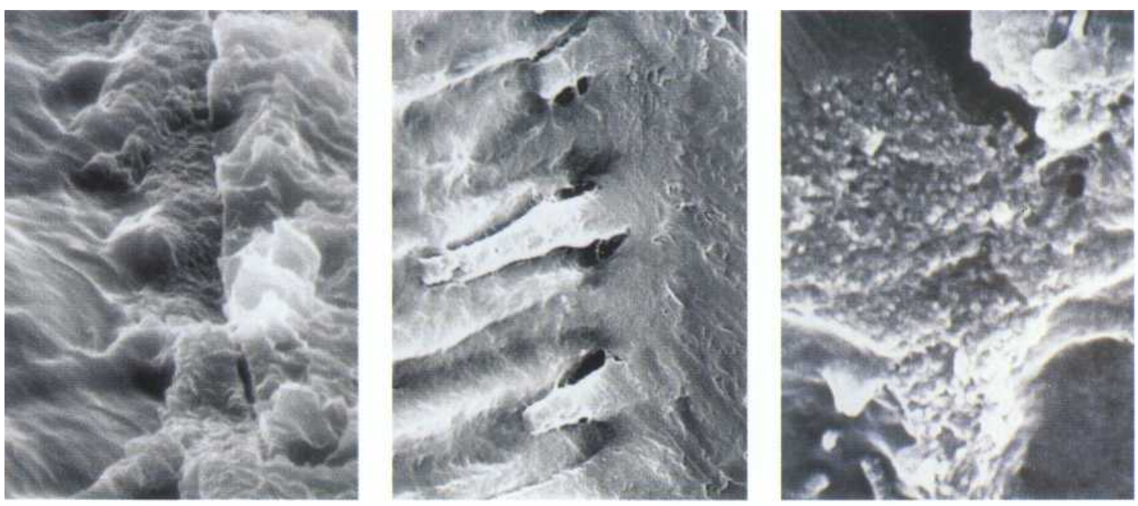
Pashley (1993), Cox and Suzuki (1994), Kanca (1992), and others studied the influence of the total etch technique on the pulp in rhesus monkeys. The teeth treated were extracted after 3, 25, and 80 days and histologically examined. An irritation of the pulp could not be recognized in histological sections.

These studies and many others confirm the early results of Fusayama et al. (1978). Etching the dentin (conditioning) and sealing it with a primer is the best possible dentin protection.

Prevention of Root and Secondary Caries

The fabrication of a hybrid layer is not only the perfect dentin closure; it is also very *acid resistant.* In an experiment, the hybrid layer remained intact even when enamel and dentin were etched away by hydrochloric acid (Nakabayashi 1991). Thus, the hybrid layer forms a caries protection of the root surface similar to fissure sealing of occlusal surfaces (Johnston and Bowen 1991). Grogono and Mayo (1993) showed this using the example of Scotchbond MP; Swift et al. (1994) did the same with the All-Bond 2 system.

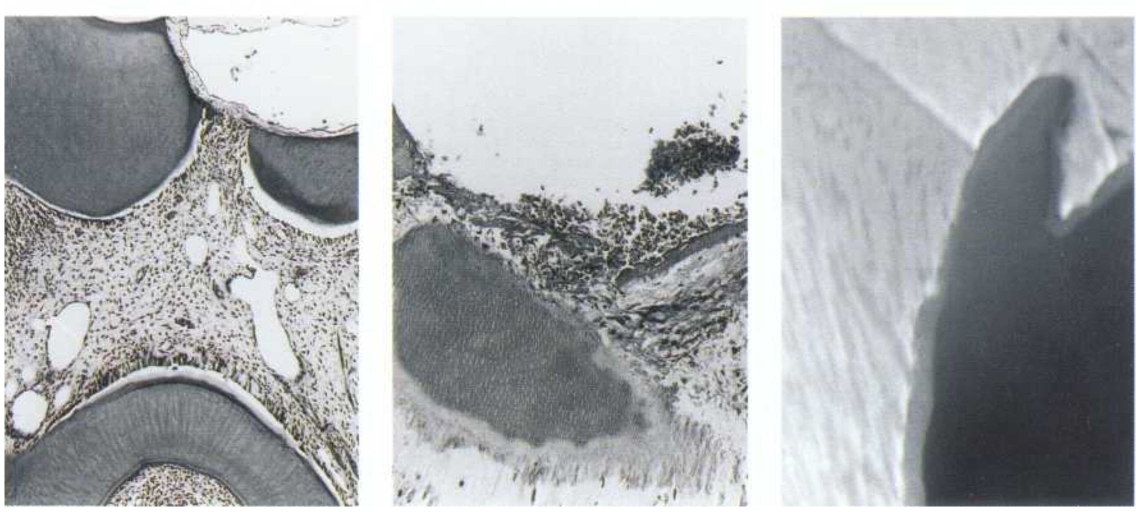
It is particularly in a time in which more and more elderly people are retaining their natural teeth and treatment of circular root caries in older people is becoming one of the most frustrating treatment forms, that applying the dentin adhesive will become a new technology in preventive dentistry.



226 Hybrid layer
Left: Primer and resin have infiltrated the collagen structure and the dentin tubules. (Courtesy of *T. Yamada)*

Middle: The resin tags closing the dentin wound are clearly visible. (Courtesy of *T.Yamoda)*

Right: Section through dentin tubule with a resin-impregnated dentin layer. (Courtesy of Bisco Inc.)



227 Direct pulp capping with dentin adhesive (Metabond C&B)
Left: Collected after three days. A slight dilatation of the capillaries, with hyperemia and inflammation, is visible.

Middle: Collected after 30 days. An inflammation reaction is not seen. Secondary dentin formation has begun.

Right: Also after 30 days, no microleakage can be detected (Tsuneda 1995).

Desensitization of Dentin and Dental Necks

One of the first clinical studies of desensitization of tooth surfaces was conducted with Gluma (Felton et al. 1991; Christensen 1993). Dental necks and prepared inlays and crowns were examined. Permeability was reduced by means of a denaturation of the proteins on the dentin surface. As soon as the dentin tubules were closed, the hydrodynamics of the dentin fluid was also reduced and the sensitivity lowered. Other dentin adhesives form a very effective closure of the dentin surface, leading to the same effect, through the formation of a hybrid layer. The closure of dentin tubules is decisive for desensitization (Swift et al. 1994). All modern dentin adhesives have that ability.

Christensen (1994) describes the desensitization of teeth after crown preparation. Cementing must not be done with resin cements or resin-modified glass ionomer cements, but rather with zinc phosphate or glass ionomer cements.

The optimal time for the desensitization:

- *During the preparation session:* The teeth are already anesthetized. A hybrid layer is formed after preparation and fabrication of the temporary arrangements, but before making a dental impression.
- *Before the cementation:* One must be careful to use products that have the smallest possible film thickness or those that work with chemical current.

Application	Product and Principle	Technique	Effect
By the patient	Sensodyne (potassium chloride or potassium nitrate [mint]) Sensodyne Gel (5 % potassium nitrate) Gel Kam (0.4 % stannous fluoride) Metal oxides block the dentin tubules	Placed on the dental necks as part of daily oral hygiene	Moderate, increases with time Potassium nitrate is twice as effective as strontium chloride
By dentist or dental staff	Calcium hydroxide	Calcium hydroxide powder is mixed with water or topical anesthetic and the slurry is polished against the tooth	Moderate
	Iontophoresis: negatively charged fluoride ions are deposited by an electric current into the dentin and block the dentine tubules	Clean teeth Adjust the electric current Topical application of the fluoride solution Start the appliance	Moderate, 70–80 % of patients perceive an improvement
	Oxalate Protect (Butler), Sensodyne Sealant Kit	Placed on the tooth and allow to take effect	Very effective over the short term
	Lasers Block the dentin tubules through heat	Nd-YAG-Laser	Effective
	Dentin adhesives Form hybrid layer	As described in Fig. 222	Durable and effective, best of all techniques

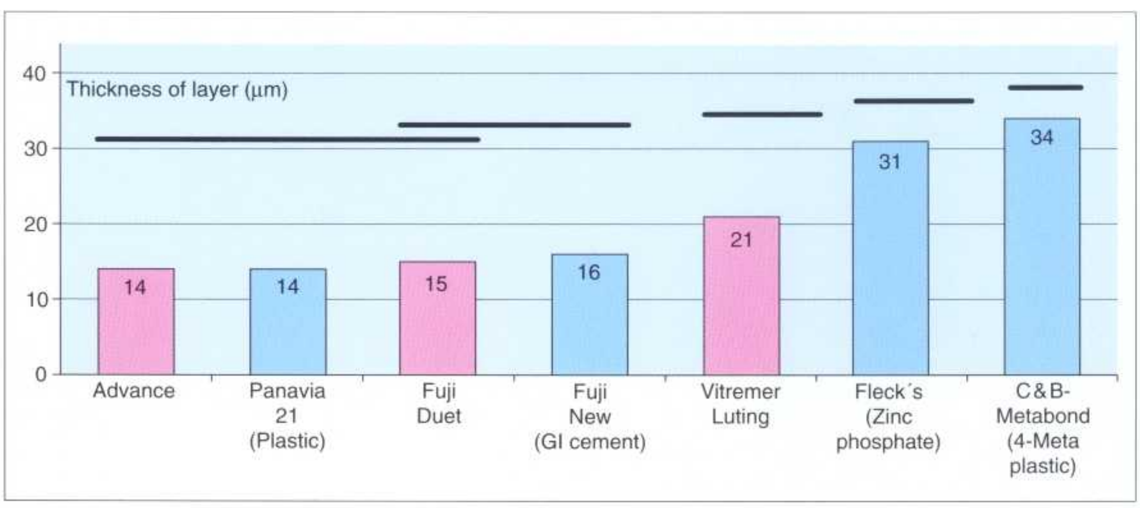
228 Options for desensitizing sensitive dental necks
After Sneed 1991

Cements and Cementation

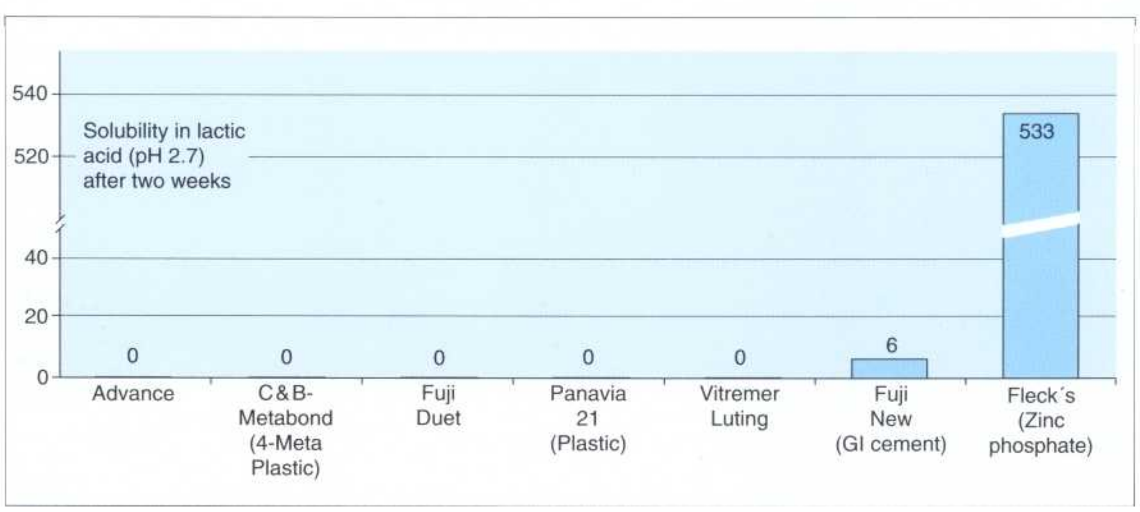
For almost a century, dentists have cemented metallic restorations, inlays, and crowns with *zinc phosphate cements.* Over the past 20 years *glass ionomer cements* have also been available. For approximately 10 years, restorations have not only been bonded through micromechanical retention, but they have also been chemically bonded to the tooth substance. The repertoire has been widened by *resin-modified glass ionomer cements* and *resin cements.* The success rate of cemented and bonded restorations depends on several factors, namely pressure and tensile strength, bonding to tooth structures, strength of the filling, handling, caries resistance, aesthetics, and ability to remove excess material.

The following picture emerges when comparing the newer materials, such as resin cement, resin-modified glass ionomer cements, and compomer cements with phosphate cements: zinc phosphate cement has the lowest flexural strength of all the cements. The *flexural strength* of the classic glass ionomer cement is essentially not different. The flexural strength of the new resin cements and the new resin-reinforced glass ionomer cements is approximately five times as high. While the classic glass ionomer cement has a *bond strength* of 2-5 MPa to tooth structure, the new resin-reinforced glass ionomer luting cement-containing about 20% resin-have bond strength values of approximately 10 MPa. The resin cements combined with suitable dentin adhesives have bond strength values around 20 MPa. However, phosphate cements do not bond to tooth structures. If a metal restoration is bonded with phosphate cement, the low bond strength is independent of whether the restoration is a gold-rich or gold-free alloy, because no chemical bond is formed between the metal and the zinc phosphate cement (0.08 MPa). The resin-reinforced glass ionomer cement on average has a bond strength value of 3-10 MPa, and the resin-based cements reach values of up to 40 MPa against a metal surface (CRA Newsletter 2/1996).

The cement with the best solubility is zinc phosphate cement. Newer generation cements are almost water insoluble. Fluoride release is an important factor when one is looking at the *cariostatic properties* of the cement. Here, resin cements are just as bad as the classic zinc phosphate cement. However, the resin-reinforced glass ionomer cements are substantially better.



229 Thickness of various cement layers
All resin-modified glass ionomer cements have an acceptable thickness, although their viscosity seems to be higher than that of some other cements.



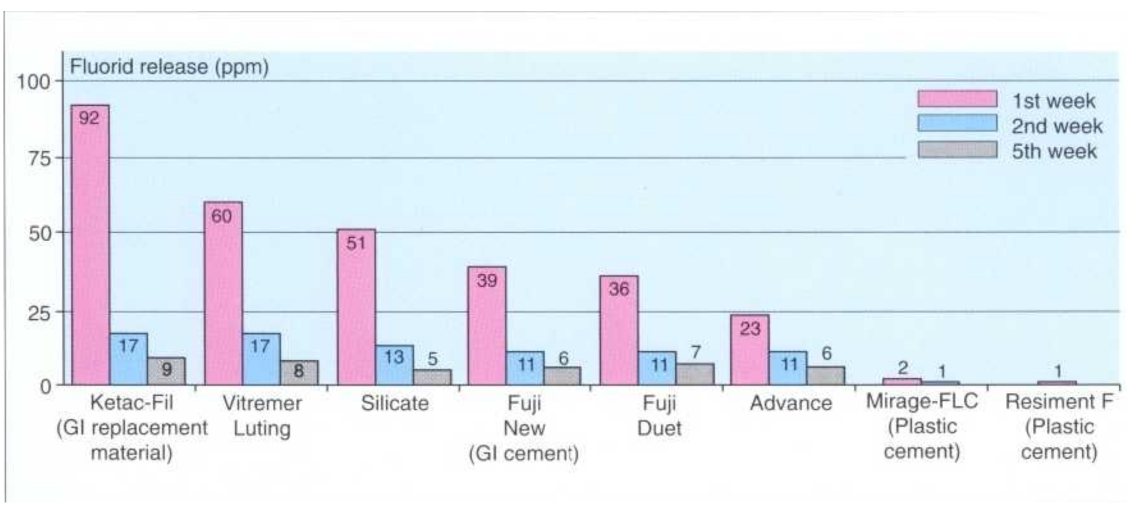
230 Solubility of various cements in lactic acid
The solubility in lactic acid is an important factor when selecting cements to attach restorations. The very frequently used zinc phosphate cement has the highest solubility. This means that in a caries active environment gaps and secondary caries will develop fastest. In contrast, the resin-modified glass ionomer cements are insoluble and the other cements exhibit only a low solubility.
Figs. 229 and 230 modified from CRA Newsletter, August 1995.

A factor that should be taken into account when selecting a suitable cement is the ability to *remove* the restoration. A restoration is not intended to last for ever. On average, metal-ceramic restorations are often renewed after 10-15 years. Restorations that are perfectly cemented with resin cements are very difficult to remove. Therefore, especially in the case of Panavia 21, they should be limited to all-ceramics, composites, or metal restorations that will never be removed, or to restorations that have a high risk of coming loose (partial crowns that are difficult to prepare with little retention on third molars and pin constructions).

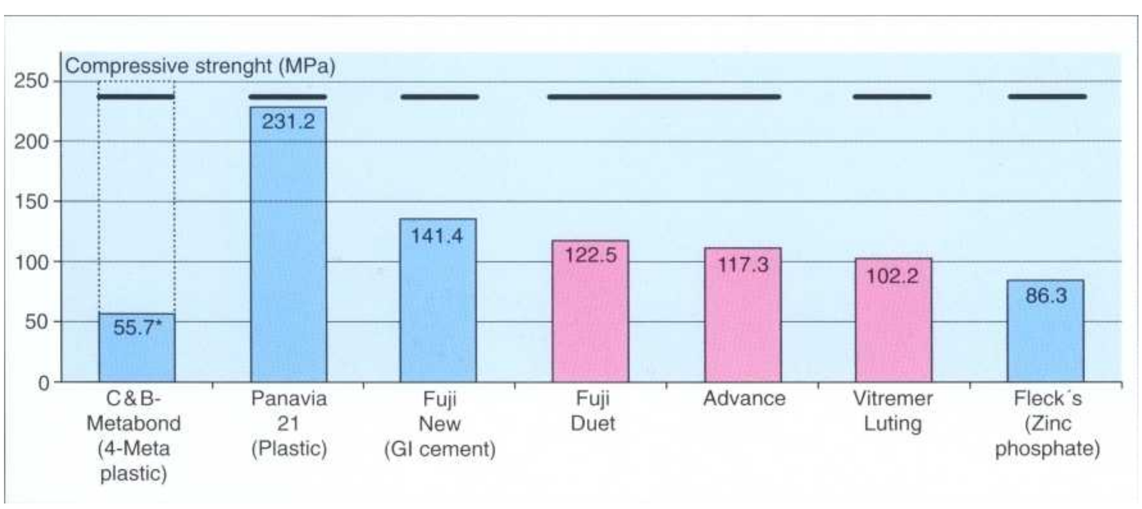
The new resin-reinforced glass ionomer cements are superior in comparison to the resin cements. Their compressive and tensile strength, their ability to bond to tooth and metallic structures, their cariostatic qualities and handling are unbeatable; in addition they have the great advantage that this restoration can also be removed again.

At the University of Zurich, Switzerland, 40% of the Dicor crowns in the molar and premolar regions and 20% of the Dicor crowns in the front tooth area fractured within six years.

Only after it had been recognized that all these restorations must be bonded could the failure rate be reduced to 2.9%. The question remains of why all restorations are not bonded-metal restorations with resin-reinforced glass ionomer cements, all-ceramics, and composite restorations with resin cements?



231 Fluoride release of different cements
The fluoride release after cementation has a cariostatic effect. However, most cements release fluorides for a short time only. Resin cements hardly release fluorides at all. After five weeks, resin-modified glass ionomer cements and glass ionomer (GI) cements release a similar amount as silicate cements, but initially there are significant differences.



232 Compressive strength of different cements
Compressive and flexure strength are other parameters that should be taken into account when selecting a suitable luting cement. Resin-modified glass ionomer cement has a higher compressive strength than zinc phosphate cement, but is inferior compared to glass ionomers or resin cement.
* C & B-Metabond distorted at a pressure of 55.7 MPa, but did not fracture.
Figs. 231 and 232 modified from CRA Newsletter, August 1995

Resin Cements

Resin cements can be subdivided into the same groups as the restorative composite materials: macrofilled, microfilled, and hybrid. However, different curing mechanisms are required for the different cements. In some cases, the restoration and the composite cement layer are too deep to be completely light-cured. Incomplete curing has negative effects on the longevity of a restoration.

In order to deal with this problem, other curing mechanisms are used with these cements besides light curing. The type of composite cement-curing mechanism also influences how the inlay is placed as well as how the margins are treated. Therefore, to justify the different clinical conditions, chemical-curing, light-curing, and dual-curing cements are available today.

Chemically Cured Systems

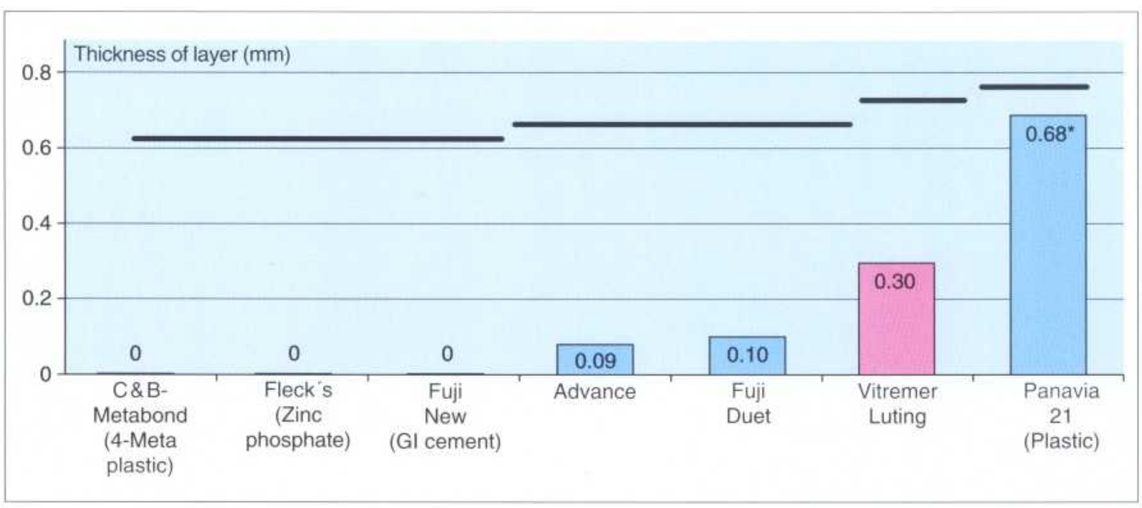
Chemically cured cements are used if the operator has sufficient time to mix the composite, apply the resin, insert the inlay, and remove the excess. Since most of the chemically cured composite cements have a setting time of 150-200 seconds, it is necessary to work fast. The advantage of these materials is that they set in regions which the light can hardly reach. If Maryland bridges are cemented, for example, chemically cured cements are the only possible solution.

Light-Cured Systems

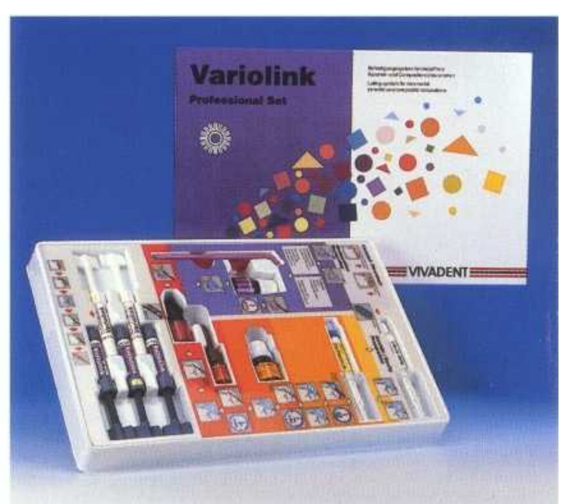
Light-cured cements are suitable if the light can penetrate through the restoration sufficiently to induce polymerization of the resin. The biggest advantage with these materials is the time it takes to work with them, which allows excess material to be removed before curing, thus considerably shortening the time taken for removing the excess and finishing the margins after setting.

The biggest disadvantage is that restorations with low transparency do not allow sufficient light to pass through, resulting in an incomplete cure, which in turn has a significant negative impact on the bonding ability.

This is a problem, since posterior inlays are seldom 3 to 4 mm thick and the maximal thickness for sufficient light transmission with a typical light source is around 2 mm. A solution to these problems is to extend the curing time recommended by the manufacturer.



233 Thickness of the oxygen inhibited layer (at 23°C)
All resin-containing cements have an oxygen-inhibited layer on the surface. The thickness of the layer must be taken into consideration when applying a die-spacer. The technician must know which cement the dentist is working with and how thick the die-spacer is.
(* Panavia 21 was used in this test without Oxygard, which is recommended by the manufacturer.)
(Modified from CRA Newsletter, August 1995.)



234 Examples of bonding cements
Left: Resin-modified glass ionomer cements are well suited for cementing metal-ceramic restorations and gold castings.

Right: Luting system for ceramics and composite restorations.

Special attention should be paid to the curing of the cervical margins. Because of their location, these margins are difficult to cure using light. A possibility for achieving a certain degree of curing is to use light-scattering plastic wedges.

Dual-Curing Systems

An important factor regarding light curing is the color of the composite inlay and the composite cement, since the color influences both the permeability of the light as well as its light scattering. The dual-cured composite cements were developed in order to deal with this problem in regions with questionable light intensity.

The light-induced polymerization of these cements starts at the margins and where the restoration is sufficiently thin to allow light to pass. In simplified terms, the photoreactive components of the resin start the bonding process. This is not quite correct, however, because the chemical reaction already starts the moment the two pastes are mixed, only that this reaction is just less obvious than is the case with the conventional chemically cured composites. That means that the chemical reaction with dual-cured composites proceeds slower than with chemically cured cements. By light activation, a large number of free radicals are added by the chemically cured accelerator initiator system, which strongly accelerates the entire reaction. Therefore, after the initial reaction has started, the curing also continues in areas that cannot be reached by light.

Since both the thickness and the opacity of the inlay influence the translucency, dual-cured composites are recommended for inlays which are more than 2 mm thick. Although the curing time of these cements is longer than it is in the case of chemical curing, compared to light-cured composites, the processing time and color stability can be judged as being less advantageous.

Characteristics	Resin Cements	Zinc Oxide Eugenol Cements (EBA)	Zinc Phosphate Cements	Resin-Modified Glass Ionomer Cements	Glass Ionomer Cements	Poly-carboxylate Cements
Examples of frequently-used brands	• C & B-Metabond (Parkell) • Bisco C & B Luting Composite (Bisco) • Enforce (Dentsply/Caulk) • Panavia 21 (J. Morita)	• Opotow Alumina EBA (Teledyne Water Pik) • Super EBA (Bosworth)	Fleck's (Keystone)	• Advance (Dentsply/Caulk) • Fuji Duet (GC) • Vitremer Luting (3M)	• Fuji 1 (GC) • Glass ionomer Type I (Shofu) • Ketac-Cem (ESPE-Premier)	• Durelon (ESPE-Premier) • Lic-Carbo (GC)
Cost	High	Low	Low	Medium	Low	Low
Application	Medium to difficult	Medium	Medium	Simple to medium	Medium	Simple
Bond strength to tooth	High, if bonding succeeds	None	None	Medium (high, if bonding succeeds)	Low	Low
Resistance against tensile forces	High	Medium	Low	Low to medium	Low	Low to medium
Postoperative sensitivity	Usually slight, but can be strong if bonding fails	None	Usually slight, sometimes strong	None	Usually slight, sometimes strong	None
Hardness	High	Low	Low	Medium to high	Medium	Low
Difficulties in removing the crown later	Significant	Minor	Minor	Minor to medium	Minor	Minor
Popularity	Low	Very Low	Medium	Increasing	High	Medium

235 Criteria for selecting bonding cements
(Modified from CRA Newsletter, August 1995.)

Bonding Composite Inlays Using Resin Cements

The composite inlay bond is still regarded as the weak link in the composite inlay system, even when it comes to repairing old composite restorations. A cured and only ground resin surface offers few possibilities for chemical bond formation. This is also the case with the surface of the cured inlay.
Nevertheless, the bond strength between composite and composite cement systems is no problem as far as most systems are concerned. In contrast, the connection between cement and the dentin surface is of primary concern (Scott et al. 1992).

The various curing levels of different composite inlays influence the mechanical properties and the quality of the inlay-cement bond. Inlays that have been cured by means of heat and pressure, for example, are often overcured, which means that a new chemical connection with the resin cement is impeded.

Therefore, the polymerized surface of the resin must be activated so that it either joins with the new resin chemically or micromechanically, or even better through both chemical and micromechanical bonding.

Bonding Ceramic Inlays Using Resin Cements

Ceramic inlays must be bonded with resin cements. Clinical studies have shown unequivocally that the success rate is substantially improved if resin cements are used. Traditional cements, including the glass ionomer cements, are inappropriate for such bonding. The reason for this lies in the solid mechanical connection that bonds the acid etched and silane-treated ceramic surface to the resin cement.

However, in order to avoid problems, the dentist should be aware of the differences between the various ceramic materials. Most ceramics can be easily etched with hydrofluoric acid, while bonding to glass infiltrated alumina ceramics (In-Ceram) is not suitable with the conventional composite cements developed for feldspar ceramics. The reason is that hydrofluoric acid does not form a sufficient etch pattern on alumina-based ceramics. In a study, alternative methods for achieving bonding to In-Ceramic ceramics were examined (Kern and Thompson 1995). The tensile strengths of six bonding systems were determined after 150 days of storage in isotonic artificial saliva and exposure to thermal cycling. Sandblasting only, or the additional use of silane, could not permanently retain a connection between a conventional BisGMA composite resin and the In-Ceram ceramic. A stable bond could be achieved with a combination of either silane treatment and a conventional BisGMA composite or from sandblasting and a composite modified with a phosphate-based monomer. These two chemical and mechanical bonding methods seem to be the most suitable for clinical bonding of In-Ceram ceramics. A delayed reduction in the bonding could be observed with a combination treatment consisting of heat silane coating and conventional BisGMA composite. After 30 days, the reduction was not yet visible, but after 150 days it was noticeable. From these findings one can infer that a longer storage time is necessary to evaluate the durability of chemically mediated bonds exposed to moist surroundings.

Based on current knowledge, it seems as if correctly executed bonding between an etched ceramic surface and a composite results in a dependable connection. If ceramic brackets are used in orthodontics, for example, the main problem is that the strong bond makes it more difficult to remove the bracket.

Bonding Metal Surfaces Using Composite Cements

The bonding of metal restorations with resin cements has started to become generally accepted. For this a micromechanical retention is necessary between enamel and the metal surface.

It is only recently that resins have been developed that form an adhesive bond to certain metals, including stainless steel. In a study, such a resin (Panavia 21 EX) was compared with a more conventional orthodontic resin (Ireland and Sheriff 1994). Two different test methods were used after the samples had been exposed to different shearing tests. The results showed that Panavia 21 EX had a stronger bond than more conventional resin cement. Of the two tested retention systems, sandblasted frameworks yielded better bonding than etched frameworks.

Adhesion to certain alloys can be improved by treating the alloy surface with gallium (Gn) or tin (Sn) (Ohno 1990). Gallium and tin are present in a Ga-Sn solution (Adlloy) and these elements are deposited on the surface of the metal. However, this method is only useful with pure dental alloys.

Direct Anterior Restorations-Aesthetics and Function

Since their introduction (Bowen 1956), composite restorations have become increasingly more important in the treatment of anterior and posterior teeth. Skillfully placed composite restorations can be superior to indirect restorations as far as their natural appearance is concerned (Buda 1994) and at the same time they can withstand the occlusal forces. The adhesion of the resin to both dentin and enamel makes it possible not only to restore teeth but also to fundamentally change them. Only little tooth substance needs to be removed for composite restorations. The margins can be gap-free, preventing bacterial penetration. Composites belong to the most important materials in cosmetic dentistry (Christensen 1995b). They can restore fractured or decayed anterior teeth cosmetically, they can close diastemas, and they can alter the color of the teeth. A person's whole appearance can be improved through a combination of bleaching, ceramic veneers, and composite restorations.

236 **Possibilities and limitations of direct composite restorations in the anterior region**
Left: Lateral incisor, a pegged tooth that was moved into the middle position between a central incisor and a cuspid by means of orthodontics.

Right. The central incisor, the lateral incisor, and the cuspid are rebuilt with direct composite bonding. An aesthetic result is achieved.

Indications for Composite Restorations

Patient's Age

To restrict the loss of tooth substance, one should prepare as conservatively as possible. The younger the patient is, the more important it is to minimize the loss of enamel and dentin. Direct composite restorations are the most conservative material available in present-day aesthetic dentistry. The age of the patient should not affect the use of composites.

Selecting Which Teeth to Restore

Small defects can be treated with small fillings, particularly if the tooth is intact and is aesthetically acceptable. As far as larger defects or poor aesthetics of the remaining tooth substance are concerned, an indirect ceramic restoration or an all-ceramic crown should be considered.

Goals

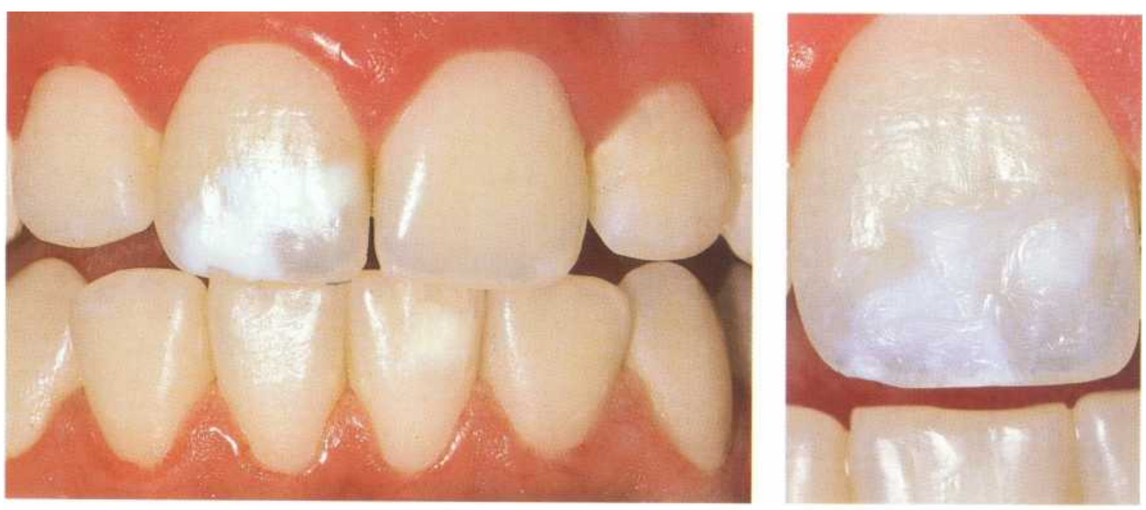
The opinions of both patient and dentist should be considered when drawing up the treatment plan. Have both decided on an aesthetic goal, or is the objective only to restore the defect? The higher the aesthetic goal, the more extensive the restorations may have to be.

Occlusal Forces

Composites do not resist high occlusal forces. If the natural tooth substance has been destroyed due to occlusal force, one should use conventional restorations, such as ceramics or metal. Cohesive and adhesive fractures can appear with direct composites. The risk of fracture can be reduced if the enamel area is increased in an attempt to increase the bonding area with the composite. The most stable resin should be used.

Material

The dentist usually chooses the material that fulfills the aesthetic needs, has sufficient occlusal stability, and is easy to process. Hybrid composites are most frequently used because of their strength and surface smoothness. They are available in different shades, opacities, and qualities-from very rigid to fluid. Microfilled composites are chosen primarily when one wants to simulate the appearance of enamel.



237 Selecting composites
The age of the patient plays a role when selecting a suitable restorative material. Since all restorations must be renewed after a certain time, younger patients should be treated using a tooth conservative restoration form. This can be a direct composite restoration. Direct composite bonding covers up this front tooth of a 17-year-old patient with white color inclusions.

Right: Result three years after direct composite bonding.

238 Composite restorations-a tooth conservative method
Small defects should be treated very conservatively, especially if the surrounding tooth structure is caries inactive and aesthetically acceptable. Direct composite restorations are ideal for these conditions.

Bonding

Many studies show that bonding systems bond to enamel and dentin with sufficient strength. By bonding, cohesive fractures are avoided in the tooth or in the composite restoration. Bonding to enamel is reliable and durable.

Oral Hygiene

All margins must be plaque-free. In vitro tests show a decrease in marginal leaching when the composite is bonded to dentin. Dentin margins need to be observed more closely due to the risk of plaque accumulation and caries. Instructions regarding oral hygiene are crucial, particularly when composites are used.

The Ability of the Dentist

Aesthetic or cosmetic dental treatments are the plastic surgery of dentistry. The dentist's understanding of shape, proportion, color, material, and the psychological effect of aesthetic dentistry are essential for diagnosis and treatment. The dentist must model the appearance of the teeth so that it corresponds to the physical and psychological requirements of the patient.

Economy

Direct composites are more advantageous than indirect fillings. Patients often choose composites to avoid high expenses, even if they are informed about the inferior durability in comparison to other restoration types.

Choosing a Composite

Hybrid composites are chosen because of their high stability and hardness. Microfilled composites are easier to polish. However, they are more susceptible to fractures and the so-called sandwich technique is often used to cover the hybrid composite. By doing so, the stability of the hybrid composite can be combined with the ename appearance of the surface of the microfilled composite. Microfilled composites are also used for fillings with little stress and on facial surfaces where an enamel look and high polish are important. The differences lie in the shades, the opacity, and the processing. The dentist should choose the composite that gives the best aesthetics and fulfills the functional requirements.

239 Limitation of composite restorations
Loss of the vertical dimension through parafunction. With bruxism and with patients who regularly use high occlusal forces, the use of composites on occlusal-incisal regions is contraindicated.

Left: Without the support of a stable reconstruction (gold or ceramics) in the molar region, these anterior teeth cannot be rebuilt.

240 Limitation of composite restorations
All composite restorations must be renewed sooner or later. The patient must know that the lifespan of composite restorations depends on many factors that can impair the appearance and the function: composition of the saliva, bacterial activity in the oral cavity, nutritional habits, occlusal forces, type of tooth cleaning, etc.

Clinical Application of Composites

Placing the Composite

1. Determining Color

The color of the tooth must be decided before it is isolated, while it is still moistened with saliva. Commercial shade guides do not usually show the real tone. The use of specially prepared shade guides, made from the composite used, makes it possible to improve color selection. Teeth appear polychromatic through the deeper layers of dentin covered with translucent enamel. The color at the gingival margin can be distinguished from areas of the middle of the tooth as well as from the proximal and incisal regions.

Selecting and placing the individual color layers and changing opacity requires careful analysis and great skill (Buda 1994). Composites transfer color and light unevenly on enamel and dentin. The irregularities of the natural tooth should be reproduced as close as possible and to achieve this the dentist must place layers of different color tones. Hybrid composites appear like dentin, while microfilled composites imitate the enamel better.

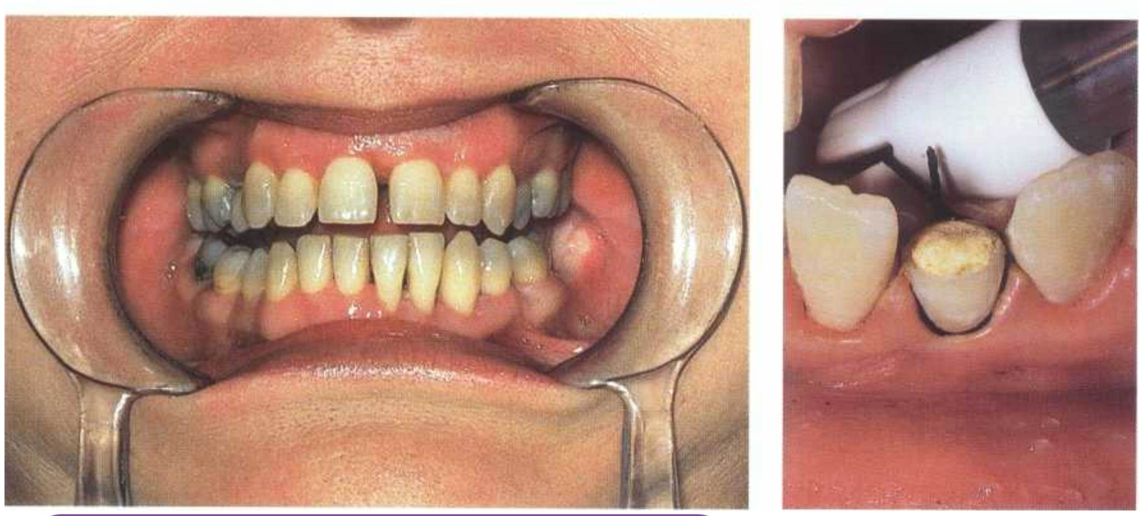
Several layers of composites or color tones can be placed without losing adhesion or stability, as long as the surface of the polymerizing composite has a moist oxygen-inhibited layer.

2. Field Isolation

Saliva and blood components decrease the bonding ability to the tooth. A rubber dam is the most effective method to avoid contamination with saliva. Drawbacks of this method can be an inferior view and decreased access (Knight et al. 1993). Alternative isolation methods include cheek retractor, retraction cords, and suction, methods that are often sufficiently effective if they are used properly. However, each of these methods must be regarded as compromises in comparison with the absolutely dry field that can be achieved with a rubber dam. The dentist must always guarantee that during all procedures the tooth and the partly finished restoration are free from contaminating saliva.

241 Isolation using a rubber dam
A rubber dam is, and remains, the best and most effective isolation technique and should be used with composite restorations as a matter of course. Care must be taken that the teeth do not dehydrate during the bonding procedure.

Right: With molar teeth, isolation with a rubber dam is especially important before bonding. The teeth should be kept moist.



242 Isolation with other aids
If isolation with a rubber dam is not possible one can use cotton rolls, powerful saliva ejectors, and retraction cords. Also a cheek retractor that is normally used for dental photography is sometimes very helpful.

Right: Here, a lower incisor was isolated using a retraction cord.

3. Preparation

- Only as much tooth substance should be removed as is needed to create a sufficient bonding surface and for a sufficiently strong restoration.

- Carious enamel or dentin are removed with conventional hand or rotating instruments.

- Removal of enamel, bevels, and retentions are prepared using water-cooling, diamonds and turbines. Higher bond stability of the composite to enamel is obtained if the enamel surface is cut with diamonds. The enamel margins are beveled broadly in order to achieve a good optical transition of natural enamel to the composite. Diamonds can also be used for further dentin preparation.

- Small pear-shaped diamonds are used for preparing the cavity, while pointed, tapered diamonds are used to remove superficial enamel or prepare the margins. Small pointed diamonds are used for small bevels and retention grooves.

4. Adhesion to Enamel and Dentin

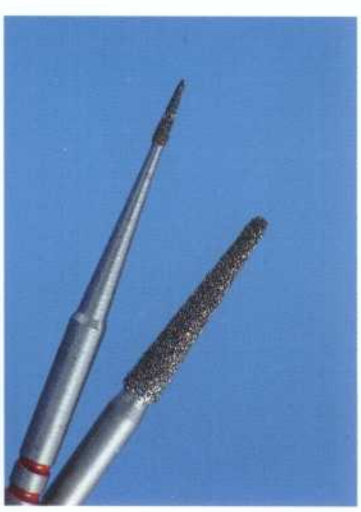
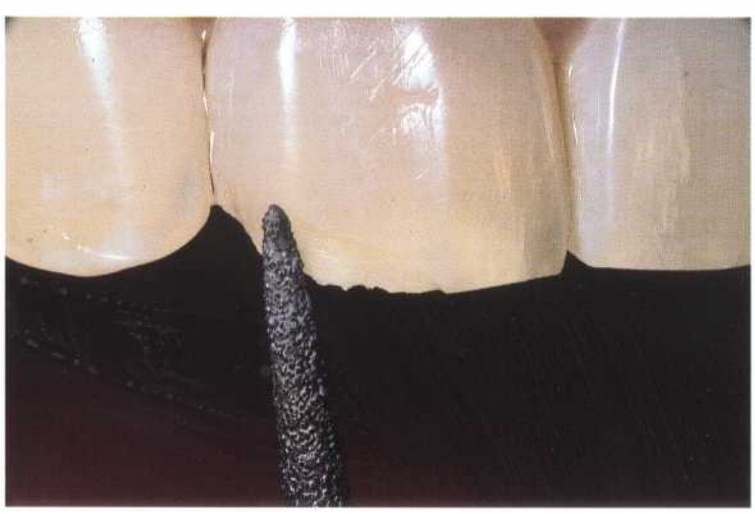
As was shown in the chapter on bonding, enamel and dentin are conditioned with phosphoric acid. Both tooth structures are etched and then rinsed with water. The primer and the adhesive are placed on enamel and dentin according to manufacturer's instructions. The correct procedure is decisive for the duality of the margins and the bonding of the restoration.

Fifth-generation dentin adhesives are suitable for direct composite restorations. The dentist and the assistant should consider the following:

The teeth must be kept moist. Directly before placing the adhesive, open the bottle (the solvent acetone evaporates immediately), place the adhesive on an applicator, close the bottle immediately, briefly dry the tooth, and place the adhesive, wait for 20 seconds (the adhesive must penetrate into all structures and the solvent must evaporate), blow lightly, and polymerize. Always place a second layer.


243 **Preparation**
Caries is removed with conventional instruments. The best to be used are water-cooled, high torching diamonds, which are used to modify the enamel and to create undercuts and retentions.

Left. Set of coarse diamonds suitable for the preparation of direct composite veneers.

244 **Preparing a bevel**
Broad bevels should be placed at preparation margins and transitions where the composite meets the enamel.

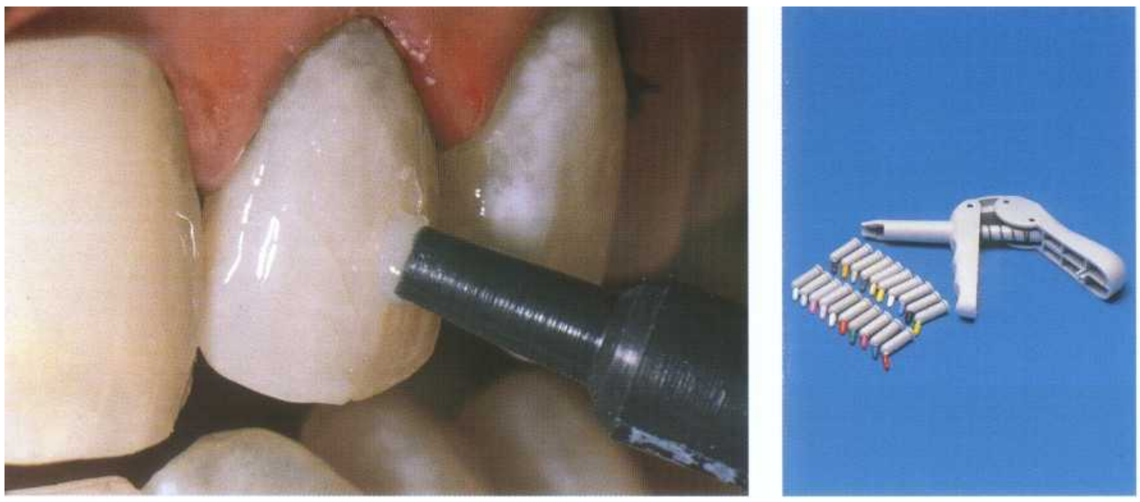
Left. Diamonds used for preparation of a bevel.

5. Placing the Restoration

Principles of proper composite placement:

- Select the composite in accordance with the required stability, handling, and aesthetics.
- Select the color tone to match the natural tooth color.
- Place the composite without incorporating porosities.
- Place composite in layers in order to imitate the natural tooth structure. Cure each layer. No layer should be thicker than 2 mm.
- Place the material flush to the tooth surface to minimize grinding.
- Grind the surface to the shape of the tooth.

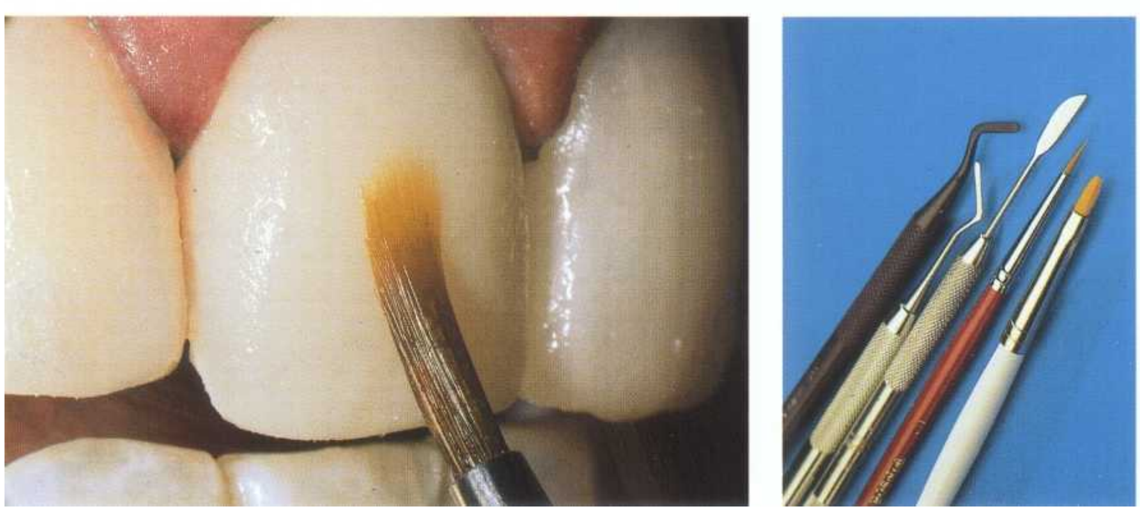
Most composites are offered in a Centrix carpule as a single portion. The composite is contoured with the help of a transparent plastic matrix or molded by the dentist with hand-held instruments. Each layer should be cured for 40 seconds. New composite layers can be added as long as the "moist" oxygen-inhibited layer has not been destroyed. If an enamel-like surface is desired, a microfilled composite should be used. This can be placed with a brush that is moistened with some bonding resin (Pagniano and Johnston 1993).



245 **Placing composites**
Direct application with a carpule system.

Right: Most composites are today delivered in carpules (Centrix System) and can thus be more simply applied.

246 **Contouring a composite surface with a particular composite spatula**
Right: The composite surface is perfectly contoured using an extremely thin composite spatulum that is slightly flexible.



247 **Surface work**
The surface of microfilled composites can be processed best with fine brushes before polymerization.

Right: Various instruments to place and shape direct composite restorations.

6. Finishing the Surface

Principles of surface finishing:

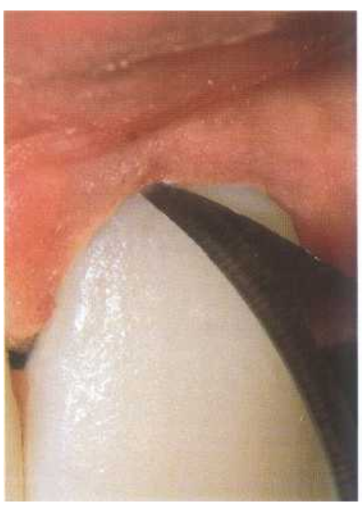
-Start with the margins.
-Adjust occlusal contacts.
-Do not use high-speed cutting.
-Correct contours in accordance with the tooth structure.
-Use rubber polishers.
-A shiny surface is achieved with superfine polishing disks.
-Seal the composite surface.

If the filling is given its correct contours in accordance with the tooth anatomy during placement, a minimum of final work at the margins and grinding is needed before the polishing step. Overfilled restorations must be given a proper contour. Disposable scalpels and abrasives are suitable for this purpose. High-speed cutting can cause microcracks and, as a consequence, pieces can possibly chip off the surface. A good surface finish can be obtained using small abrasive disks, rubber cups, disks, or spheres without sacrificing the morphology of the surface. Use of a direct airflow during the grinding process prevents overheating of the restoration. After grinding and polishing, the composite restoration should possess not only a complete anatomy but also offer maximum aesthetics and match the natural tooth optimally.

7. Sealing off the Surface

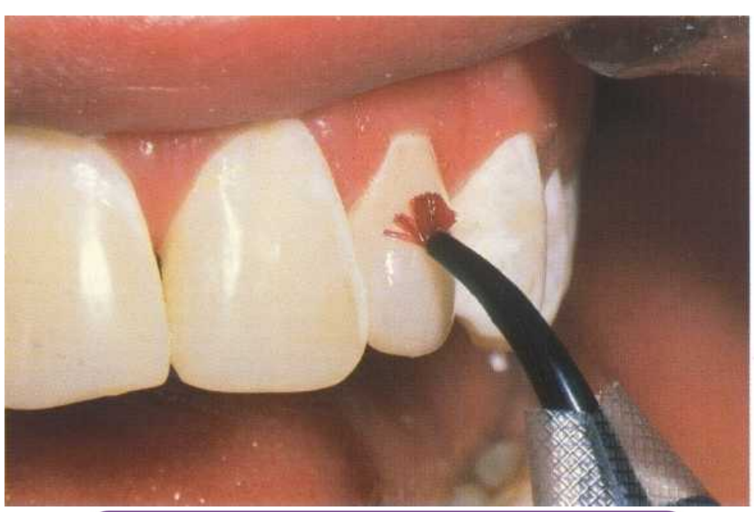
All direct composite restorations have microscopic defects and porosities. Penetrating surface sealants (like the bonding agents) that are actually intended to seal the marginal gaps can also seal surface defects (Dickinson and Leinfelder 1993; Dunn et al. 1996).

After polishing is completed, the entire surface of the filling and the margins are etched, washed, and dried. Then a thin film of composite surface sealant is placed and air dried, the contact points are cleaned with dental floss, and the resin is cured. Remains of the sealer at the gingiva margin or in the proximal spaces must be removed.



248 **Finishing and grinding**
Various disks, finishing strips, and rubber caps are available for grinding and finishing of the composite restoration (see section on Bonding, Finishing Composites).

Left: Scalpel blades can be an enormous help for trimming the margins.



249 **Sealing the composite surface**
Some manufacturers offer composite sealers that seal microscopic defects which arise during grinding and polishing.

Class V Restorations

Types of Class V Defects

Abfraction

Facial-lingual flexure of the tooth during chewing can lead to class V defects in the cervical region. A flexible material is needed to restore these. Microfilled composites are the materials of choice.

Abrasion

Cervical defects are caused by an incorrect toothbrushing technique or too frequent toothbrushing. Less abrasive materials should be used. Microfilled composites, hybrid composites, or a sandwich technique using both materials is recommended.

Caries with Loss of Enamel

The reason for this is poor oral hygiene. The restoration is simple. It is best to use only hybrid composites.

Caries with Dentin Involvement

The cause is poor oral hygiene combined with a gingival recession. The restoration is simple. The material used should also release fluoride. Here, glass ionomer cements, resin-modified glass ionomers, or compomers are suitable.

Crown Repair

Caries is at the gingival margin of the crown. Curing should be possible under the metal margin and fluoride-releasing ability is recommended. Following materials are suitable: Glass ionomer cements or dual curing resin-modified glass ionomers.

Crown Repair (Good Aesthetics Required)

The cause is caries at the gingival margin and/or gingival recession. Microfilled or hybrid composites (ceramic margin should be exposed and silane-treated) are the materials of choice here.

Acid Erosions and Solubility

Vomiting, frequent consumption of candy, or continuous consumption of acid-containing foods or beverages lead to these lesions. A fluoride-releasing material with low solubility should be used. Here, it is best to use compomer or resin-modified glass ionomers.

250 **Class V restorations**
Class V restorations can have different causes: caries, erosion, abrasion, and abfraction. Occlusal interferences can further promote splintering of enamel prisms.

251 **Typical class V carious lesion**
Caries activity, toothbrushing technique, and nutrition should be checked and discussed with this patient.

Procedure

1. Isolate.
2. Remove caries; roughen the uncut dentin.
3. Bevel the enamel margin; place inner retention grooves.
4. Place dentin bonding material.
5. Use suitable restorative material.
6. Place material in layers.
7. Grind and finish with abrasive instruments.
8. Seal.

Class V cervical defects can be caused by caries, erosion, or abfraction. Occlusal interference generally seems to be a cause for class V defects, particularly in combination with abfractions (Galliwn et al. 1994; Tyas 1995). The gingival margin must be well isolated in order to minimize marginal debonding. A 212 rubber dam clasp is suitable for this purpose.

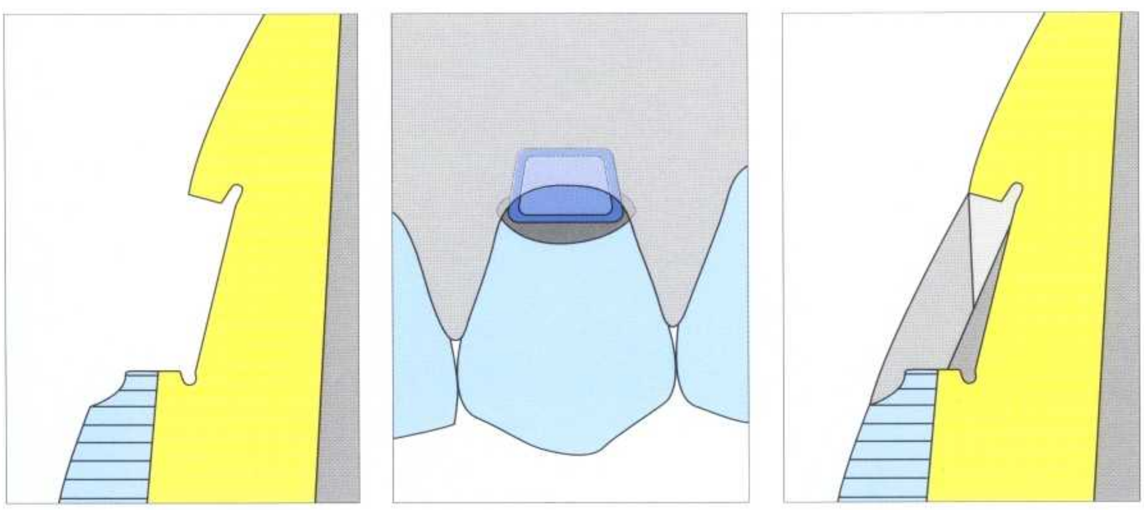
Small pear-shaped and fine spherical diamonds are used for preparing the class V cavity. If the lesion is in the dentin, a conventional class V cavity is cut under water-cooling with pear-shaped diamonds. The enamel margins and retentions are cut with fine spherical diamonds.

There is no reason to strive for a standardized cavity design. The size of the lesions and the retention needed for the restorative material alone decide the shape.

Class V lesions that are surrounded by enamel are only shaped with a diamond. In order to minimize the shrinkage and formation of marginal gaps, a suitable bonding system and a composite with low viscosity (e.g., Degufil Flow) is used and is placed in several steps (Leinfelder 1994).

Shaping the gingival margin of the class V restoration is easiest with surgical scalpels. The contour is shaped with flexible disks. For the surface polish, use suitable abrasive rubber cups or disks.

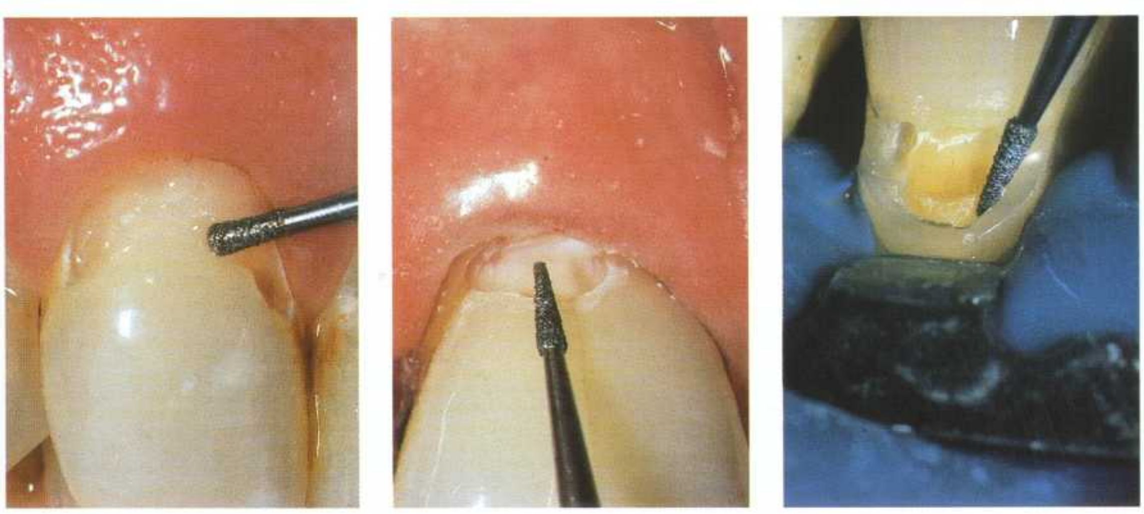
The shaped restoration and their margins are etched, washed, and dried. Then, a surface sealer is placed, air-thinned, and cured with light.



252 Steps to place a class V restoration
Left. Notice that the enamel has received a strong bevel. Resin restorations show the best retention at the enamel margins.

Middle: A conventional class V cavity should (with exploitation of optimal retention) be treated with a composite.

Right. The construction of the composite restoration is best done in two to three layers.



253 Preparing a class V cavity
Left. High-torch and slightly conical diamonds are recommended for preparing the cavity.

Middle: The occlusal bevel is prepared with small flame-shaped, pointed diamonds in order to achieve as large as possible an enamel bonding surface.

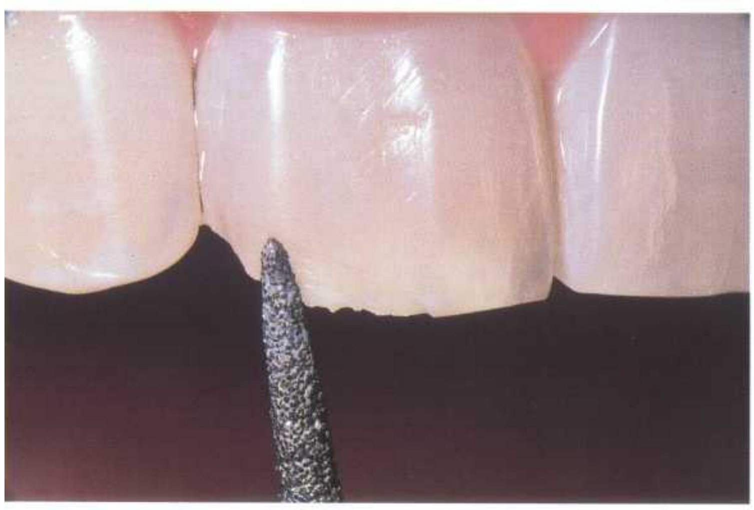
Right: Small retention grooves are also placed with the same diamond.

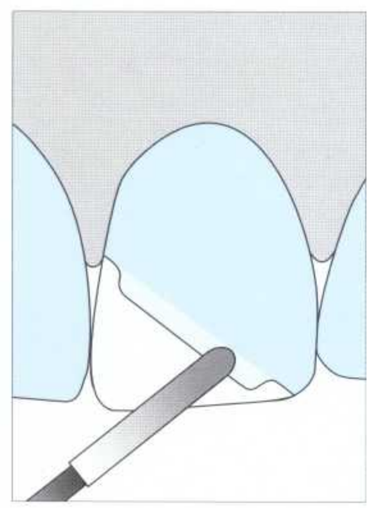
Class IV Restorations

1. Carry out occlusal analysis.
2. Excavate and cut a bevel around the entire defect.
3. Use large enamel surface to improve bonding.
4. Reduce the occlusal surface sufficiently.
5. Use a hybrid composite on the lingual surface and a microfilled composite on the facial surface.
6. Opaqueness and color tone of the composite should match the body of the tooth and the incisal edge.
7. Extend the incisal edge to its proper length.
8. Imitate the form and the surface of the natural tooth.

The class IV restoration is one of the most important aesthetic restorations in the anterior region. The length of the central incisors and the relative length of the adjacent lateral incisors, and the cuspids, determine the aesthetics of a smiling face and have a decisive effect on language function. Long central incisors with an emphasized incisal curve are associated with youthful looks, while straight incisal edges and reduced curvature are related to older patients. Before the change to the incisal edge is made, the function of the front teeth must be checked.

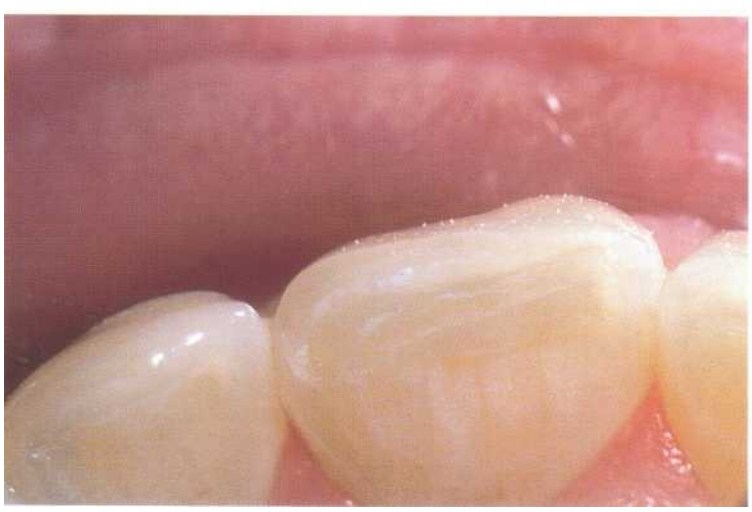
254 Central incisor before composite restoration placement (large class IV)
It is possible, with the use of modern composites, to restore a fractured incisal corner of a defective anterior tooth like the one shown here and to achieve an optimal aesthetic result.





255 Preparation of a class IV restoration
A distinct bevel in the enamel is cut around the entire tooth. This bevel is extremely important for achieving an optimal retention and a good color transition.

Right: Enamel bevel.



256 Occlusal view
The strong enamel bevel should stretch around the entire tooth in order to achieve maximal retention of the composite.

Thin, long and small spherical diamonds are used to prepare a wide bevel. The most effective preparation design is with a curved wide bevel in the enamel surrounding the entire defect (Tan and Tjan 1992).

The filling covers the incisal part of the tooth like a cap and resists fractures or loss. To improve the mechanical retention of the filling, grooves are placed in the dentin. The larger the surrounding enamel part, the better the adhesion of the filling to the tooth will be. In order to reduce the visibility of the facial margin, prepare an arched edge rather than a straight one. This technique is more effective if the margin follows the mamelon pattern of the tooth. After preparation, dentin and enamel are treated with a bonding system, which is then cured. Matching color tones in opaque and translucent composites reinforce the natural appearance of a restoration. Layers of hybrid composite are placed on the lingual side and microfilled composite on the facial surface to meet the functional and aesthetic prerequisites.

257 Reconstructed composite
In order to achieve optimal physical and aesthetic qualities, it is recommended that a small particle hybrid composite is used on the lingual surface of the corner construction and that the facial surface is covered with a microfilled composite.

258 Completed and trimmed reconstruction
Finished with disks and polishing paste.

Left. **Incisal view of the completed filling.**

259 The accomplished aesthetic effect

Incisal Elongation

The analysis of the incisal edge line is essential before a planned elongation of the front teeth is carried out. A sufficient overjet, protected by the cuspids from lateral movements of the lower jaw, and a sufficiently large surface area for enamel etching are decisive for the construction of an incisal edge. The unprepared incisor can be elongated before treatment starts by rebuilding the edge with wax or composite in order to check both function and aesthetics.

Using a pointed diamond, the teeth are prepared with a bevel on all four sides surrounding the incisal edge. Fractures of the restoration surrounding the incisal edge must be prevented with sufficient retention for the composite. The lingual filling margin should be placed so that the occlusal contact either hits the enamel or if possible at a composite region which is as thick as possible, but it should under no circumstances be at the restoration margin. The facial margin should be arched in order to reduce the visibility of the contrast between composite and enamel.

260 **Elongation of short incisal edges**
Function, abrasion, splintering of enamel prisms, aging, and parafunction all lead to a gradual shortening of the front teeth. Many patients would like the original incisal length to be restored.

Right: Incisal view

261 **Close-up of abraded and splintered anterior teeth**
A furrow running around the tooth was prepared.

262 **Bonding**
Left: The enamel is sufficiently etched and rinsed.

Middle: Bonding agent is placed.

Right: Light-curing.

Hybrid composites are used for stability and for dentin replacement, while microfilled composite is used for the facial surface. The correct anatomy is molded whilst the individual layers are placed. Facial and incisal curvatures are decisive for a natural appearance.

The surface is trimmed with high torching instruments. Gingival marginal overhangs are removed with a new No. 12 disposable scalpel. The interproximal surface is shaped with grinding and polishing strips. Flexible disks or rubber cups help to produce a highly polished surface without the anatomical surface shape being lost.

After grinding and polishing are completed, the restoration is etched with phosphoric acid again, washed, and dried. After this has been done, the surface is sealed and the sealer is air-thinned before it is cured. Finally, any excess is removed.

263 Reconstruction of the incisal edge
If possible, a small particle/hybrid composite should be used on the lingual side here too and the facial surface should be covered with a microfilled composite.

Left: **Incisal view.**

264 Shaping the restoration
The coarse shaping of the placed composite is shown here.

Left: **Incisal view of the finished restoration.**

265 Aesthetic result after two years

Diastema Closure

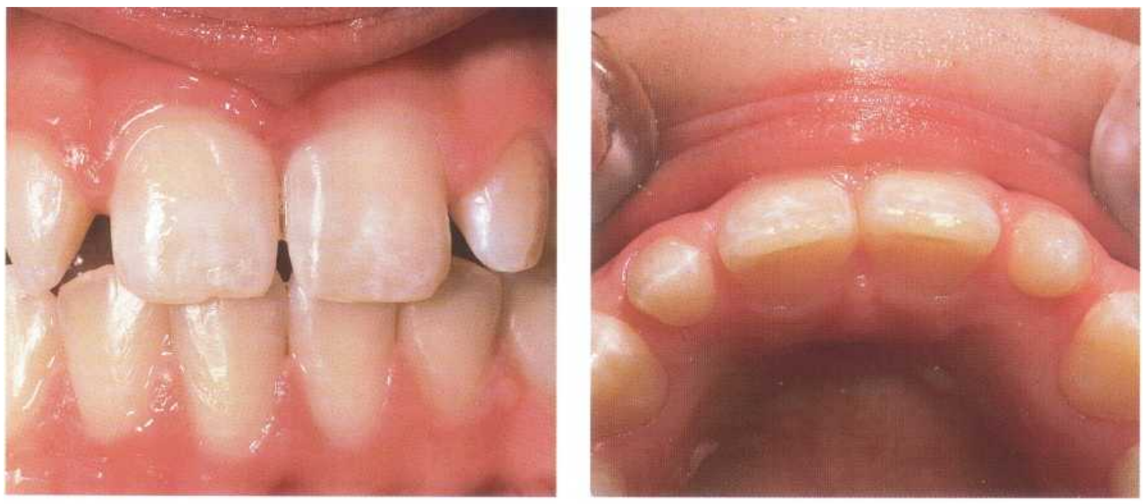
1. Analyse the smile, tooth size, and proportions. Diagnose of the cause.
2. Analyse the course of the gingiva and papilla.
3. Minimally prepare, lightly roughen the enamel.
4. Layer the composite to produce right color, tone and translucency.
5. Anatomy, line angles, curvature and contact regions.
6. Surface morphology and structure.
7. Seal composite surface.

Diastemas disturb the symmetry of a patient's smile. They are therefore less acceptable than incorrect tooth proportions. Here the dentist can change the shape of the teeth and reestablish the proportions of the smile. If the interproximal spacing is large, it may be that the papilla does not follow the gingival course and after treatment a big black triangle is visible. This should be discussed with the patient before treatment starts. Diastemas can also be closed orthodontically.

266 **Bilateral diastemas between first and second anterior teeth**
Diastemas can be closed very well with composite additions.

Left: The initial situation shows a pegged tooth (12) and a lateral incisor which is too small (22).

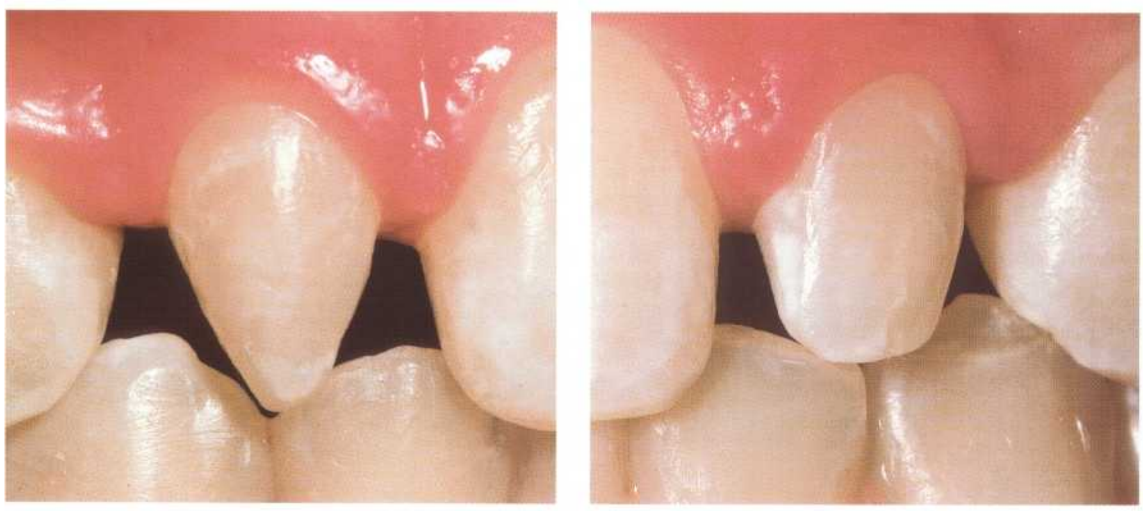
Right. Incisal view.



267 **Initial situation**
The proximal areas of the teeth have been roughened with a diamond.

Left. Pegged tooth (12).

Right: Lateral incisor which is small too (22).



268 **Preparation**
Left: Phosphoric acid is placed on the prepared enamel surface and rinsed off.

Right. The typical frosty-looking enamel surface after drying.

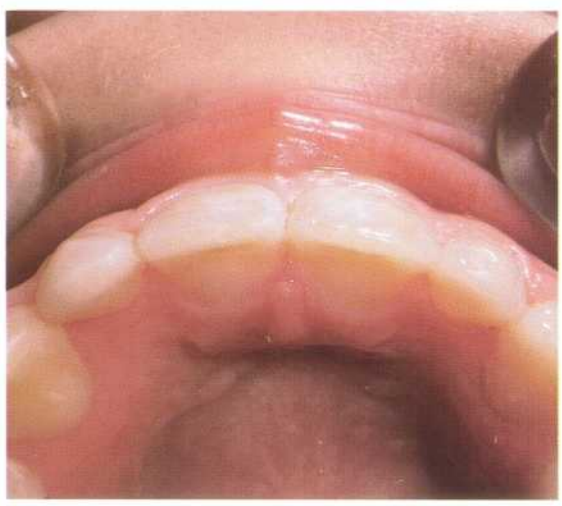
This is frequently associated with recurrence. Many patients are afraid of long orthodontic treatment with concomitant expenses. Closing of a diastema with a composite is a tooth-saving, effective treatment.

Procedure

1. The proximal surfaces that form the diastema are lightly ground with a rough diamond (the enamel should only be roughened).
2. A matching transparent crown-former is cut and prepared.
3. The roughened enamel areas are etched for 30 seconds with 30-35% phosphoric acid, then rinsed and dried.
4. A thin adhesive layer is placed and polymerized.
5. The prepared matrix is filled with composite, placed and wedged, whereupon it is cured with an extra-powerful polymerization lamp for one minute from the labial and the lingual surfaces.
6. If necessary, cut away some of the composite and add layers of different colors.
7. Grind and finish as with a class IV restoration.


269 Bonding and reconstructing the tooth
Left: **The bonding resin is placed and the polymerization initiated.**

Right: **After placing the bonding agent and polymerizing, a transparent matrix band is positioned, the composite placed and polymerized.**

270 Completing the diastema treatment
Left: **The contour of the lateral incisor is shaped with composite.**

Right: **The central incisor and the canine are also slightly widened.**

271 Final result two years after treatment

Direct Composite Veneers

Direct composite veneers are particularly indicated in teenagers exhibiting changes in tooth color, hyperplasia, and strong labial erosions. *Directly produced veneers* have important advantages for adults too, as only one treatment session is necessary and no laboratory expenses are added. The technique can be combined with a bleaching treatment. However, one should wait approximately two weeks after bleaching before the veneers are produced, since bleaching dramatically reduces the bond strength values for a few days.

An alternative is to use *indirectly manufactured* composite veneers that are placed during the same session. In this case one proceeds in the same way as with the immediate inlay. After an impression has been made with silicone or poured with a quick-setting plaster (e.g., SnapStone, Whipmix), the dentist prepares the veneers on this model and cements them during the same session. This process may be simpler for many dentists.

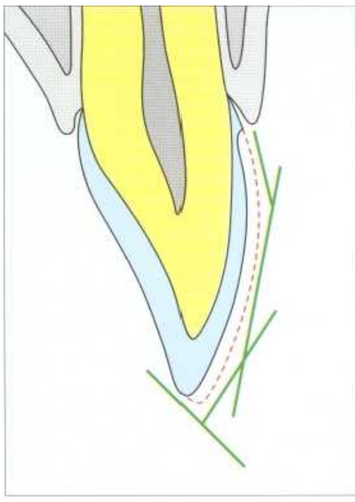
Procedure

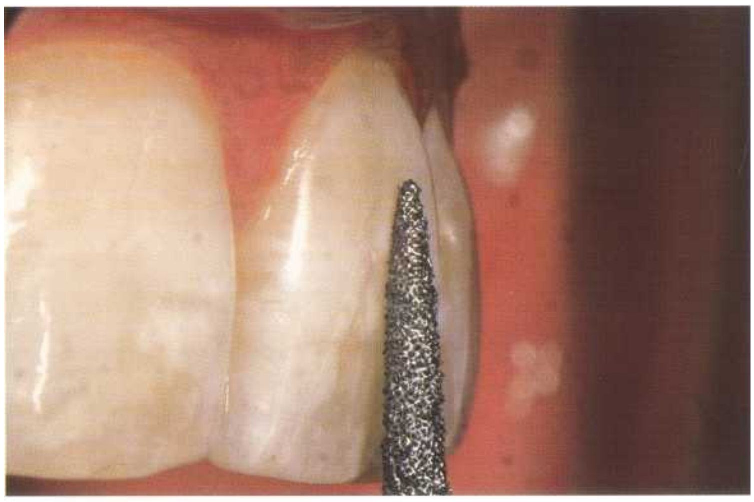
1. Diagnosis, discuss alternative treatments, bleaching, ceramic veneers.
2. Composite versus ceramic veneers.
3. Preparation: Remove part of the enamel in order to produce sufficient space so the veneer will not become overcontoured. Strong changes in tooth color necessitate more space.
4. Select suitable composite, color tone, and translucency.
5. Model the right anatomy, surface morphology, and cure.
6. Grind and shape to a natural anatomy and surface.
7. Seal the composite surface.

Direct composite veneers have physical and aesthetic limitations. They can, however, if they are placed properly, be an excellent aesthetic alternative (Nash 1993). The dentist must be capable of effectively handling all materials that will be used. The diagnosis must consider all traumatic occlusal force that can damage the composite veneer. Also, take into account whether there is a sufficient amount of enamel to produce a solid bond. Composite veneers are normally used when only little enamel is removed or if ceramic veneers are not indicated.

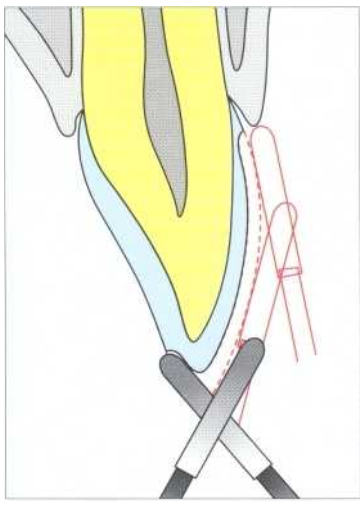
272 **Changes in tooth color** The most reliable result is achieved with ceramic veneers, which produce optimal aesthetics. However, if the goal is to remove as little as possible of the tooth structure, direct composite veneers can be very useful.

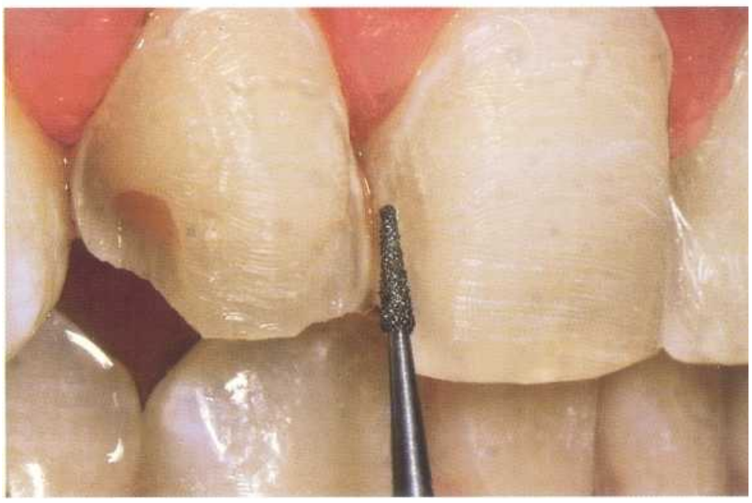
273 **Result after direct veneer placement with microfilled composite**





274 Preparation of direct composite veneer
The preparation for a direct composite veneer is done in the same way as for a ceramic veneer. The only difference is that the composite veneer requires less enamel to be removed. The incisal edge must be capped if crown length and shape are to be increased.
Left. The illustration shows the relationship between initial enamel and remaining enamel and the cutting with the diamond bur.

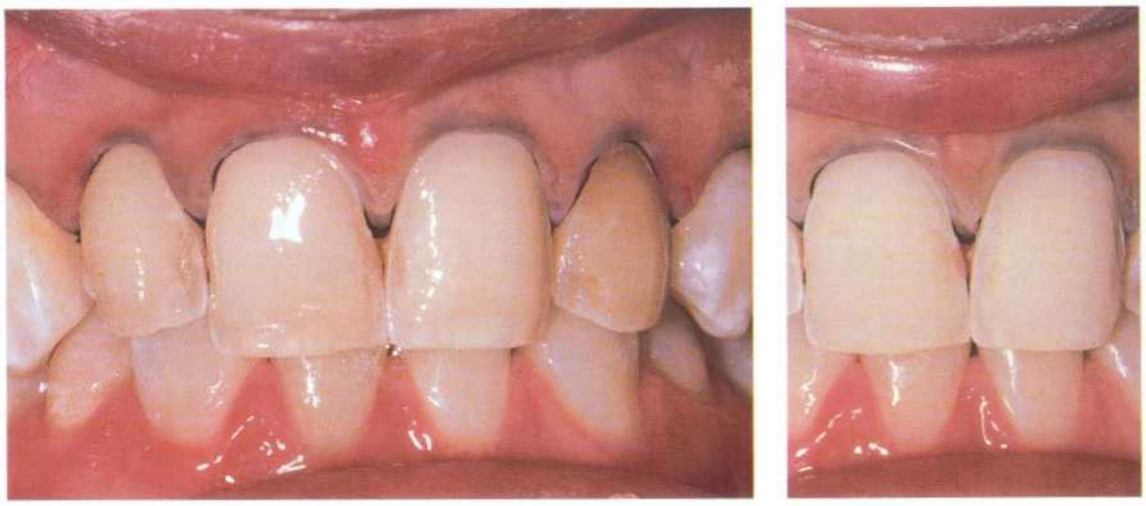




275 Interproximal preparation and removal of old restorations
As is the case when preparing a ceramic veneer, the interproximal and cervical regions are cut to a fine, rounded shoulder, which facilitates the placement of the composite and later shaping. Old composite restorations should be removed during this step and be replaced and supplemented with veneer composite.
Left: The diamond cuts must be parallel to the tooth surface in order to guarantee even enamel removal.

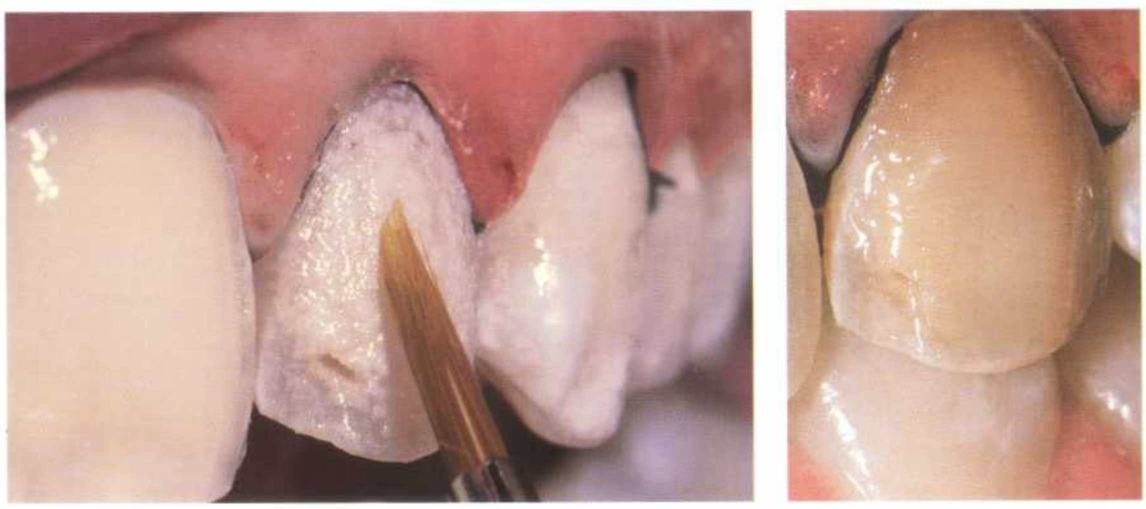
276 Etching
The prepared surface is sufficiently etched with phosphoric acid.

277 Placing the bonding agent
After the enamel has been etched and dried, the bonding resin can be placed. If dentin has been exposed, the primer should be used before the bonding agent is placed.



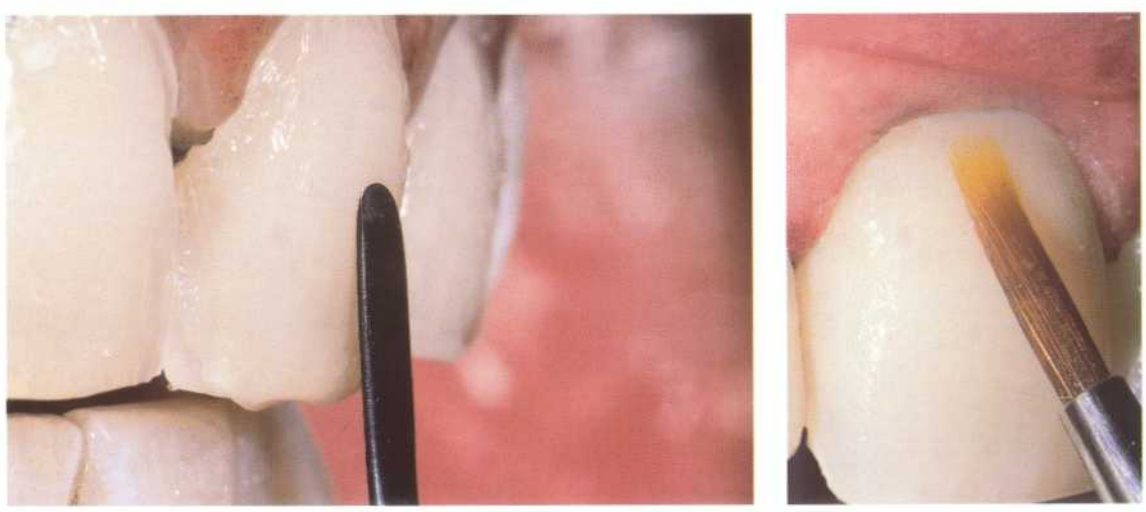
278 Polymerization of the bonding agent
The bonding agent is exposed to ultraviolet light and cured. It is important to check that the teeth do not stick together as a result of the bonding agent. This is best accomplished by placing a plastic strip between the teeth whilst curing.

Right. Etched enamel surface. The frosty surface is visible.



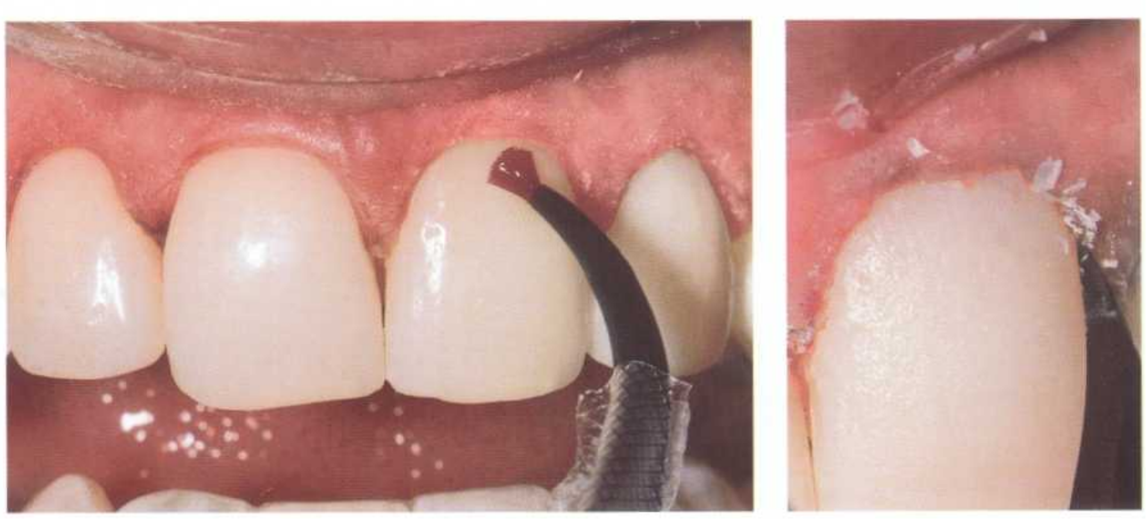
279 Placing composite in layers
If necessary, a more opaque resin can be used for the first layer. For this purpose, thinner, more fluid composites are very helpful.

Right: Tooth pretreated with primer and bonding agent before composite is placed.



280 Shaping the veneer
The outer layer is best placed with a microfilled composite, since this material has the most enamel-like optical qualities. Placing and shaping the composite is best done with the help of a spatula.

Right: Finer details on the surface of the composite are shaped with a brush.



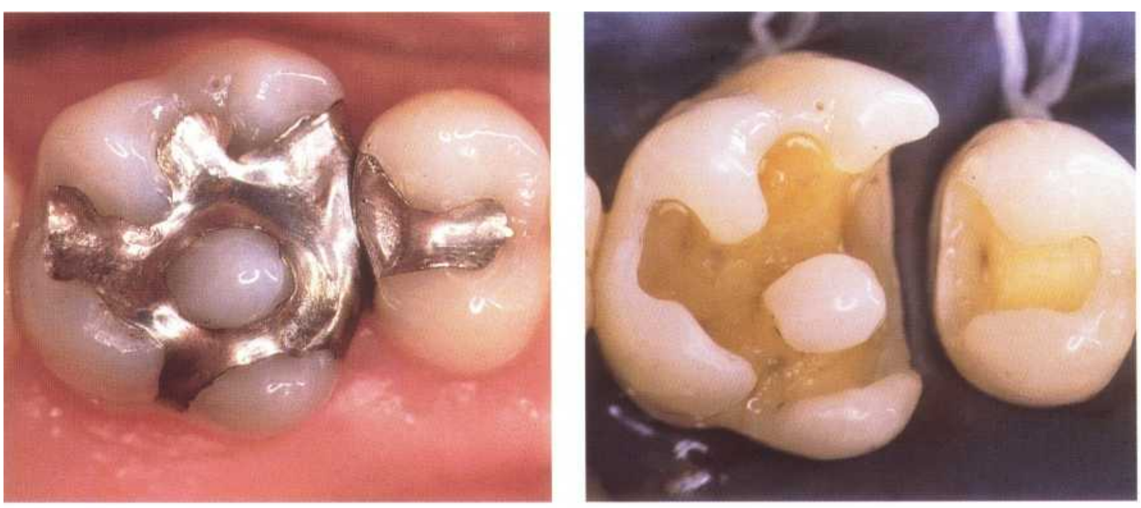
281 Final adjustments to the veneer
After the direct veneer has been ground and polished, the surface is sealed with a composite surface sealer.

Right: Excess at the cervical margin can be removed carefully with a scalpel.

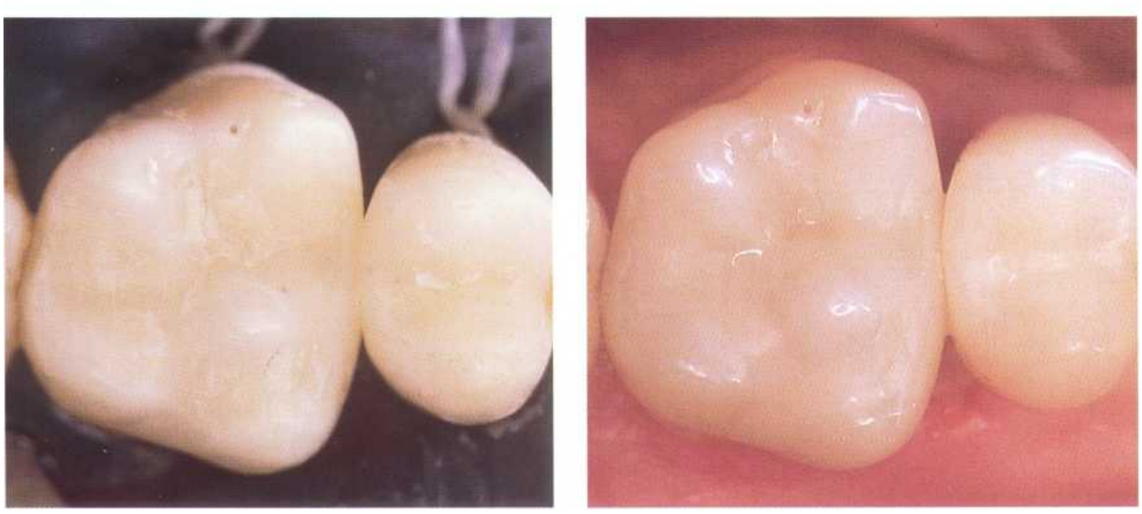
Direct Posterior Restorations

The composition of composites has already been discussed in detail. This section outlines the step-by-step procedure for placing a direct posterior composite filling. Placing a direct posterior composite is quite demanding and to optimize the clinical success basic knowledge of the material and its behavior is a prerequisite.

The composites used in dentistry are very complex materials as far as their chemistry and behavior are concerned. According to their chemical composition, they should not be more biocompatible than other generally used restorative materials. It is especially important to realize this considering the fact that during the past few years the fear regarding the potential dangers of mercury being released from dental amalgams has increased.



282 **Direct composite restoration in the posterior region**
Left: Initial condition includes two amalgam restorations that are to be replaced. The indication for replacing existing amalgam restorations must carefully be judged by each dentist (e.g., caries) because the risk of secondary caries under composites is considerably higher than under amalgams.
Right: When removing the old amalgam, mercury is released. A rubber dam offers optimum protection.



283 **Finished restoration**
Left: Rubber dam facilitates the placement of a direct composite restoration in the posterior region.

Right: Finished restoration.

Advantages and Disadvantages of Composites

Due to the fears surrounding amalgam, which have until now not been scientifically substantiated, some dentists have ceased using amalgam. Instead they are using composites to treat the posterior teeth. Considering the complex chemistry of composites and the rather limited knowledge we have gained regarding their interaction within the biological surroundings, this does not seem justified at the present time. In other words, the opinion that composites are more *biocompatible* than amalgam and gold has not been proved and should not be used as an indication to replace the amalgams.

If one looks at the available clinical results regarding composites, one can hardly claim that these materials are superior to the traditional restoration materials such as gold and amalgam. In actual fact, clinical studies indicate that the lifespan of composite restorations used for posterior teeth is inferior to that of amalgam and gold.

The inferior longevity can be attributed to the fact that composites are *subject to more wear* in vivo than metallic restorations, even if in vitro studies may refute this. However, there are many factors in the mouth that can not be imitated in vitro.

In addition, the risk of developing *secondary caries is* higher at the composite restoration margins, a disadvantage that can be attributed to polymerization shrinkage of the methacrylate-based resins. However, recent advances of the past few years in the field of dentin bonding may have resulted in a substantial reduction in the risk of developing secondary caries. Nevertheless, it is still too early to conclude that such a reduction has occurred.

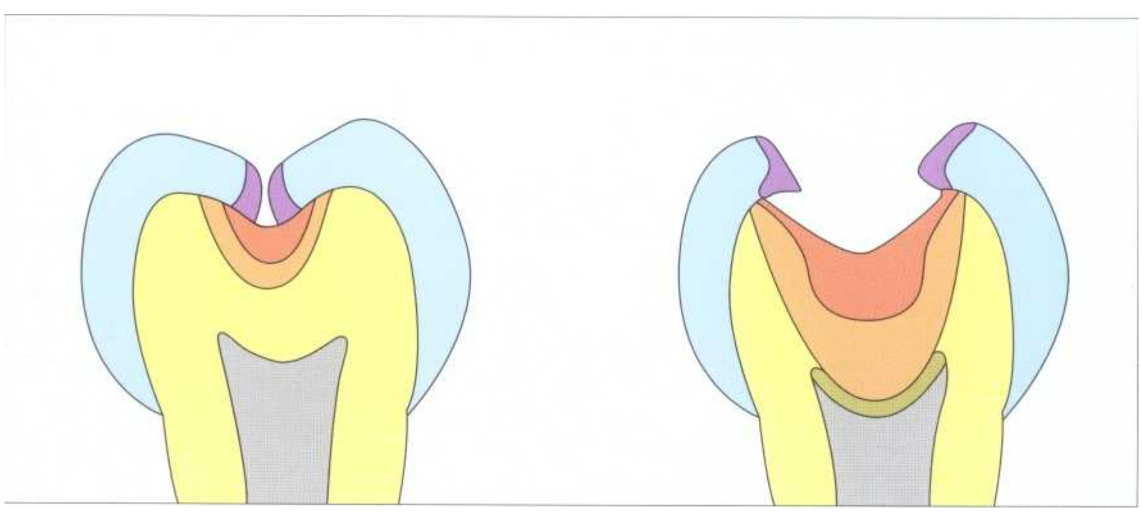
The crucial advantages of composite restorations in the posterior regions are that their *aesthetic qualities* way surpasses that of amalgam and gold and that the application of the adhesive technique with composites enables the placement of smaller and more conservative restorations. The latter can be an important advantage if composite restorations can save more tooth substance and postpone more invasive treatments.

284 How the caries detector works
Left: An unstained carious lesion in cross section.

Middle: The caries detector stains only infected dentin.

Right: Caries detector by the Japanese company Kuraray (Osaka).

Courtesy of *T. Yamada*



285 Structure of carious tooth in a schematic cross section
The caries detector stains only the outer, infected carious dentin (red). The dentist can focus on the diseased dentin layer and remove it virtually without pain. The dentin that is not stained by the caries detector, such as carious discolored inner dentin (orange) as well as the healthy dentin (yellow), will be left intact (green = secondary dentin).

(Adapted from T. Yamada et al. 1995.)

Caries Detector for Tooth Conserving Preparations

Posterior composites require a tooth substance conserving preparation. Therefore, only infected dentin should be removed. This can be detected using a caries detector.

Fusayama (1979), a professor at the Tokyo Medical and Dental University, showed that dentin weakened by caries consists of two layers:

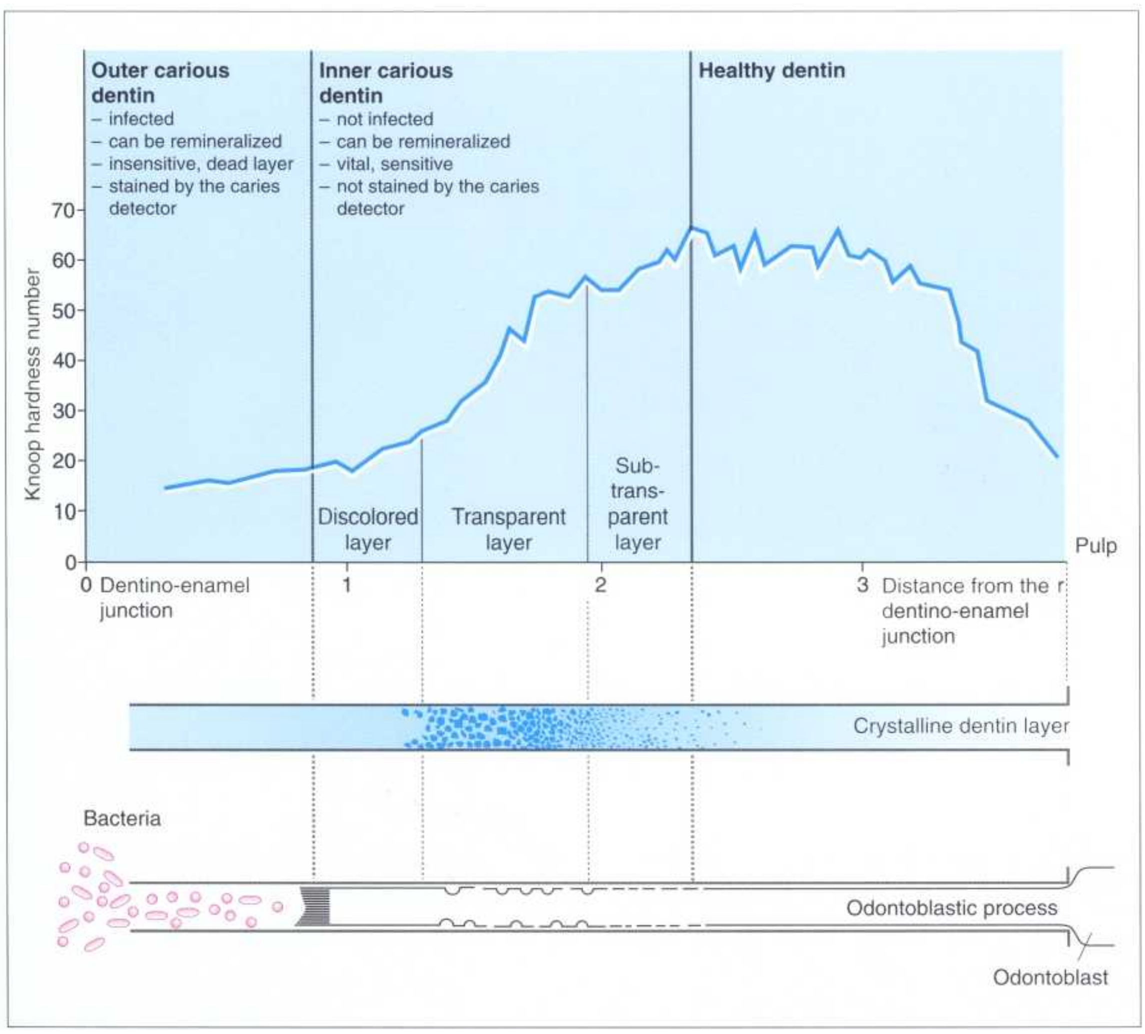
- The insensitive, dead *outer layer is* highly demineralized, infected and cannot be remineralized. It consists of irreversibly damaged collagen fibers. The odontoblastic processes have collapsed.
- The sensitive *inner layer* is only partially demineralized, is not infected and can be remineralized. It contains reversible denatured collagen and intact odontoblastic processes.

The traditional criteria for the necessary removal of caries were softening and change in color. However, neither of the two criteria are truly reliable clinical parameters, since they do not correlate with the depth of the infected and no longer remineralizible layer (Fusayama 1979).

The *caries detector* consists of 0.5% basic magenta or 1% "acid red 52" that is dissolved in propylenglycol. It stains only the outer layer and leaves out the softened or discolored area. When used clinically, the dye makes it possible to remove minimal amounts of carious tissue, i.e., the total elimination of the infected outer (carious) dentin, while the inner, unstained and consequently uninfected and healthy dentin is completely retained. This is not only a very tooth conserving method, but also a very important approach to preserving the vitality of the tooth.

Advantages of using the caries detector during tooth preparation before placing posterior composite restorations include:

- The infected and no longer remineralizable dentin is completely removed.
- The preparation of the cavity takes place almost without pain, thus often malting it possible to avoid using anesthesia.
- It is a very simple technique due to the minimal amount of necessary preparation.
- A maximum lifetime of the tooth is also guaranteed through the utmost protection of tooth structure and vitality.



286 **Schematic section through carious dentin**
The odontoblastic processes do not extend into the infected, non-remineralizable, dead layer of the carious dentin. Therefore, removing the softened layer is virtually painless. The inner dentin layer discolored by caries, whose hardness increases toward the pulp, is not infected and remineralizable.

(Adapted from Yamada et al 1995.)

Indications For Posterior Composites

- Cases where the aesthetic appearance has top priority
- Small lesions, in which the occlusion is supported by the surrounding enamel
- Incipient caries

These indications mean that posterior direct composite restorations should be considered as an early treatment alternative for class I and II lesions on premolars and molars.

Contraindications For Direct Composite Restorations in the Posterior Regions

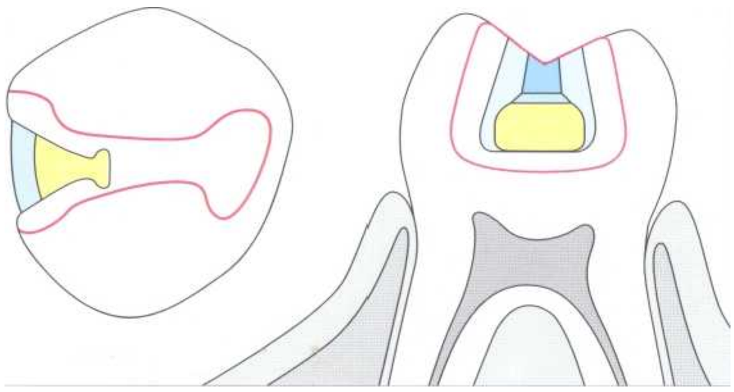
- Unfavorable occlusion and bruxism
- High caries activity
- Difficulty keeping the operation field dry
- Patients who cannot tolerate lengthy treatments
- Allergies against components present in the composite


287 **(Contra-) indications for replacing amalgam restorations**
Left: Initial condition.

Right: Tooth 45 with small, not occlusion-bearing defect as an example of an indication for a composite inlay.
Tooth 46 with big, occlusion-bearing defect as an example of an indication for a ceramic onlay or a partial ceramic crown. Tooth 47 is an example of an indication for a gold restoration, since the aesthetics of a gold restoration is acceptable in this region.

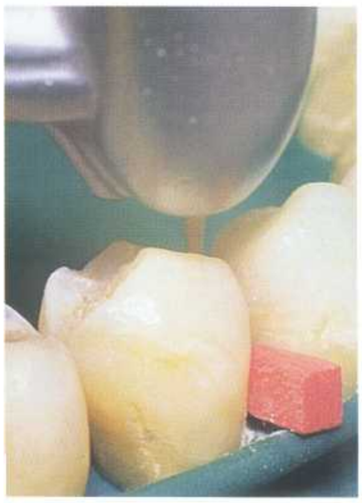
Checklist—Placing a Direct Class II Composite in the Posterior Region

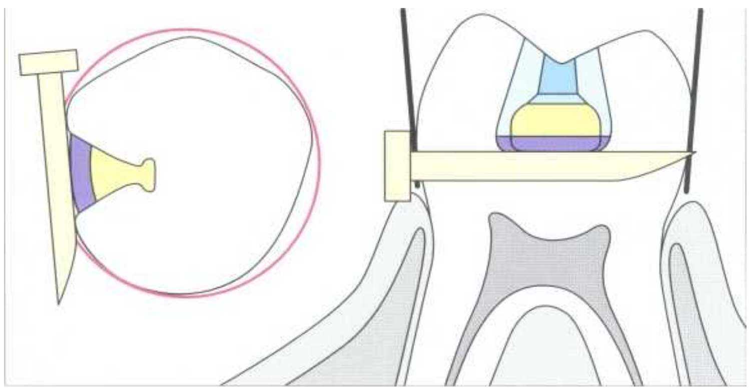
1.	Determine the outline.
2.	Secure a dry area to work in, preferably use rubber dam.
3.	Place an interdental wedge before treatment starts in order to get a tight contact point.
4.	Prepare and remove the active caries lesion after it has been stained using a caries detector.
5.	Condition enamel and dentin (35 % phosphoric acid).
6.	Place a dentin primer.
7.	Place the bonding agent and polymerize the bonding agent (dentin adhesive).
8.	Place the matrix band.
9.	Wedge the matrix band with a light-scattering wedge.
10.	Cure the cervical composite layer (1 minute).
11.	Build the restoration incrementally and polymerize each layer for 1 minute.
12.	Prepolymerizing composite sphere consolidates the contact point.
13.	Occlusal curing (1 minute).
14.	Grind and polish the restoration.
15.	Check the occlusion.
16.	Seal the margins and the surface.



288 Analysis of the defect
Thanks to modern adhesive materials it is possible to remove only the carious dentin and prepare a cavity which is as small as possible. The traditional preparation would include the entire occlusal fissure.

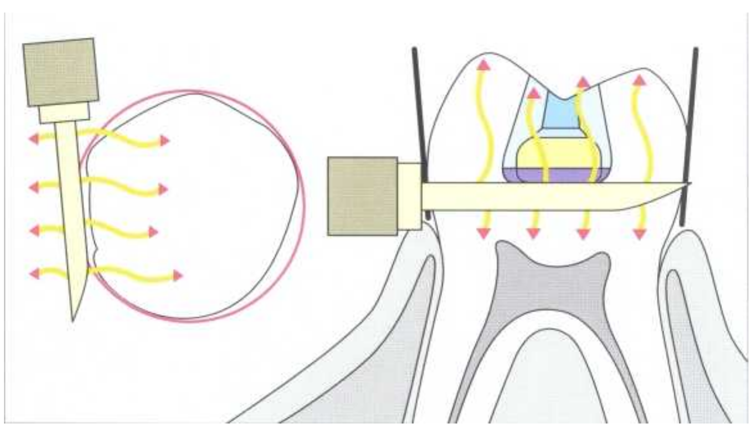
Left: Defect and occlusal points are shown.





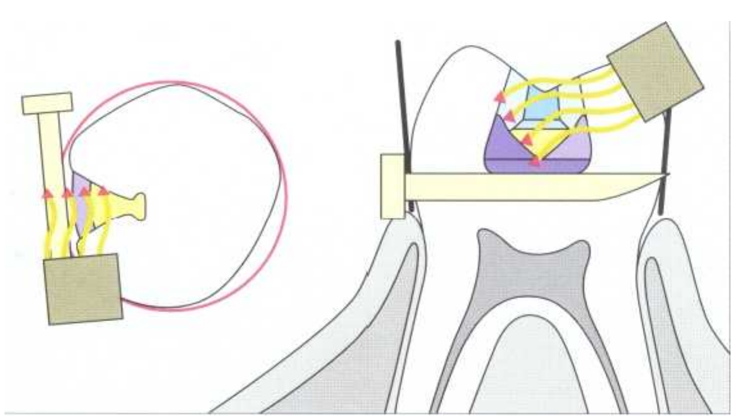
289 Preparation and placing the first layer
After placing a suitable dentin adhesive (condition enamel and dentin with phosphoric acid, place primer and bonding agent), the first and lowermost composite layer is placed.

Left: After placing the rubber dam, the contact point is opened with a wooden wedge.



290 Polymerization
The first increment of the composite is polymerized.

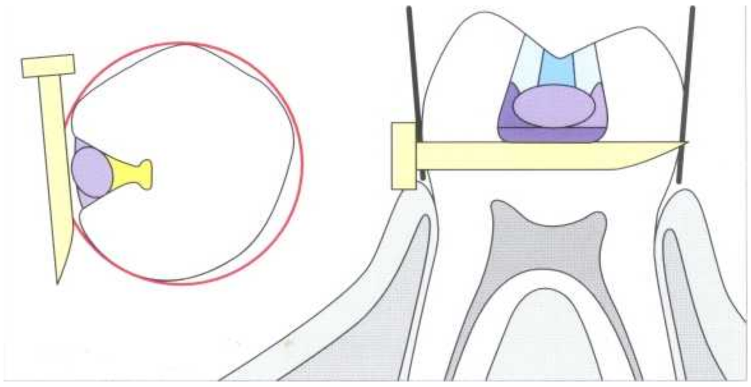
Left: Applied phosphoric acid as the first step in the total etch technique.



291 Top of the buccal and lingual wall
The lateral walls are covered with composite and polymerized.

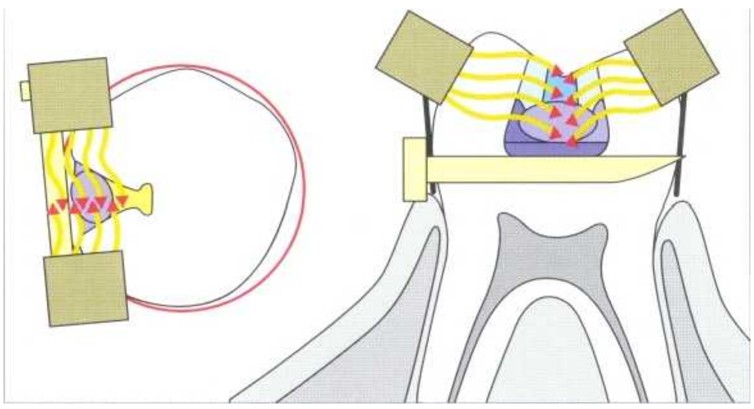
292 Homemade inserts
A matching, extraorally prepolymerized insert is brought into the proximal box that has already been filled with a small amount of nonpolymerized composite. Rather than using a homemade insert, ready-made commercial ceramic inserts are also available for this purpose.

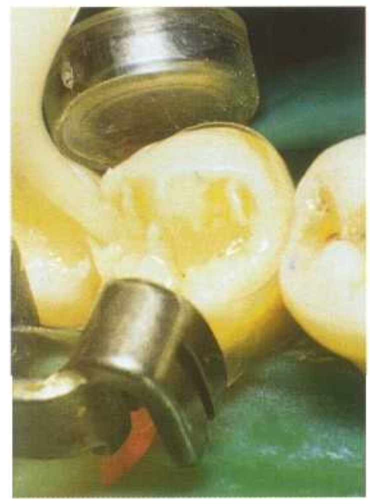
Right: Placing the insert.



293 Polymerization
After the extraorally manufactured insert has been placed in the proximal box and the composite insert has formed an optimal contact point, the filling is polymerized.

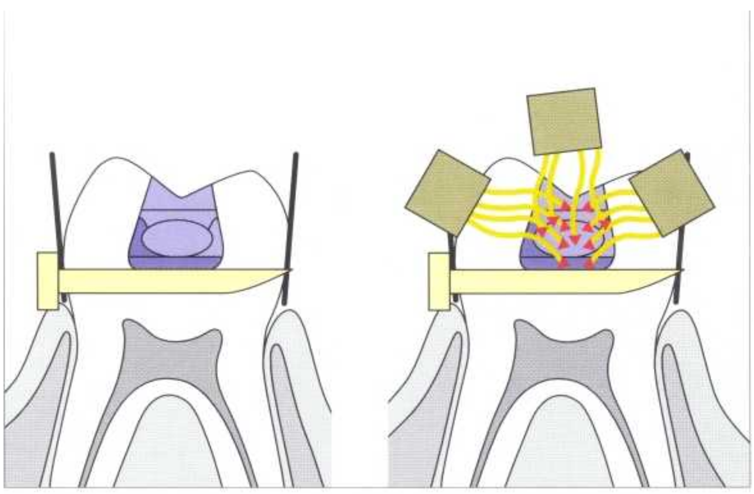
Right: Polymerization of the restoration.

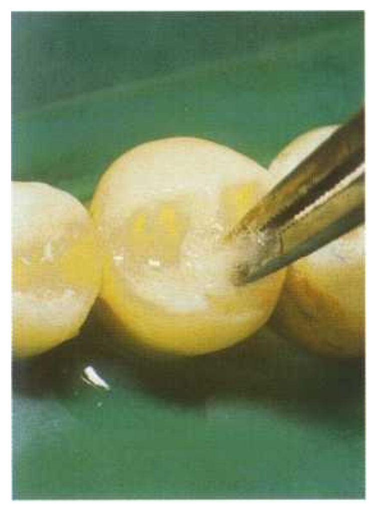




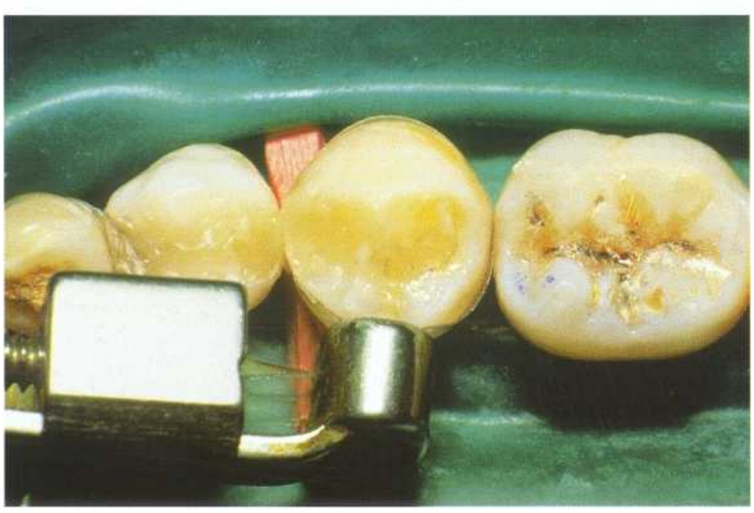
294 Anatomy
After coarse grinding and polishing, the restoration and its margins are lightly etched and sealed, whereupon the restoration is cured again from the lingual, buccal, and occlusal surfaces for one minute at each location.

Right: Polymerization of buccal surface of the restoration.



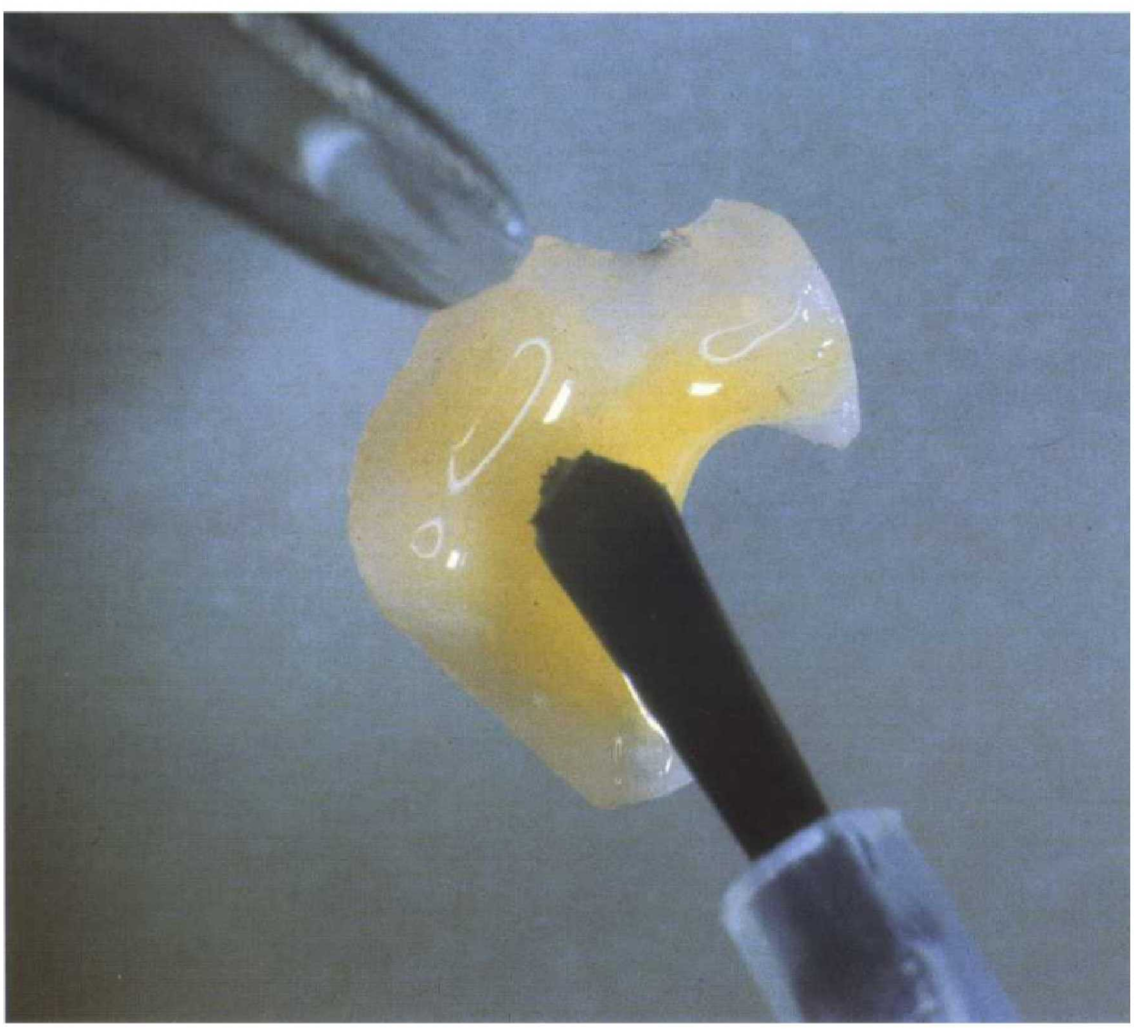


295 Completed restoration



Composite Inlays

Direct composite restorations are not always suitable for replacing amalgam. Without doubt it is the restoration of choice in the case of incipient, small carious lesions. However, with bigger defects, when larger parts of the occlusal surface and the interproximal surfaces are involved and need to be replaced, composite inlays and onlays offer clear advantages. The biggest problem with modern posterior composites is their polymerization shrinkage and the stresses it induces around the margins. These stresses can cause debonding, form gaps, increase tooth sensitivity, and lead to progression of the caries process. Therefore, a goal must be to reduce the tensile stresses which arise around the margins during the making of a composite, which is done with a complex, time-consuming layering technique. Today's resins do not allow polymerization shrinkage to be completely eliminated. The composite inlay should be considered at this point as superior to the direct composite restoration, since the contraction of the inlay takes place extraorally.



296 **Composite inlays**
Composite inlays can serve as an alternative to amalgam restorations if the defects are large. The cementation technique, among other things, is decisive for the success of these restorations. Composite inlays must be bonded with an adhesive technique.

Advantages and Disadvantages of Composite Inlays

Composite inlays and onlays can be placed to reduce polymerization shrinkage and composite wear. The advantage of this method is that the main part of the composite is cured outside the oral cavity and only a thin resin layer, the resin cement layer, contributes to shrinkage of the restoration in the oral cavity. Advantages of this include a reduced tensile stress level around the margins and reduced risk of debonding, particularly at the tooth-cement interface (Lutz et al. 1991). However, despite reduced tension around the margins between tooth and inlay, a perfect bond is not always formed (Cassin and Pearson 1992; Zuellig-Singer et al. 1992).

Although most posterior composites which are placed nowadays are direct composites, dentists should master the technique of making a posterior composite inlay, since such a technique simplifies many of the curing and trimming stages and will probably increase the chances of success with this type of restoration.

Advantages of Composite Inlays Compared to Ceramic Inlays

Aesthetics

- The aesthetics of adhesively bonded composites is often better than that of ceramic inlays. Studies at the University of Zürich, Switzerland have shown that these restorations have very high longevity if they were produced using state-of-the-art technology and a proper bonding procedure.

Abrasion Resistance

- Studies have shown that the in vitro abrasion resistance of some composites corresponds to the abrasion resistance of enamel. Most of these studies, however, were carried out in vitro. Ceramic inlays wear the antagonists more strongly than composite inlays.

Tooth Conservative Aspects

- Very little tooth substance needs to be removed to prepare the composite inlay. Frequently, removal of the carious defect and minimal preparation is sufficient. This is a big advantage compared to ceramic inlays that require a relatively large amount of space.

Repairability

- Composites can be repaired with new composite.

Simple Technique

- Simplest technical procedure of all tooth-colored restorations.

More Affordable Than Ceramics

Disadvantages Compared to Ceramic Inlays

- Lower wear resistance than ceramic inlays.

- Still inappropriate for substituting occlusal surfaces exposed to large forces.

Advantages of Indirect Composite Inlays Compared to Direct Composite Restorations

- With the indirect technique the dentist can
  —more easily control the cervical adaption
  —shape the interproximal and occlusal surfaces
  —make an appropriate contact point

- Through the processing and shaping of the composite in the laboratory it is possible clearly to improve the material properties (density, wear resistance, and water absorption). An examination (Shikai et. al. 1996) has clearly shown the positive effect of the heat treatment of some composites in the laboratory. After a heat treatment, Charisma, e.g., improves its
  —wear resistance by 50 %
  —modulus of elasticity from 6.2 GPa to 11.6 Gpa
  —flexural strength from 109 to 140 Mpa
  These improved physical properties, shown in the quoted study, were caused by additional heat treatment for Charisma and Herculite, while no such improvements were found for Heliomolar and P50.

- Since the clinical process is relatively simple for composite inlays and it is easier to produce good and sealed margins, composite inlays show lower secondary caries frequency and fewer color changes than direct composites when used in the posterior region.

- Reduced microleakage.

Drawbacks of Indirect Composite Inlays Compared to Direct Composite Restorations

- Composite inlays often require a second treatment session and a temporary restoration.

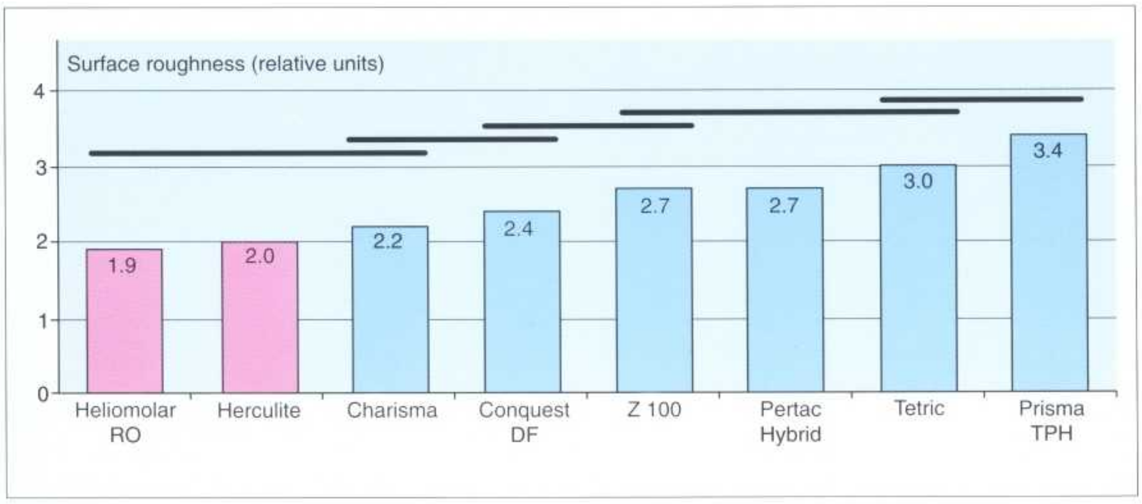
- Laboratory expenses are also incurred, making the total price of the restoration significantly higher than that of a direct composite restoration.

Composite Inlay Systems

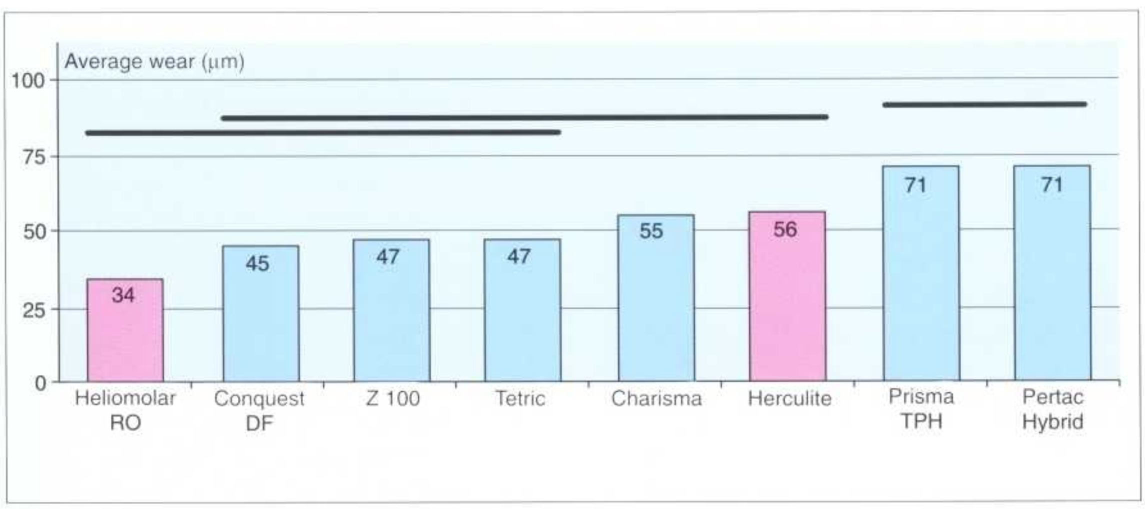
All modern small particle/hybrid composites can be used for making composite inlays. A new generation of composites is extremely suitable for this purpose-these materials are Art-Glass, Solidex, and Bellglas.

Methods for making composite inlays:

- The technique for direct composite inlays enables the dentist to prepare inlays directly inside the oral cavity, perform an extraoral polymerization, and place it at the same treatment session.
- Immediate inlay: After the tooth has been prepared, a simple impression (e.g., alginate) is made and poured with a silicone or a quick-setting plaster. The composite is placed and polymerized on this model. It is bonded to the tooth during the same session.
- Laboratory-processed inlay: After a dental impression has been made, the inlays are produced in the dental laboratory and bonded during the second session.



297 Surface roughness of materials used for composite inlays
Any small particle hybrid composite can be used for composite inlays. The surface roughness is a variable that should be considered during selection. The black horizontal lines overlapping two or more bars indicate products that statistically are not significantly different from each other.



298 Average wear of the same products as in Fig. 297
The wear resistance of the different composites is another criterion to be considered during selection of a suitable inlay material. There is no statistically significant difference between Conquest DF, Z100, Tetric, and Heliomolar RO, which was introduced on the market many years ago.

Figs. 297 and 298 adapted from CRA Newsletter, July 1995.

299 New materials and products
In the coming years, many new products, which should not differ significantly in their clinical behavior from ceramic inlay materials, will be marketed as composite inlay material. However, they will be substantially simpler to process. Art-Glass and Solidex are just the beginning.

Diagnostics and Treatment Planning for Composite Inlays and Onlays

A good hygiene phase is important if composite inlays are to be used. The bond site is a weak link in the transition from the tooth to the inlay. The bonding composite is not as filler loaded in this region and is exposed to more severe wear. Such bonding sites have a porous surface and a concavity where plaque can often be seen after the bonding resin has worn. Since this region often is difficult to clean, secondary caries easily originates here. The cervical margin is at particular risk.

Before the treatment, it is necessary to assess the bacterial activity in the oral cavity. If there is a high risk of caries, patients must be informed that secondary caries can originate easily at the bond site of the inlays if they do not clean their teeth perfectly. Patients need to be informed that the margins of the inlay must be checked twice a year after completed treatment. Furthermore, bitewing radiographs should be made at regular intervals.

At the first session the following tasks should be carried out:

- professional tooth-cleaning
- assessment of the caries activity
- radiographs
- intraoral photography
- color registration
- situation models if several inlays are going to be placed
- written information to the patient
- treatment and financial plan

The dental hygienist performs most of these tasks. All diagnostic records are available to the dentist at the beginning of the treatment. The situation models are used as counter bite models and to manufacture temporary restorations. It may happen that an inlay was planned originally, but after finished preparation an onlay or a partial crown is necessary. Available situation models then facilitate the provisional care.

Preparation of Composite Inlays and Onlays

The preparation of composite inlays is very similar to that of gold inlays. An essential difference is that no feather edges are prepared and the walls are shaped so that they diverge somewhat. The layer strength with composite inlays is allowed to be 1.5 mm in each direction, while in the case of ceramic inlays it should not be less than 2.0 mm. A blocking restoration is desirable with large defects, otherwise the preparation will become over extended. If maximal conservation of healthy tooth substance is the goal, blocking restoration forms an important part of the preparation.

Making the Blocking Restoration, Materials, and Techniques

It is not necessary to prepare the inner line angle. Nevertheless, refining the preparation with hand instruments leads to straight walls, which leads to better results in the case of impression taking, model and inlay processing, but also cementation and finish.

Here are the individual steps:

1. Anesthesia.

2. A rubber dam is desirable and helpful.

3. Remove the old restoration.

4. Remove caries.

5a. If regions are close to the pulp (approximately 0.5 mm from the pulp), a base is used to protect the pulp. This can be placed as the same time as the blocking filling and consists of a resin-modified glass ionomer cement. The advantage of the blocking filling placed with a glass ionomer cement is possible protection against secondary caries through fluoride release.

5b. The total etch technique described by Fusayama offers the best possible pulp protection. The procedure is as follows:
- Etch the entire cavity with 10% phosphoric acid for 20-30 seconds or with 30-40% phosphoric acid for at most 15 seconds. (It is important that the dentin is etched for no longer than 15 seconds, since the dentin bonding can be reduced otherwise.) The acid is placed first in the periphery and then in the center. By doing so, the dentin surface closest to the pulp is etched somewhat less.
- Rinse thoroughly and dry only briefly. Many dentin adhesives perform better when bonded to moist dentin than when bonded to dry dentin.
- The dentin adhesive is immediately placed. As long as a fourth or fifth generation dentin bonding agent is used, it is not significant which one of the newer dentin adhesives is used.

-After the dentin adhesive and the bonding agent have been placed and polymerized, the cavity is filled with a composite. There are certain composites that have very transparent filler particles that let them be quickly polymerized and are easy to shape (e.g., Clearfil Photo-core). However, all other composites can also be used. An advantage of lighter composites (especially those placed incisally) is that they are quicker to polymerize. Darker composite colors (e.g., D3, C4, and similar) should, therefore, be polymerized longer in accordance with the recommendations of the manufacturer. An advantage of the darker colors is that they offer a stronger contrast during the subsequent preparation. The blocking restoration is placed in several layers.

6. Preparation with rotating instruments. The initial preparation is best done with diamonds, since hard metal drills become dull very quickly when they cut the glass filler particles of the composite. During preparation, one should be careful that all preparation margins are placed in the enamel. It is possible that the cervical margin may end up in the dentin. After coarse preparation with the diamond, the first refinement of the preparation can take place with a carbide drill.

7. Refine the preparation with hand instruments. For refining and smoothing the proximal wall and the cervical margins, two hand instruments are available (angled chisel No. 42/43 and 44/45).

8. Polish the proximal wall with a disk. During preparation with the rotating instruments, a sigmoid-shaped margin is frequently formed. If such a margin is left, it is very difficult for the dental technician to achieve good marginal adaptation. Using a disk eliminates this weak point.

9. Check the preparation. Are all preparation margins outside the restoration located in healthy tooth substance? Was sufficient space created for the intended inlay? Is an onlay or even a partial coverage crown the adequate treatment for this defect?

10. If necessary, prepare an onlay or a partial coverage crown.

Checklist—Inlay Preparation

1. Anesthesia.
2. A rubber dam is desirable and helpful.
3. Remove the old restoration.
4. Remove caries after it has been disclosed with the caries detector.
5. The blocking filling can be placed using a glass ionomer cement, a resin-modified glass ionomer cement, a compomer, or a composite. The advantage of making such a filling with glass ionomer cement or compomer is possible protection against secondary caries through fluoride release. This protection is particularly desirable when the cervical step finishes in the dentin.
6. Preparation of a classic cast inlay with conical diamonds. The preparation has no feather edges and should have been somewhat diverging (approx. 6°).
7. Refine the margins with carbide burs, possibly also with hand instruments.
8. After the rubber dam has been removed, make a dental impression with an A-Silicon or Polyether. A tray that covers just one quadrant is often sufficient.
9. Make a direct provisional restoration with gutta-percha and resin (e.g., Dentalon).

Preparation-Step by step

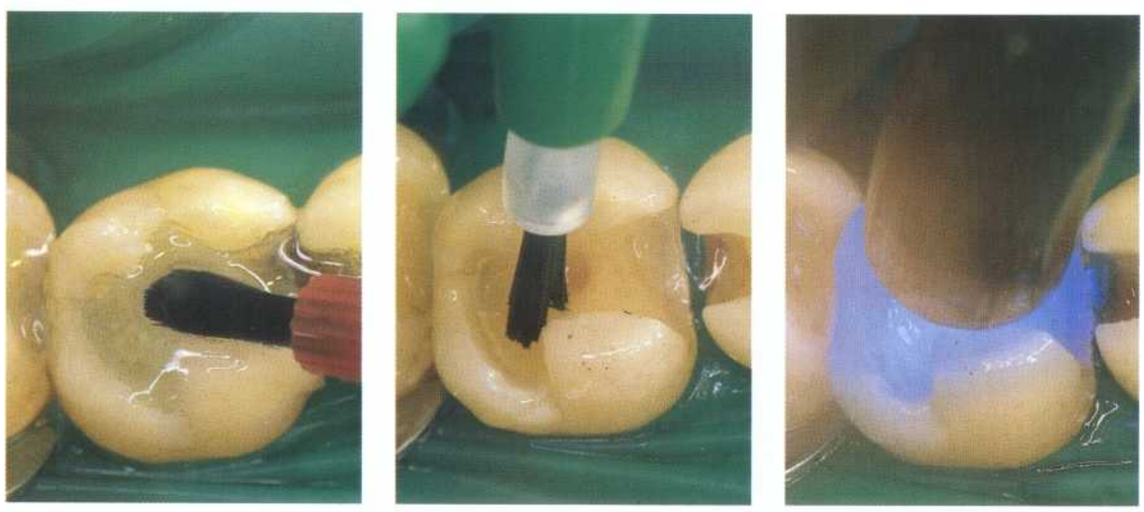
300 Condition before the composite inlay is prepared
A rubber dam is placed before the old amalgam filling is removed.

301 Removing the old amalgam filling and completely excavating the caries

302 Preparation for placing the base
Left: The entire prepared enamel and dentin surface is conditioned for 15 seconds with phosphoric acid.

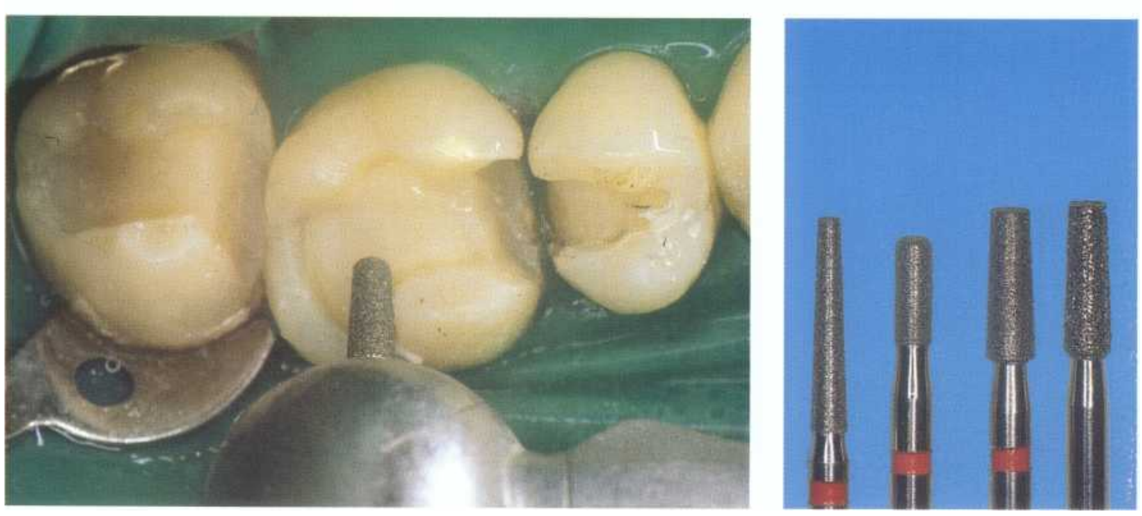
Middle: Primer and bonding agent are placed one after the other.

Right: Polymerization of primer and bonding agent.

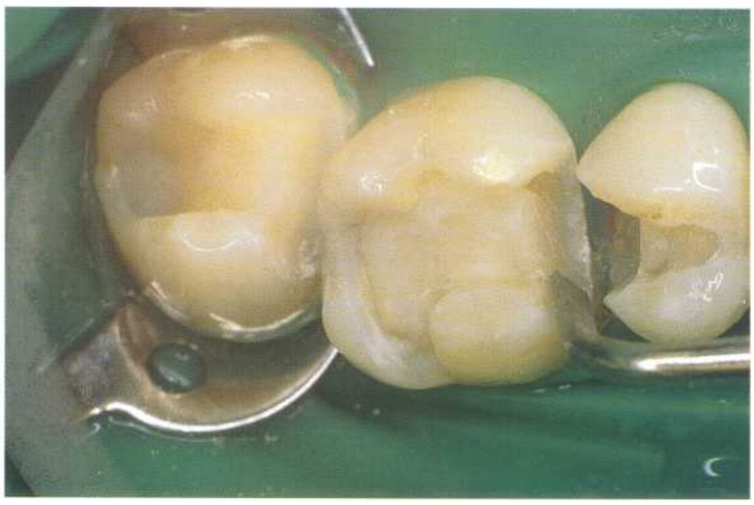


303 Preparation
The blocking filling enables a tooth substance-saving preparation. This is begun with usual, slightly conical diamonds.

Right: Typical coarse preparation diamond.



304 **Refining the preparation with hard metal burs**
Left: Typical carbide burs for one-way use.



305 **Fine adjustment with hand instruments**
Irregularities caused by the bur on the cervical step are removed and smoothened out with hand-held instruments. It is not used to create inner line angles.

Making a Dental Impression

Malting a dental impression is a procedure that does not deviate from the everyday routine. Three different materials are suitable for making impressions for tooth-colored ceramic or composite inlays:

-addition silicone
-polyether
-hydrocolloid

Hydrocolloids have the advantage that one can quickly and inexpensively make two impressions. An important advantage of this procedure is that the inlays are made on a cut plaster model and at the end these inlays are placed on the second, uncut model. The fit and the contact points can be checked carefully. Fitting the inlays on the second model saves a lot of clinical time. If the restorations fit on the second model without erasing the die unnecessarily, one can be sure that the restorations also fit in the mouth.

The most current method of malting a dental impression includes the use of the elastomers addition *silicone* and *polyether.* These impression materials can be poured a second time. Moreover, the advantage with single inlays is also that the prepared tooth and its antagonist can be recorded simultaneously with a double tray impression. For the tooth-colored restorations it is also true that the final result cannot be better than the impression sent to the laboratory. It is wrong to believe that possible marginal defects caused by poor precision can be taken care of with a composite cement. Since the weakest point of the restoration is the transition from the inlay to the tooth, the composite-sealed joint should be kept as small as possible. To succeed with the restoration, it is crucial that a precisely matching inlay is placed using the corresponding cementation technique. In order to obtain such an inlay, a good preparation must be delivered to the laboratory as a perfect impression.

Temporary Restoration

The temporary restoration for a tooth-colored inlay does not differ from the gold inlay technique. The two techniques described in the following have crucial advantages, namely they are simple and quick and it is not necessary to shape them or to extraorally cement them.

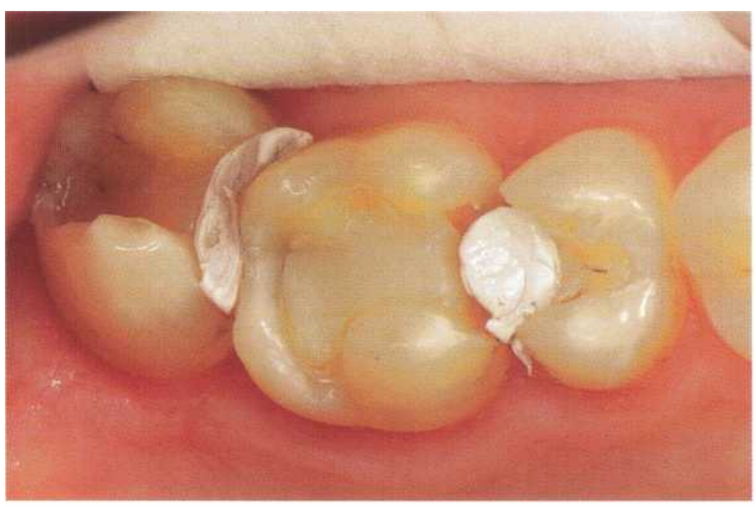
First Option: A small amount of gutta-percha is warmed up carefully over a flame and placed in the proximal box. The gutta-percha should protect the resin from coming into contact with the papillae when it is later inserted. The cavity is then filled directly with the temporary resin material. All the excess is removed and the patient closes the mouth whilst the resin remains plastic. The hardened resin is not removed from the mouth. It is not removed until the inlay is cemented.

Potential problems with this technique: If undercuts exist and the resin has entered these spaces, it can be difficult to remove the temporary restoration. Under such circumstances it can be necessary to cut through the temporary restoration.

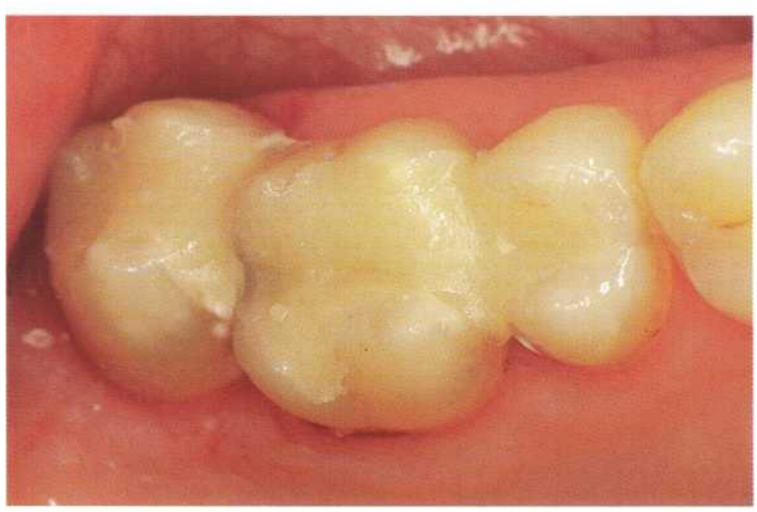
Second Option: One can treat onlays and partial coverage crowns as follows: A vacuum-processed plastic tray is made and is filled with resin for the temporary restoration. If the resin has a pasty consistency, the tray is placed in the mouth. Shortly before the resin has solidified completely, the tray is removed, including the resin, cooled shortly under running cold water, and repositioned in the mouth. After hardening, the resin is removed from the tray, trimmed, polished, and reinserted.

Try-in of the Inlays

Special instruments are needed for the try-in and cementation of the inlays. A possibility for holding the inlay is to attach a plastic pin (Accuplacer) to the inlay. The occlusal checking should under no circumstances take place before cementing because it can cause a fracture of the inlay at this time. The contacts are checked particularly carefully. For adjustments of the contacts, a fine flame-shaped diamond is used. The color is also checked and can to a minor extent still be corrected with the resin cement. Composite inlays should fit as well as gold inlays.



306 **Protecting the papillae with gutta-percha**
The proximal box is filled up with a layer of gutta-percha that is 1 mm thick. Gutta-percha is a very tissue-friendly material. It pushes down the papillae temporarily and prevents the gingiva from coming into contact with the resin used in the temporary restoration.



307 **Temporary restoration**
The cavity is filled directly with a resin for temporary restorations (e.g., Dentalon), and the temporary inlay is shaped with a spatula and coated with a vaseline film. The inlay is not removed until it is time to try in and cement the inlay.

Cementing the Inlays

The insides of the inlays or the onlays are sandblasted again after the try-in. A pressure of approximately 2 bars is recommended for 50 pm aluminum oxide particles. This sandblasting gives the best possible retention between inlay and resin cement.

Usually dual-cured cements are used for the cementing of composite inlays. Since these begin to harden immediately after being mixed, the setting time of the cement should be checked the first time. In order to extend the time available, the cement can be stored in the refrigerator or mixed on a cool glass plate.

Before cementing, the enamel and dentin must be conditioned and the primer and the bonding agent must be placed. The bonding agent should not be hardened before the inlay is cemented because the inlays may not fit after the bonding agent has been cured. At the same time, though, the inside surfaces of the inlay are moistened with the bonding agent.

If there is any doubt as to whether curing of the bonding agent can be complete with the existing light source, one should use a chemically or dual-hardening adhesive system (e.g., Scotchbond MP Plus).

After the dual-cured resin has been mixed (usually 30 seconds), the time to complete a typical dual-cured cement is four to five minutes.

To simplify the procedure, the cement can be placed by means of an applicator (Centrix, Hawe-Noes). Either the tooth surface or the inside surface of the inlays is generously covered with cement. Then, the cement is quickly distributed with a brush over all bonding surfaces of the prepared cavity or the inlay. Both surfaces should not be covered with cement, since this is too time-consuming. It should further be guaranteed that no visible air bubbles are present in the cement.

The viscosity of available cements differs depending on their filler fraction. This influences the cement's physical properties.

If highly viscous cements are used, the inlay should first be placed at a location about 0.5 mm away from its final position. First the excess is removed and then the inlay is brought into its final position. The reason this is done with highly viscous materials is that, because of the rubbery viscosity, cement between the inlay and the tooth can be pulled out when excess is removed.

Another possibility when working with viscous cements is to use (old amalgam) vibrators or ultrasound appliances.

Inserting inlays as well as removing excess material is substantially facilitated by new, highly filled, highly viscous cements.

As soon as the inlay is currectly positioned, the surplus cement must be removed. On the proximal surfaces, this is best done by means of wide dental floss. The margins are adjusted with a brush that is moistened with some bonding agent. Strong light should be avoided because it will accelerate the setting reaction and decrease the amount of available time. As soon as excess has been removed, the margins are covered with glycerin (Airblock, DeTrey).

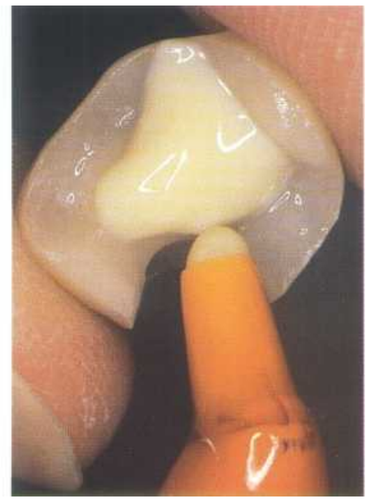
All the processes described must be executed before the dual-curing cement gelates. The curing of the composite should take place both from occlusal as well as from the proximal surfaces. To cure the proximal-cervical margins, light-scattering wedges (Luciwedge, Hawe-Neos) can be used.

The light intensity of the lamp should be high and checked regularly. One minute light exposure is recommended for each proximal (both the mesial and the distal) surface and one minute of the occlusal surface. The light tip must be in contact with the inlay in order to optimize the curing. It must not be forgotten that resin shrinks during curing and that thin margins fracture easily.

308 Completed restorations-try-in

Tooth *24* is being reconstructed with a composite inlay, teeth *25* and *26* with ceramic partial crowns, and tooth *27* with a gold inlay. All restorations will be bonded.

Right: Composite inlays must be bonded adhesively exactly like ceramic inlays. The difference only lies in the conditioning of the inlay surface.



309 Prearrangements for bonding

The composite inlay and the ceramic partial crowns are placed simultaneously and bonded with a light-curing cement. First, the teeth are conditioned with phosphoric acid and coated with primer and bonding agent. The bonding agent is polymerized together with the light-hardening cement. Chemically or dual-cured systems are also suitable.

310 Conditioning method and resulting shear bond strength of resin bonding

Adapated from Latta et al., *1994.*

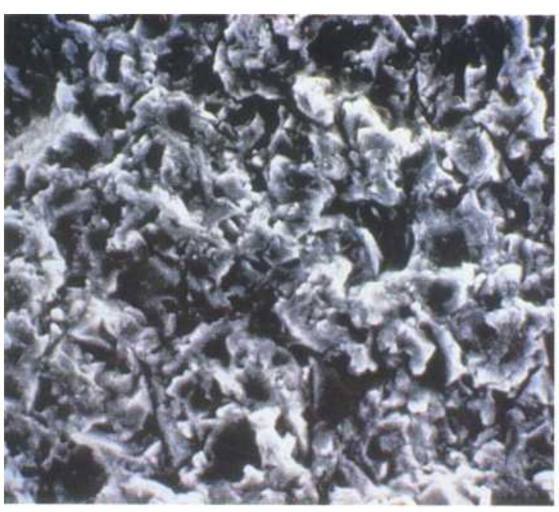
Conditioning Method	Shear Bond Strength (MPa ± SD)
Hydrofluoric acid	9.9 (± 1.2)
Control group without conditioning	13.0 (± 4.9)
Ammonium bifluoride	14.5 (± 2.8)
Composite adhesive	19.6 (± 2.3)
Sandblasted and composite adhesive coating	25.1 (± 2.2)
Sandblasted only with Al_2O_3	26.7 (± 5.6)

311 Pretreated resin surface

Left: The resin surface is optimally conditioned by sandblasting with alumina.

Right: This resin surface has only been roughened with a diamond.

SEM by *Bisco Inc.*



312 Placing the inlays
The inlays are inserted with light-curing cement (not the gold inlay of tooth 27).

313 Finished restorations
After excess cement has been removed occlusally and interdentally, the inlays are polymerized for three minutes per tooth (one minute each for the occlusal, buccal, and lingual surfaces).

Finishing and Polishing Steps	Convex and Smooth Surfaces	Concave and Occlusal Surfaces Sulcus Area Particular Shaping Procedures	Proximal Surfaces
Coarse shaping	Flexible disks*, coarse	Diamond finishing burs** 40 µm	Interdental files*** 80/40 µm
Contouring	Flexible disks*, coarse and medium	Diamond finishing burs** 40 µm	Interdental files*** 40/15 µm
Fine trimming	Flexible disks*, medium and fine	Diamond finishing burs** 15 µm	Interdental files*** 15 µm; Strips, coarse and medium
Final shaping and polishing	Flexible disks*, fine and ultrafine	Flexible disks*, fine and ultrafine	Strips, fine and ultrafine

* Soflex
** Composhape
*** Proxoshape

314 Instruments recommended for shaping and polishing composite inlays (University of Ziirich)
Adapted from Krejci et al. (1991).

315 Result
The composite inlay on tooth 24 and the ceramic onlays on teeth 25 and 26 are exclusively cemented with a light-hardening cement system (Scotchbond MP and opalescent cements from 3M). The gold inlay on tooth 27 was cemented with a resin-modified glass ionomer cement (Vitremer, 3M).

Trimming

Soflex disks and polishing diamonds (Composhape, intensive) are used to trim inlays. Soflex disks should be used as often as possible since they give the best results. The red/yellow series is thinner, but also stiffer. On curved surfaces, it is simpler to work with the thicker black/blue disks, since these are extremely flexible.

Occlusal surfaces are difficult to trim with disks. Here, the red Composhape diamond is used. First, it is best to work at a slow speed and without water so that the difference between tooth inlay and composite cement can be recognized.

After the margins have been finished, the rubber dam is removed and the occlusion checked. Emphasis should be placed on proper centric and lateral relationships. Red Composhape diamonds can be used to adjust the contact points. The surface is smoothened using a fine Soflex disc and with generous water cooling. Proximal surfaces are finished with small Soflex strips.

After the margins have been checked for overhangs the inlay is complete. The entire surface is etched again, rinsed, dried, and coated with a sealer and afterwards polymerized. As the last step, the margins should be treated with a fluoride solution.

If the inlay fits well, cementing a composite inlay is not more difficult than cementing a gold onlay.

As shown, inlays can reduce the problem of polymerization shrinkage, but not eliminate it. Clinical studies suggest that the frequency of postoperative sensitivity with composite inlays is slightly smaller than with the direct technique. However, it must be emphasized that even with composite inlays postoperative sensitivity exists. The frequency is approximately the same as it is for amalgams (Kreulen et al. 1993).

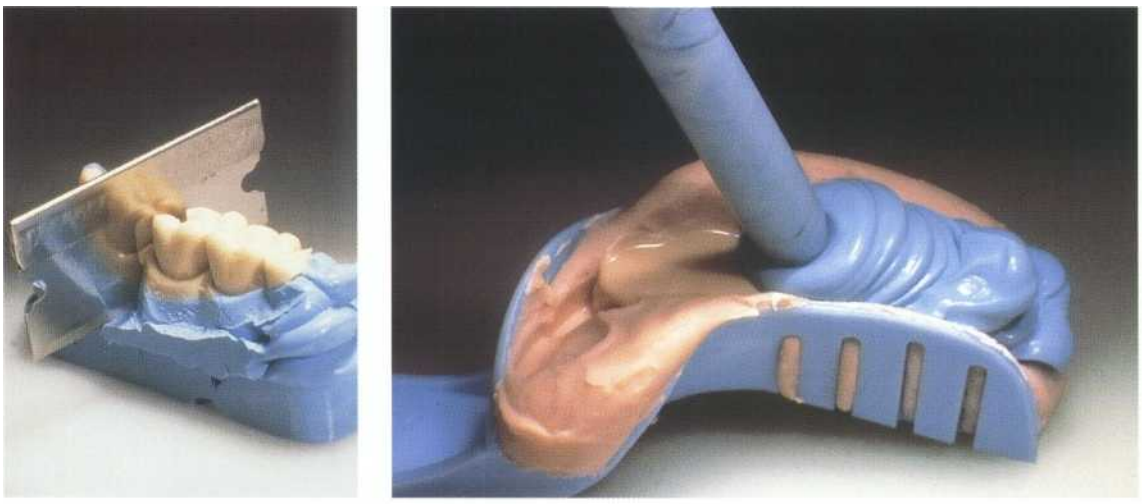
Checklist—Cementing and Finishing

1. Local anesthetic.
2. Temporary restoration removed.
3. Clean the prepared teeth thoroughly with pumice and a rubber cup.
4. Inlay try-in. Check color and contact points, not occlusion (fracture risk).
5. Conditioning. Sandblast the inner surface of the composite inlays; etch ceramic inlays with hydrofluoric acid and treat with silane.
6. Place rubber dam.
7. Condition tooth surfaces. If intraoral sand blasting units are available (e.g., Microetcher, Danville, English), sandblast the blocking filling and the cavity surface before etching them with phosphoric acid.
8. Select adhesive system. With very transparent inlays and sufficiently strong light source, use only light-curing adhesives. With less transparent inlays or large restorations, chemically or dual-cured bonding systems (bonding agents or cements) are preferred (e.g., Scotchbond MP Plus and opalescent cement by 3M).
9. Primer and bonding agent are placed on the tooth surfaces. Bonding agent is also placed on the inlay surface (possibly add catalyst for chemical hardening), and place inlay with bonding cement.
10. Remove excess of the cement from occlusal and proximal surfaces with dental floss or Dental Tape. Leave dental floss in the interproximal spaces.
11. Polymerize the inlays briefly and check if the interproximal spaces are free from excessive cement and remove any excess. At this point the resin is easy to remove if it has not yet completely hardened. Nevertheless, the inlay is sufficiently attached and can therefore not be dislocated.
12. Polymerize the inlay completely: With light curing materials, cure for three minutes per tooth (one minute from each of the occlusal, buccal, and lingual surfaces).
13. Remove any additional excess.
14. Remove the rubber dam.
15. Finish the occlusal surface and check the occlusion.
16. Instruct the patient (home care, recall) and after two weeks check again in order to remove possible cement remains.

Immediate Inlays

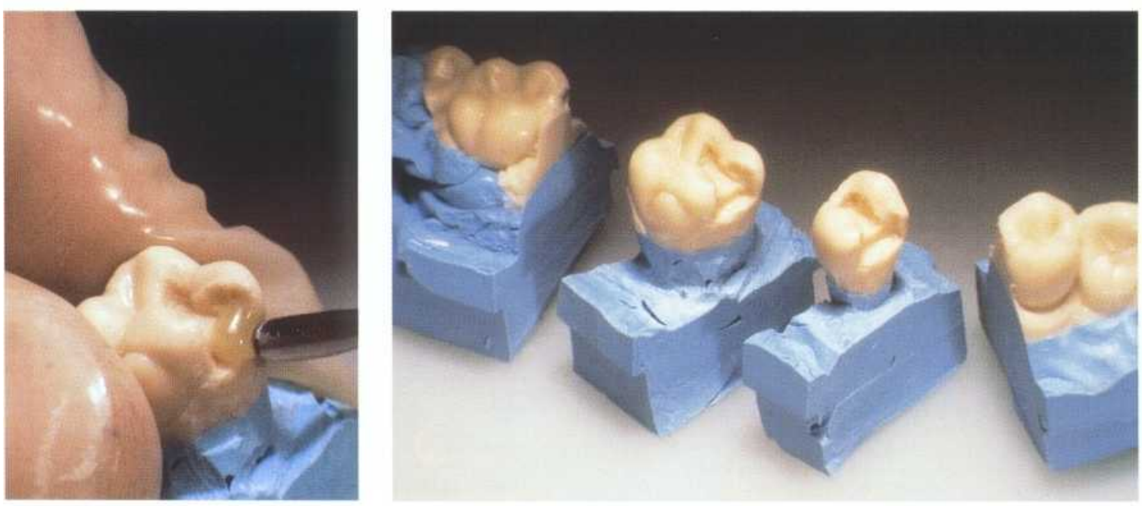
Many patients have large amalgam fillings which need to be replaced. Direct composites can be placed, but they require a great deal of time and patience. A skillful dental assistant who has been trained in the fabrication of such inlays can produce immediate inlays. The *procedure is* amazingly simple and takes only 6 to 20 minutes-shorter than a direct restoration:

1. Preparation as described on page 152f.
2. Make impression in alginate.
3. Pour impression with liquid, quick setting silicone and make a base with a solid silicone.
4. The dies are separated with a razor blade.
5. The composite is placed on these dies. Proximal surfaces, contact points (somewhat tighter shaped) and occlusion can be easily modeled. A counter-bite is not necessary.
6. It is not necessary to build the inlay up with several colors. (An IPS Empress Inlay is also a monochrome block.)
7. The inlay is finished-as described on page 157-in the same session and cemented.



316 Preparation of immediate inlays
An alginate impression is made of the inlay preparation and a flexible silicone model is made (Mach-2 System, Parcell).

Left: The individual dies are separated with a razor blade.



317 Die-manufacturing
Left: The composite material is placed and polymerized directly on the die. The individual die is repositioned to try out the contact points.

318 Polymerization and completion
The inlays are trimmed on occlusal and proximal surfaces (without opposing occlusal contact).

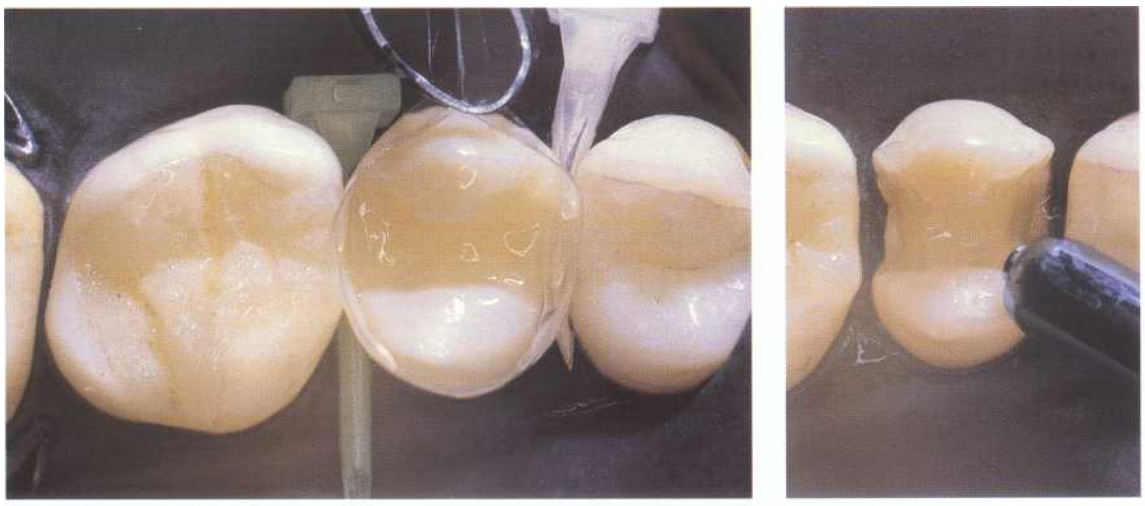
Left: After repeated curing of the inlay with the polymerization lamp, the inlay is attached with an adhesive. The occlusion should be adjusted after cementation.

Direct Composite Inlays

Mormann (1987) was the first to describe an inlay which is produced directly in the patient's mouth, refined extra-orally, completed and then adhesively bonded in the mouth. The aim was also to use the extraoral technique to eliminate the problems caused by polymerization shrinkage of the composite

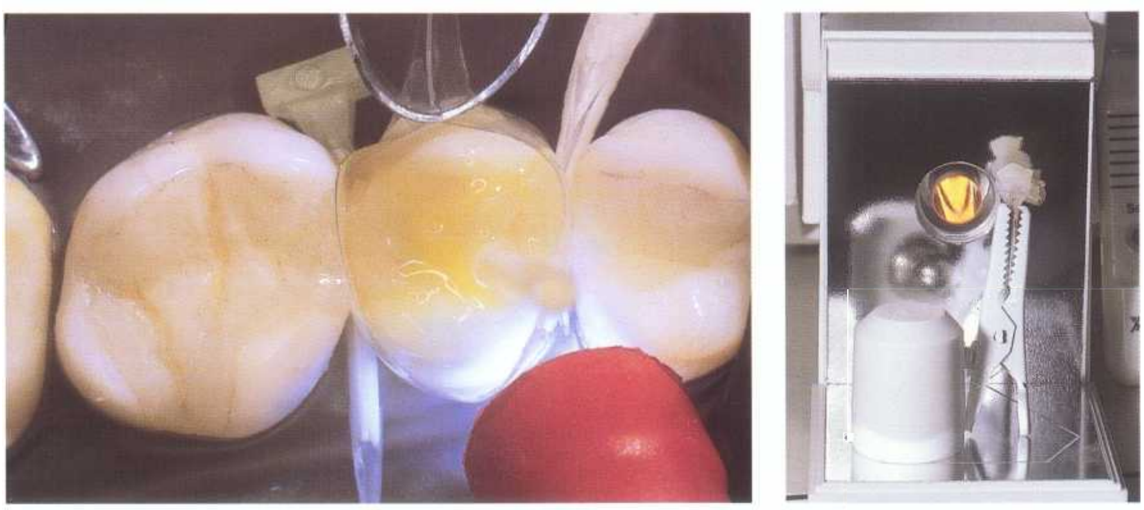
During preparation, it is important to make sure that no undercuts are formed. Also the inlay should be prepared somewhat more diverging (approx. 10'Q so it can be easily removed from the cavity. The cavity is carefully insulated after the preparation (insulating gel, Heraeus-Kulzer). After a transparent matrix is placed and wedged, the composite is placed in two to three layers and polymerized.

After the first polymerization the inlay is removed, pre-pared, and adhesively bonded.



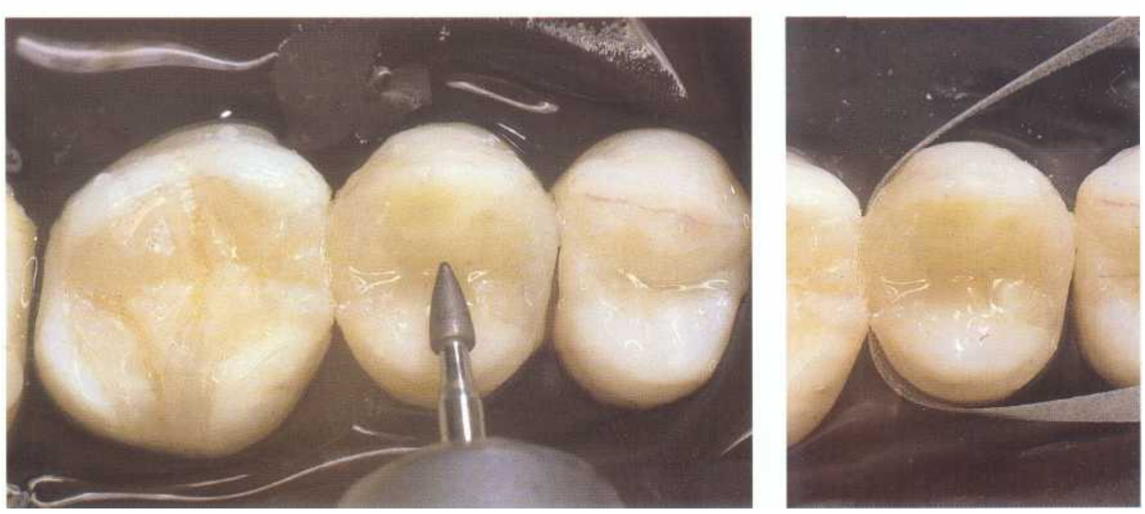
319 **Direct inlay**
After a matrix band has been placed, the composite is built up in the prepared cavity.

Right: The prepared cavity should be insulated with an insulating gel before the composite is placed.



320 **Polymerization and extraoral refinement**
The inlay is bonded to the cavity.

Right: After short prepolymerization, the inlay is removed from the cavity, whereupon it is refined extraorally and any adjustments are made.

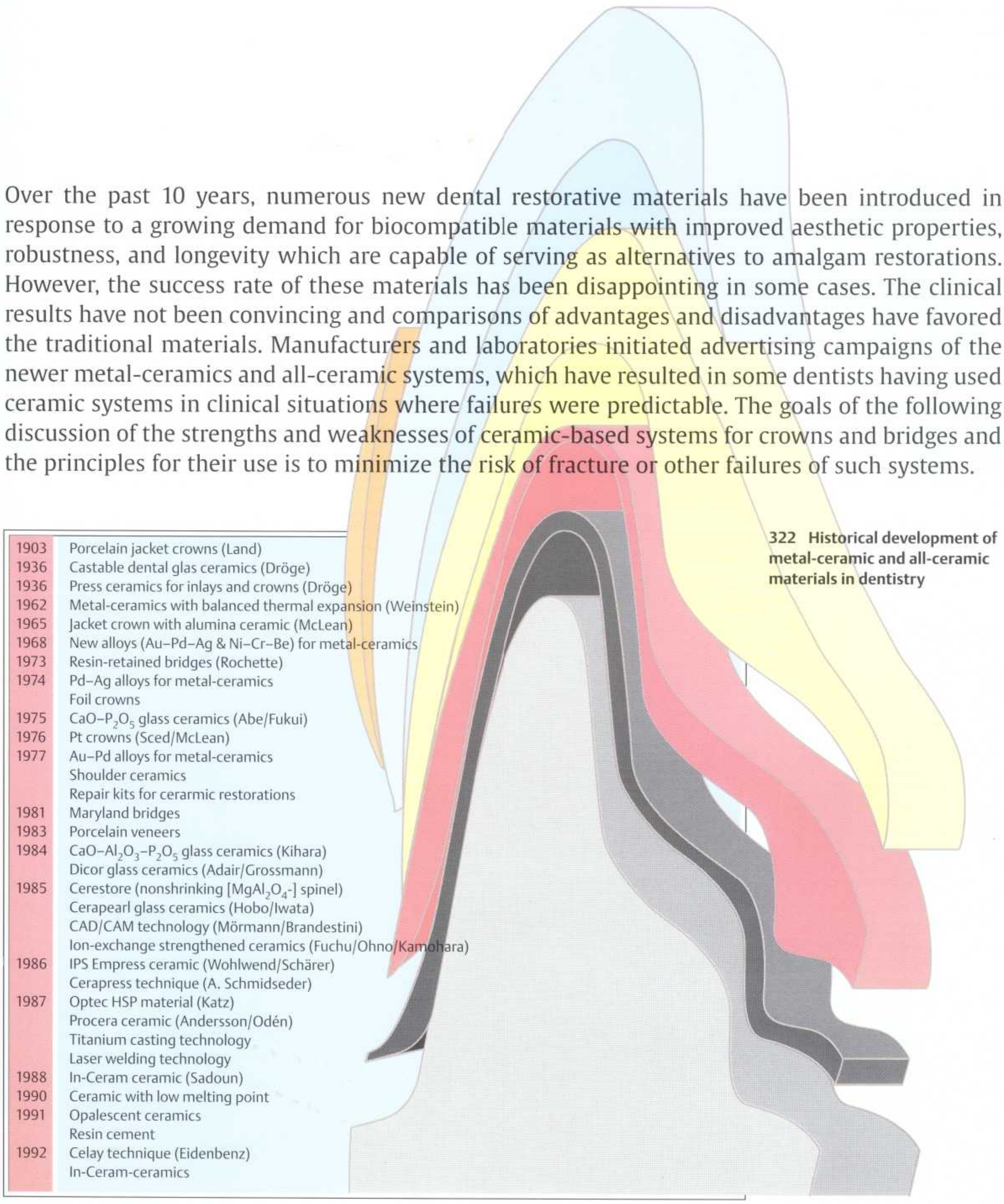


321 **Placing and finishing**
The finished composite inlay which was produced directly in the mouth is seen on tooth 15.

Right: After the inlay has been bonded, it is finished and polished.

Metal-Ceramic and All-Ceramic Restorations

Over the past 10 years, numerous new dental restorative materials have been introduced in response to a growing demand for biocompatible materials with improved aesthetic properties, robustness, and longevity which are capable of serving as alternatives to amalgam restorations. However, the success rate of these materials has been disappointing in some cases. The clinical results have not been convincing and comparisons of advantages and disadvantages have favored the traditional materials. Manufacturers and laboratories initiated advertising campaigns of the newer metal-ceramics and all-ceramic systems, which have resulted in some dentists having used ceramic systems in clinical situations where failures were predictable. The goals of the following discussion of the strengths and weaknesses of ceramic-based systems for crowns and bridges and the principles for their use is to minimize the risk of fracture or other failures of such systems.



1903	Porcelain jacket crowns (Land)
1936	Castable dental glas ceramics (Dröge)
1936	Press ceramics for inlays and crowns (Dröge)
1962	Metal-ceramics with balanced thermal expansion (Weinstein)
1965	Jacket crown with alumina ceramic (McLean)
1968	New alloys (Au–Pd–Ag & Ni–Cr–Be) for metal-ceramics
1973	Resin-retained bridges (Rochette)
1974	Pd–Ag alloys for metal-ceramics
	Foil crowns
1975	$CaO–P_2O_5$ glass ceramics (Abe/Fukui)
1976	Pt crowns (Sced/McLean)
1977	Au–Pd alloys for metal-ceramics
	Shoulder ceramics
	Repair kits for cerarmic restorations
1981	Maryland bridges
1983	Porcelain veneers
1984	$CaO–Al_2O_3–P_2O_5$ glass ceramics (Kihara)
	Dicor glass ceramics (Adair/Grossmann)
1985	Cerestore (nonshrinking [$MgAl_2O_4$-] spinel)
	Cerapearl glass ceramics (Hobo/Iwata)
	CAD/CAM technology (Mörmann/Brandestini)
	Ion-exchange strengthened ceramics (Fuchu/Ohno/Kamohara)
1986	IPS Empress ceramic (Wohlwend/Schärer)
	Cerapress technique (A. Schmidseder)
1987	Optec HSP material (Katz)
	Procera ceramic (Andersson/Odén)
	Titanium casting technology
	Laser welding technology
1988	In-Ceram ceramic (Sadoun)
1990	Ceramic with low melting point
1991	Opalescent ceramics
	Resin cement
1992	Celay technique (Eidenbenz)
	In-Ceram-ceramics

322 Historical development of metal-ceramic and all-ceramic materials in dentistry

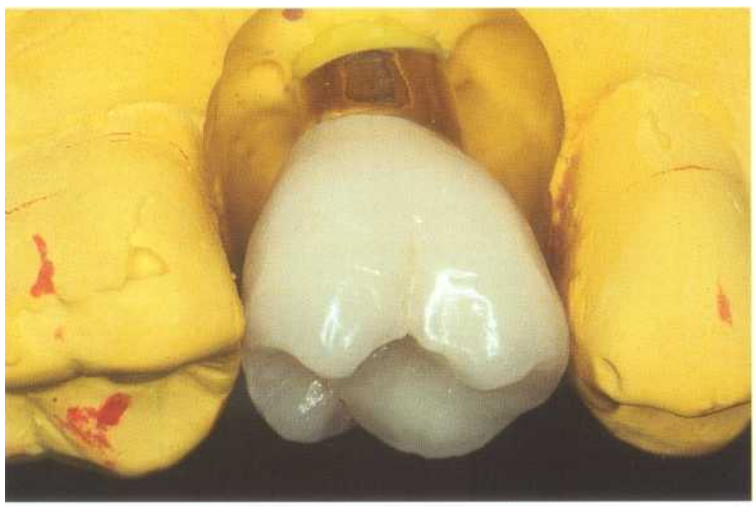
Metal-Ceramic Restorations

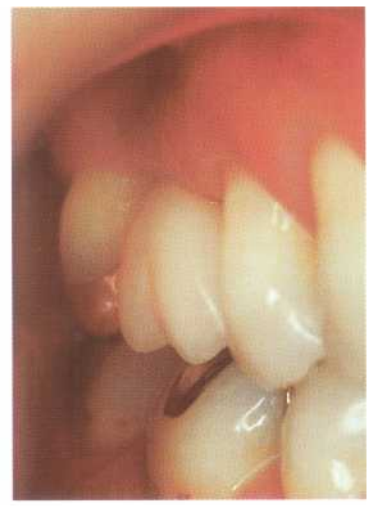
The biggest advantage of the ceramic restoration is its permanent aesthetic quality. Since there is a solid connection between the masking ceramic and the metal, almost no changes of color will occur in the ceramic construction.

A metal-ceramic crown that has been correctly produced is also more stable and more durable than a regular jacket crown. However, a metal-ceramic bridge involving several teeth can fracture and chip the ceramic under stress due to its inferior flexure strength. Because of this, it is very important to consider occlusal conditions when such a bridge is made.

Another advantage of metal-ceramic restorations, in contrast to all-ceramic restorations, is that less tooth substance needs to be removed to create enough space for the crown if metal is used to cover the occlusal and lingual as well as palatal surfaces.

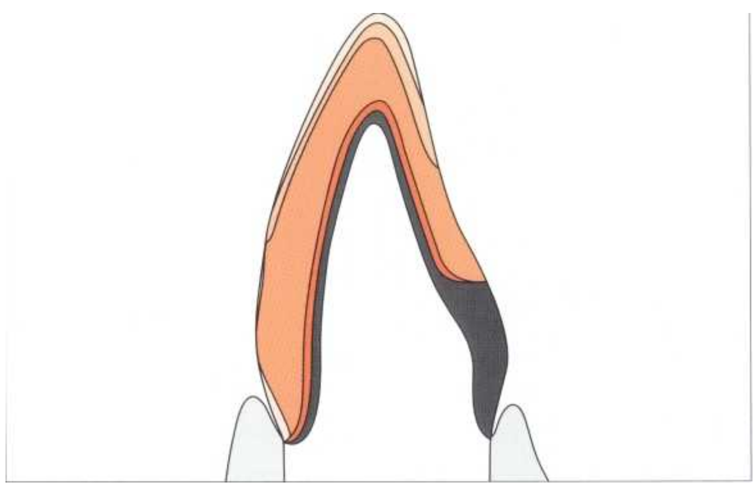
The flexural strength needs to be optimized to prevent a fracture of the ceramic. The modulus of elasticity of ceramics is relatively high, while both tensile and shear strengths are low and as a result the flexibility is low.



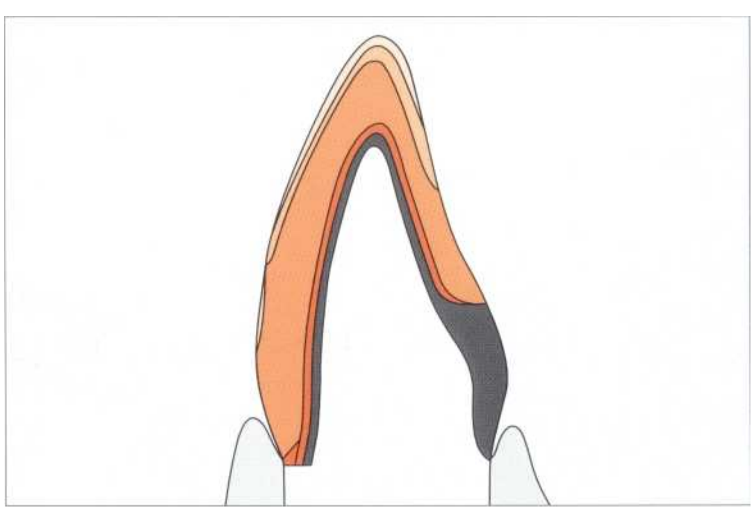


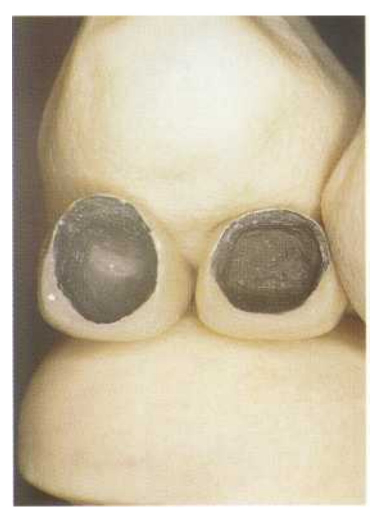
323 Metal-ceramic crown
Metal-ceramic is and remains the most important restorative material for crowns in the posterior regions. Metal-ceramic restorations are indispensible for implant-supported restorations.

Right: The same metal-ceramic crown on an implant in the mouth of the patient.



324 Structure of a metal-ceramic restoration
The metal framework of a metal-ceramic crown must support the sintered ceramic as much as possible. To prevent the dark metal framework from shining through, a layer of an opaquer must be placed and fired before the ceramic masses can be fired. This layer can lead to poor aesthetics if sufficient space is not available for the ceramic masses.





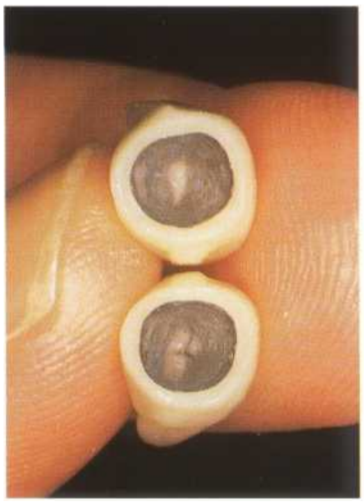
325 Structure of a metal-ceramic restoration with cervical ceramic margin
To improve gingival aesthetics (unsightly metal edges), the metal framework is shortened and an all-ceramic margin is made.

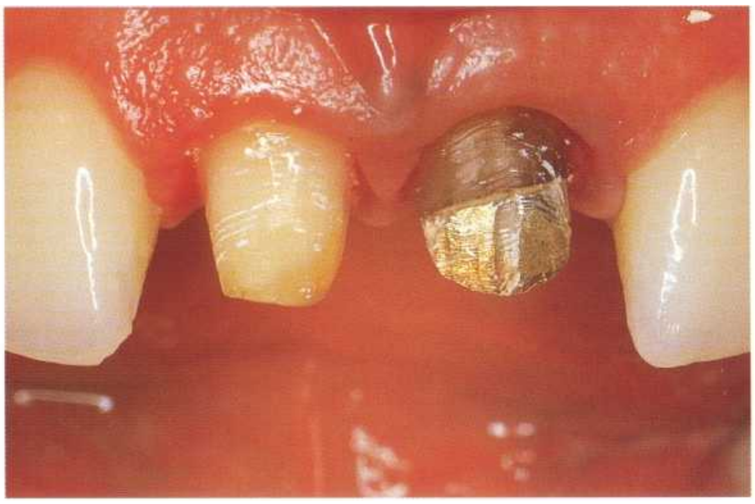
Right: If aesthetic demands are greater, one can make a labial short ceramic shoulder.

Stresses exceeding the proportional limit result in brittle failures. Accordingly, the ceramic can only resist limited elastic deformation. The metal framework must be rigid in order to support the ceramic sufficiently. Since the anatomical form of the crown must not differ from that of the natural tooth, more tooth substance must be cut away in order to produce sufficient space for the crown.

Despite some disadvantages, metal-ceramic restorations belong to the most common treatments with fixed prostheses.

The advantages and disadvantages of metal-ceramic restorations in comparison to all-ceramic systems are represented and summarized in Figure 327. An overview of the different all-ceramic systems as well as the advantages and disadvantages of all-ceramic crowns is presented on page 192.



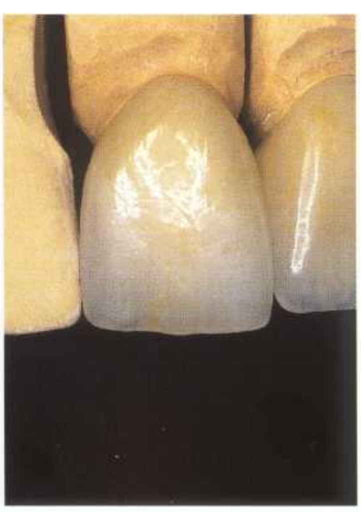


326 Metal-ceramic restorations with circular ceramic margin
Endodonticallytreated, strongly discolored teeth can best be treated with metal-ceramic restorations.

Left. **For the highest aesthetic requirements, a circular, all-ceramic margin can also be constructed.**

Advantages	Disadvantages
• Good to excellent aesthetics	• Potential metal allergy
• Excellent fit of the metal framework	• Unaesthetic metal margins
• Reliable solder joints on bridges	• Problems with translucency
• Less removal of tooth substance is often needed	• Chipping of ceramic margins
• More favorable cost–benefit ratio (durability)	• Wear of the antagonist
• Well-known technology, easier to apply	• High cost

327 Advantages and disadvantages of metal-ceramics



328 All-ceramic and metal-ceramic restorations
Over the next few years, bridges will continue to be made in the posterior regions in metal-ceramics because no all-ceramic system is yet available on the market that has proved longevity for such treatments.

Left: **If metal-ceramic crowns are directly adjacent to all-ceramic restorations (e.g., veneers), the different optical qualities of the two materials are obvious under certain lighting conditions.**

Clinical Success of Metal-Ceramics

Metal-ceramic restorations have, compared with all-ceramic crowns and bridges, a much lower risk of fracture. Further advantages include excellent to outstanding aesthetic results and longevity. Metal-ceramic crowns and bridges show success rates of 97% during the first seven and a half years. After 10 years, 95% of the metal-ceramic restorations are still present in the oral cavity.

Established metal-ceramics systems can be applied successfully as long as two basic principles are fulfilled:
- compatibility of the materials (thermal compatibility and ceramic bonding ability) as well as
- proper framework-design and material processing

However, the success rate after seven and a half years refers only to noble metal alloys with a gold content of at least 40% as well as castings with conventional metal margins. Only a limited amount of information is available on crowns with ceramic shoulders. It may be possible that ceramic margins crack under high pressure and finally fracture. Data on metal-ceramic crowns that are built on titanium frameworks are not yet available. Therefore, the use of the latter crowns is recommended exclusively for the treatment of anterior teeth.

The Nature of Ceramic Tooth Restorations

Weak points in a ceramic construction include sharp angles, clear changes in the thickness of the ceramics, and high tensile stress levels in the ceramic framework. This is particularly true for ceramic bridges, which require the interdental spaces be carefully shaped and rounded. Tensile stresses are developed under occlusal force in these regions.

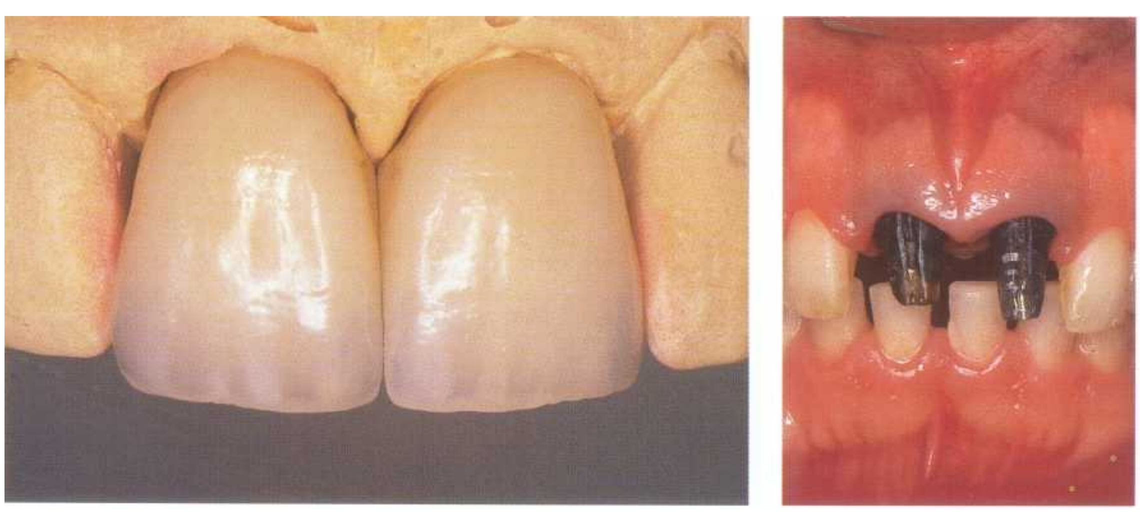
Ceramic shoulders improve the aesthetics in the gingival third of the metal-ceramic crown. However, the risk of fracture is increased, particularly with crowns in the molar regions.

Foil and electrochemically plated crowns enable improved aesthetics on the basis of the reduced metal thickness. However, they are also more susceptible to fracture than conventional metal-ceramic crowns. Commercial pure titanium, one of the most biocompatible metals, is also being used as the metal base. However, the latter procedure requires a ceramic with a very low melting point (850°C) and an extraordinarily low thermic expansion coefficient (≤ 8.5 · 10^{-6}/°C).

Thermal Compatibility

To protect the ceramic from cracking or fracturing due to thermally induced tensile stresses, the ceramic should be in slight compression before the final adjustments and trimmings are made. To induce such compression during the firing process, the *coefficient of thermal expansion* of the metal should in principle be slightly higher than that of the ceramic during the cooling process to room temperature. Such a small difference causes a certain amount of pressure in the ceramic and thus strengthens the restoration.

In the case of metal-ceramic restorations, the coefficients of thermal expansion of the ceramic and the metal are of particular interest in the 600-625 °C or 500-525 °C temperature range. Metal-ceramic systems that have a difference in the coefficients of thermal expansion (metal minus ceramic) of 0.5 · 10^{-6}/°C or less are acceptable. According to some experiments, it seems as if a somewhat higher difference up to 0.75 · 10^{-6}/°C can be used without the risk of cracks or fractures in the ceramic.



329 **Advantages of metal-ceramic restorations used on strongly discolored teeth**
Metal-ceramic crowns can cover strongly discolored teeth and can bring about an aesthetically appealing result.

Right: Initial situation consists of old metal post reconstructions that are very strongly discolored. These can no longer be removed. In this case a satisfactory result can only be achieved with metal-ceramic restorations.

The Ceramic-Metal Connection

One of the most important prerequisites for a successful metal-ceramic restoration is the lasting connection between the ceramic and the metal alloy and their thermal compatibility. The oxidation level of the alloy to a great extent determines its ability to form a lasting bond with the ceramic: alloys that produce a solid oxide layer during the degassing process can also produce a reliable bond to the ceramic. In contrast, alloys with a weak oxide layer form poor bonds with the ceramic.

Fractures of metal-ceramic restorations are rare. However, they may appear if one uses a new alloy, a new ceramic, or a new processing technique. Although there is a multiplicity of possible *fracture line locations,* below are three types that are particularly significant (Fig. 333):
- fracture lines in the opaque layer or between the opaque layer and the oxide layer
- fracture lines in the oxide layer
- fracture lines between metal and oxide layer

It is necessary to use 100 x magnification to recognize the location and cause of a fracture, since otherwise the fine transitions are not visible. Each of the above types of fracture line suggest material or processing failures. If the fracture is exclusively restricted to the ceramic, the failure is most likely due to high pressure, hyperocclusion, grinding of teeth, or larger defects present in the material structure.

To achieve a stable metal-ceramic bond on a cast metal framework, it is necessary to use an oxide generated by a basic metal component (e.g., indium or tin). This oxide layer is formed through a special thermal treatment method or during the first firing step of the opaquer.

Metal frameworks for foil and chemically plated crowns, such as the *Captek System* (Leach & Dillon), the *Renaissance System* (Unikorn), the *Ceplatec System* (Ceplatec) and other galvanic manufacturing processes, use a ceramic binder like the Capbond metal-ceramic agent for the Captek foil crown system (Leach & Dillon).

The gold-like color of the foil thimble improves the tone of the ceramic. A covering opaque layer is required with the normal dark oxides of the typical metal-ceramic alloys. Since one can vary the tone of gold from reddish-brown up to gray, this is an additional way of influencing the color of the ceramic.

Advantages and Disadvantages of Shoulder Ceramics

- Improved aesthetics
- Risk of fracture during cementation
- Restricted utilization in the labial region of upper incisors
- Special shoulder ceramic is necessary
- Higher cost

Tips For Reducing Fractures

- Perfect impression and die is needed
- Avoid using on molars under heavy stress
- Not suitable for bridges
- Use adhesive bonding technique (resin cements)

330 Advantages and disadvantages of shoulder ceramics used on metal-ceramic restorations (above) and tips on how to lower the risk of fracture of all-ceramic crowns and crowns with a ceramic shoulder (below)

Classification of Dental Ceramics

The following ceramics belong to the dental ceramic category: feldspar ceramics, leucite reinforced ceramics, ceramics with low melting point, glass ceramics, high-strength core masses (alumina), glass infiltrated alumina as well as CAD/CAM ceramics.

Dental ceramics are divided into different groups according to their chemical composition (feldspar, leucite, alumina, glass alumina, and glass ceramics), application (tooth reconstruction, ceramic-covering metals, veneers, inlays, crowns, and anterior bridges), the manufacturing procedure, or the structure of the material (cast metal, burnished metal foil, glass ceramics, CAD/CAM ceramic, and sintered ceramic core).

Sintering, pressing, casting, slip casting followed by glass infiltration, and machining (manually or computer-operated) are the different *manufacturing methods* that can be used for making ceramic restorations.

Classification of dental ceramics based on the *firing temperature:*
-high melting point: 1201-1450°C
-medium melting point: 1051-1200°C
-low melting point: 850-1050°C
-very low melting point: < 850°C

Ceramics with medium to high melting point are used for making teeth used in dentures, while low and very low melting point ceramics are used for crown and bridge constructions.

Ceramics with especially low melting points are used to cover titanium frameworks (or titanium alloys), since their coefficient of thermal expansion is close to that of the metal. These ceramics can also be used to cover certain low melting type IV gold alloys. However, some of the ceramics with a low melting point can also be used for conventional metal-ceramic alloys (highly noble, noble, or nonnoble metals), since they have sufficiently high coefficients of thermal expansion.

Two of the very low-fusing ceramics (Duceram-LFC and Duceragold) are the so-called *hydrothermal ceramics.* They owe their improved resistance to a hydrolytic shrinkage that occurs when hydroxyl ions interact during heat and steam impact. The glazing temperature of conventional ceramics is lowered by the addition of alkali oxides.

331 Classification of ceramic materials

Extremely Low Melting Point <870 °C	Low Melting Point All-Ceramics 870–1050 °C	Low Melting Point Metal-Ceramics 870–11050 °C	Medium Melting Point 1051–1200 °C	High Melting Point 1201–1450 °C
• Duceram LFC (660–680 °C)	• Vita Alpha for In-Ceram and In-Ceram Spinell	• Biobond	• Denture teeth	• Denture teeth
• Duceratin (Ti) (700–750 °C)	• Empress Ceramics for IPS Empress	• Ceramco		
• Procera ATI 24 & ATI 30	• Optimal for OPC	• Ceramco II		
• Carrara Bodx Porcelain (830–850 °C)		• Ceramco Silver		
• Noritake TL-22		• Creation		
• Vitas Omega 800 (800 °C)		• Excelco		
• Ceramco finesse (770 °C)		• Ivoclar/Willias IPS Classic		
		• Jelenkos		
		• Jeneric/Pentrons Synspar		
		• Ney		
		• Noritake		
		• Shofu Crystar		
		• Vincent		
		• 3M Vintage		
		• Vita Omega		
		• VMK-68		
		• VMK-68N		
		• Will-Ceram		

However, the chemical and hydrolytic stability decreases with increased amount of alkali oxides (above a certain concentration). In addition, decreased fracture resistance occurs due to the presence of new inclusions. With low-fusing ceramics, the hydroxyl enriched surface makes the ceramic more flexible and allows the repair of surface inclusions.

Dental ceramics are classified into different types. A simple classification that is based on the application type is shown in Figure 331. Here, different brand names are also given for each group. The general qualities of these materials, their clinical advantages, and disadvantages as well as the steps in processing them will be reviewed in the following sections.

Ceramic products such as colors and *glazes will* here be classified as class 4 ceramics and will not be discussed further, since they do not have any significant effects on strength and fracture resistance of ceramic restorations.

As far as chemical durability is concerned, self-glazing ceramics are preferred over glazing masses. A higher concentration of glass modifiers reduces the resistance of the applied surface glaze compared to the normal surface glaze of the ceramic. During glazing a thin outer layer is formed. A certain temperature and treatment time leads to the formation of a softer glass phase and to the formation of crystalline particles within the surface region.

Water is another important glass modifier, although it is not one of the intended additives present in ceramics. In ceramics that contain glass modifiers, such as sodium or other metal ions, these ions can be replaced with hydronium ions. This phenomenon can result in slow crack propagation in the ceramic if it is exposed to tensile stresses or a moist surrounding. Also, this may be the reason why ceramic restorations fracture after some years without a recognizable reason.

Strength and Risk of Fracture of Ceramics

Ceramic materials do not show the strength one would expect from their molecular structure. Small defects, for example scratches, can be found on the *surface* of almost any material and these scratches are the reason for the lower strength. Such surface defects are comparable to sharp cuts with crack tips that can be as narrow as the distance between two atoms. The stress concentration that results from the defect results in a local increase in tensile stress. However, the theoretical strength of the material is based on the assumption that there is an even distribution of stresses in the entire structure. If the tensile stress exceeds the strength limit at the tip of a defect, the chemical bond breaks at this tip, and a crack starts propagating. The tensile stress at the tip of the crack remains until the crack has propagated through the entire material or has reached another crack, a pore, or a crystalline particle, so that compression occurs and the stresses are distributed. This phenomenon explains why some materials fail at pressures far below their theoretical strength values.

The failure of ceramics and their low tensile strength values can be explained on the basis of how stress concentrations are generated at surface inclusions. Under certain conditions, inclusions can also initiate cracks *within* the material. Since ceramics have no other stress distribution mechanism available to deal with tensile loads besides crack growth, cracks can continue to grow under low pressure conditions through the entire material. Therefore the *flexure strength* of ceramics and glass is essentially *lower than their compressive strength.*

Complex stresses develop in the mouth. The maximum pressure appears at the surface of the restoration. Therefore, surface inclusions are especially important in judging the strength of a ceramic. Removing or reducing the number of surface inclusions can result in a considerable improvement of the fracture resistance. This is one of the reasons why it is necessary to polish and glaze dental ceramics. The fracture strength of the material can be improved in two ways:

- through introducing a compressive stress within the material surface, and
- through interrupting crack propagation in the material.

Procedures For Strengthening Ceramics

Pressure Induced by Residual Compressive Stresses

A commonly used procedure for strengthening ceramics is to introduce compressive residual stresses within the material surface. To do so, one selects ceramics that have a smaller thermal expansion coefficient than the metal.

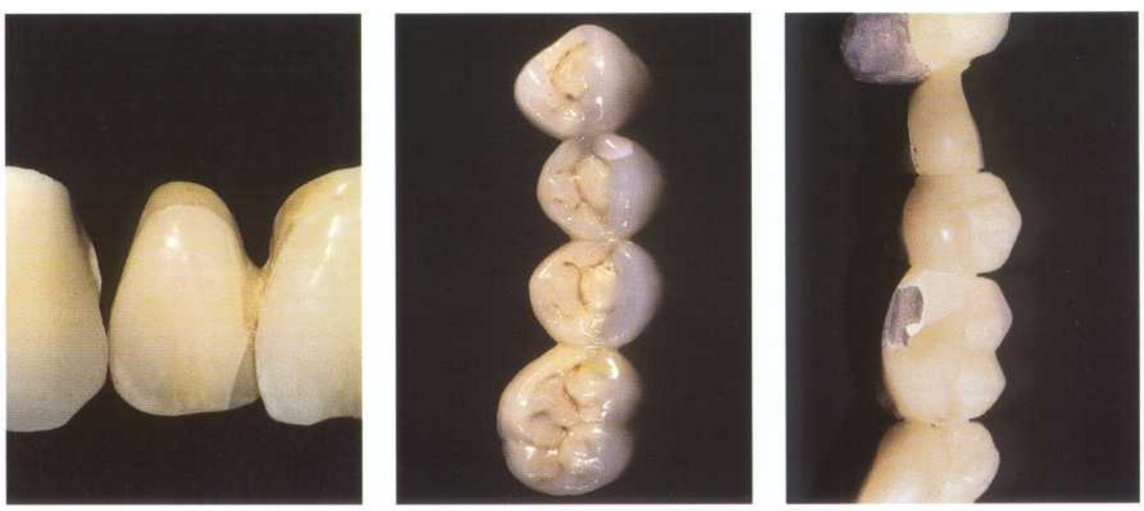
Ion exchange

Ion exchange is an effective method used to generate compressive stresses in the ceramic surface. The procedure is also called *chemical hardening* and includes sodium-ion exchange. Sodium is a common component in many glass types and has a relatively small ion radius. If one places glass which contains sodium into a bath containing melted potassium nitrate, sodium ions on the glass surface are replaced by potassium ions. Because the radius of the potassium ion is larger than the radius of the sodium ion by approximately 35%, the potassium ion will occupy a larger volume when it enters the surface and the material surface will increase its surface compression level.

GC Tuf-Coat (GC Corp.) is a potassium-rich substance that reacts well with ceramic surfaces. When heating (30 minutes at 450'C), a sufficient amount of exchange occurs between potassium ions and the sodium ions at the ceramics surface. The flexure strength can be increased by up to 100% with some current ceramics products, assuming they contain a sufficient amount of sodium ions.

Addition of Crystalline Particles Which Inhibit Cracks

Ceramics and glasses can be strengthened by the addition of particles which inhibit cracks. These prevent cracks from propagating through the entire ceramic because the particles are not as easy to split as the ceramic or the glass. This explains the higher fracture resistance found in almost all newer, stronger ceramics. Such strengthening is achieved, for example, with an increase in the crystalline amount of leucite ($K_2O \cdot Al_2O_3 \cdot 4\,SiO_2$) or alumina ($Al_2O_3$). Most ceramics with a matrix which contains glass can be strengthened in this way. In dentistry, this technology has been used with the alumina ceramics (Al_2O_3 particle in a ceramic matrix containing glass) in jacket crowns.

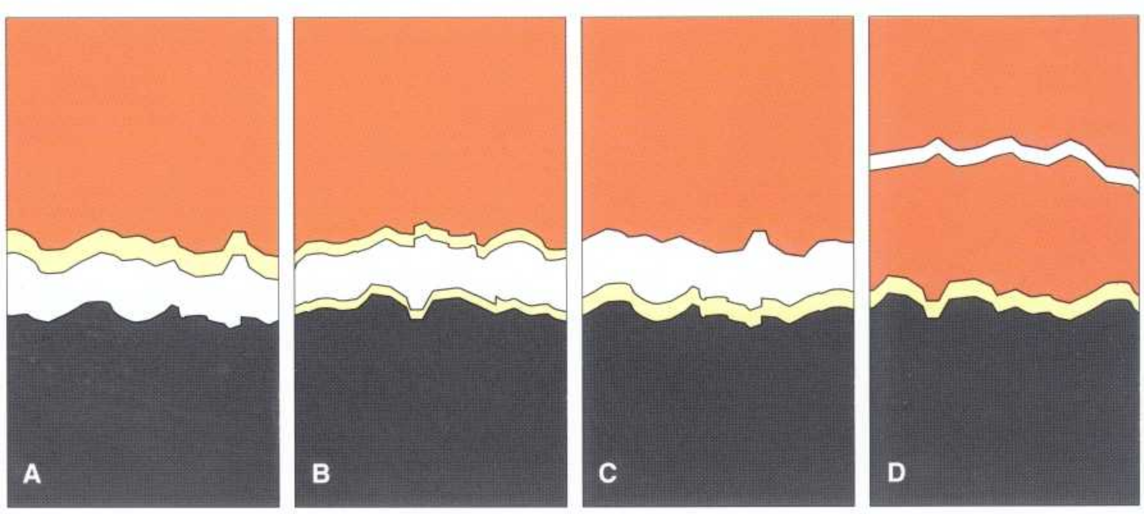


332 Fractures seen in metal-ceramic restorations
All-ceramic restorations have small microscopic defects. Through continuous pressure, these defects grow larger over time and lead to fractures within the ceramic.

Left: Stress failure.

Middle: Fracture caused by occlusal trauma.

Right: Fracture within the opaque layer.



333 Type of ceramic fracture
- A The opaque layer (yellow) and the ceramic layer are loose (red-brown).
- B The fracture is within the opaque layer.
- C The opaque layer remains on the metal (black) and the ceramic is coming off the opaque layer.
- D The fracture is within the bulk ceramic.

The firing process can be improved after one has microscopically analyzed the fracture surface.

Minimizing Failures with Metal-Ceramic Restorations

Minimizing Tensile Failures

Harder and more stable ceramics resist higher pressure without crack formation. Conventional feldspar ceramics should no longer be used as all-ceramic crowns, particularly not in the posterior regions, because such usage can result in the appearance of occlusal force that exceeds the tolerable tensile stress levels.

Tensile stresses that are concentrated at the surfaces of posterior crowns are particularly significant. Sharp edges induced during preparation also cause areas with high tensile stress within the restoration, particularly when these regions have to resist bending forces. Small inclusions located at the inner ceramic margins of a crown also lead to high local tensile stresses. Therefore, the ceramic surface must be checked very carefully before cementing. If the inner surface has to be ground to improve the fit, one should grind away the interferences with the finest grain size diamonds.

Because front teeth are exposed to relatively low levels of pressure that generate low-average tensile stress levels, all-ceramic crowns are suitable here. However, if a big vertical overbite meets with an only average overjet, great stress can arise.

A metal-ceramic crown consists of a metal cap on which the ceramic is fired. The metal minimizes the flexibility of the ceramic structure of the crown that is in immediate contact with the stressed region.

Highly polished ceramics resist 100 to 200 times higher tensile stress than nonpolished ceramics. Surface defects increase the tension at the tip of the inclusion. Deeper grooves or scratches lead to an increase in tensile stress levels.

Minimizing the Number of Firing Cycles

The goal of ceramic firing is to achieve denser sintering of the powder particles and to manufacture a relatively smooth, glassy layer on the surface. In some cases, a layer of color is fired to adapt to the color of the natural teeth or to simulate color lines or craze lines. During firing, different chemical reactions occur, of which the most important one is the increase in concentration of crystalline leucite crystals in the ceramics.

Leucite ($K_2O \cdot Al_2O_3 \cdot 4SiO_2$) is a crystal that has a high thermal expansion. The leucite crystal permanently influences the coefficient of thermal expansion of the ceramic. Several firing steps clearly increase the leucite content, which could cause a disparity in the coefficients of thermal expansion between ceramic and metal. During the cooling phase, this can lead to tension that finally causes cracks in the ceramic.

334 Allergic reaction to metal
More and more people are developing hypersensitivity to metal alloys. This patient reacted strongly to a highly noble metal-ceramic alloy.

Glazing

All-ceramics, metal-ceramic crowns and veneers should appear like natural teeth. The firing temperatures of the glazes are lowered by adding glass modifiers, which, however, impairs the chemical resistance of the glazes. Ceramic colors are available as thinned glazes of the same chemical degradation ability. However, most of the presently available glazes are resistant against dissolution if they are at least 50 pm thick.

To make sure that the selected color remains stable, one can layer the ceramics. A good layering technique gives the construction a very natural appearance, particularly if enamel cracks and other characteristics are brought into the ceramic instead of on the surface only. The drawback of this procedure though is that the entire ceramic must be removed if it does not correspond to the color or the description one had expected.

For rough ceramic surfaces a self-glazing procedure is recommended, since strength increases in contrast to unglazed ceramics. The glaze also decreases the risk of crack propagation. If the glaze is removed by grinding, the strength is reduced by half in comparison to a surface with intact glaze layer.

Polishing

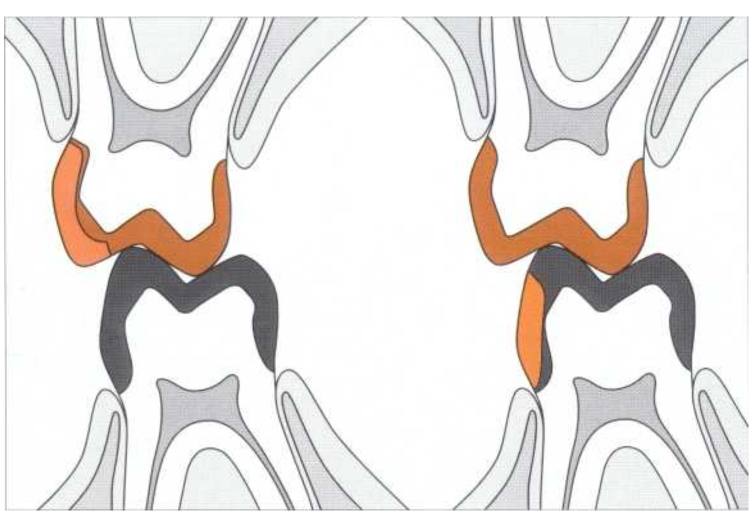
As studies have shown, certain ceramics with highly polished surfaces have comparable strength to similar ceramics that are both polished and glazed. This observation is of clinical importance, because it is common practice to adjust the occlusion by grinding the ceramic surface after the ceramic crown has been cemented. By doing so, the glaze is removed and a relatively rough surface exposed that weakens the ceramic significantly. In order to cope with this problem, the surface is polished with Soflex finishing disks (3M) or polishing tips (Shofu Dental ceramics laminate polishing kit) and diamond polishing paste. A smooth surface also reduces the abrasion on the opposing teeth.

Laboratory Control of Cooling

Proper cooling of the ceramic restoration from the firing temperature to room temperature is very important, particularly if the coefficient of thermal expansion of the ceramic is higher than that of the metal. In this case, faster cooling is desirable in order to minimize tensile stresses that arise during the cooling.

If a more stable material is used as a core in an all-ceramics crown and if there is a stable bond with the outer ceramic, cracks can occur only if the stronger inner material is deformed or broken. The fracture risk of the entire ceramic can be reduced to a minimum if the process is carried out properly and if the physical properties of the ceramic and the subconstruction are well balanced.

The metal-ceramic substructure is a cast metal base. However, new, noncast metal bases are increasingly being used.



335 Avoiding ceramic fractures in areas exposed to high chewing forces
If it is acceptable aesthetically, occlusal surfaces that carry great bite forces (e.g., due to bruxism) should largely be shaped in metal. This is only possible in the region of the first or second molars.

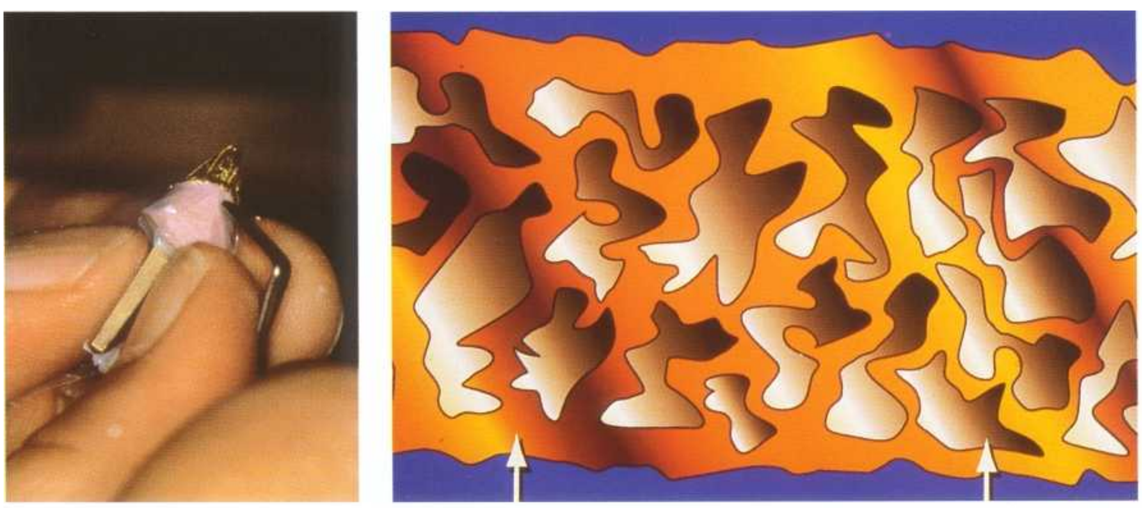
Foil and Electrochemically Plated Crowns

Renaissance and Ceplatek

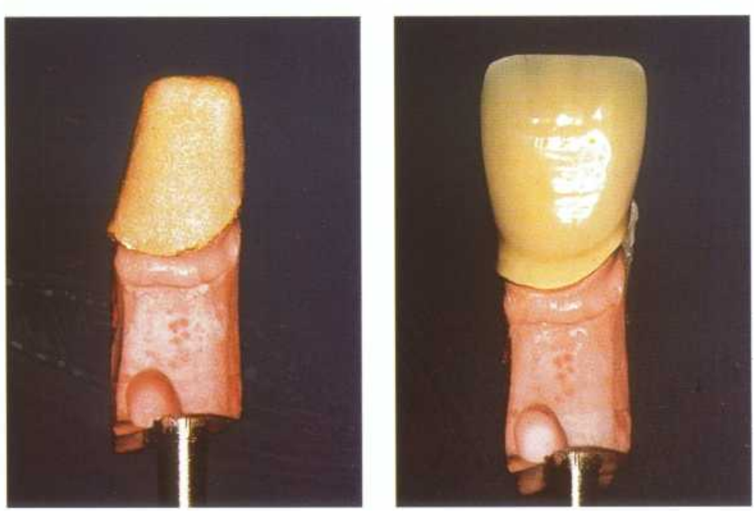
Foil crowns are a new concept for producing metal-ceramic crowns in a shorter time by eliminating the casting process. Renaissance and Ceplatek are both systems that have eliminated glazing and casting. A three-layered, gold alloyed (gold/platinum/palladium) foil that is shaped like a miniaturized coffee filter forms the initial material. It is shaped with a suitable hand-held instrument, highly polished, and then heated over a Bunsen burner. During this process a stable bond is formed between the folds formed, resulting in a cap with sufficient strength. An alloy powder is used as a foil coater, which is burned and fused to the surface of the foil. The cap is coated with feldspar ceramic that is condensed and sintered at the usual ceramic firing temperature. The only *indication* for foil crowns is for treating a single anterior tooth. They are not used in the posterior area due to their lower fracture resistance. The caps can be covered with any thermal compatible ceramic. The occlusion should be adjusted with diamonds or stones, whilst being water cooled, to produce smooth surfaces. The grinding and polishing procedure is first done with flexible rubber disks or cones, whereupon the surface is finished with felt tips and diamond polishing pastes.

Captek

The metal base is produced by shaping polished strips of Captek P (gold/platinum/palladium) on a hard plaster model and then sintering them at 1075 °C. Adaptation is achieved with strips of Captelc G (pure gold) that are placed and again burned at 1075 °C. The porous metal structure joins through capillary migration of the melted gold. Pontics are prepared from precast 2% gold-palladium elements. The pontics are placed on the master cast between the tooth preparations and a soldering model is made. A liquid which has the composition of the Captelc P layer, is placed in the interdental regions. Then a strip of Captek G is placed over it and accordingly burned in the oven on the soldering model. This system is suitable for inlays, onlays, anterior and posterior crowns, and for small bridges (exposed to low pressure). The Captelc units are covered with a ceramic with a low melting point. Ceramics with very low melting point can also be used. Like the conventional metal-ceramic crowns, every cement type can be used. Shaping and polishing is done with the usual materials and techniques.



336 Foil and electrochemically plated crowns
The illustration shows the structure of a gold foil with embedded crystalline gold particles. When Ceplatek and Renaissance crowns are made, such gold foils are placed on the die of the prepared tooth. They form relatively stable frameworks that after processing are covered with ceramic masses. Only indication: single front crowns. *Left:* Instead of using a foil, as shown here, the gold framework can be fabricated by electrochemical plating.



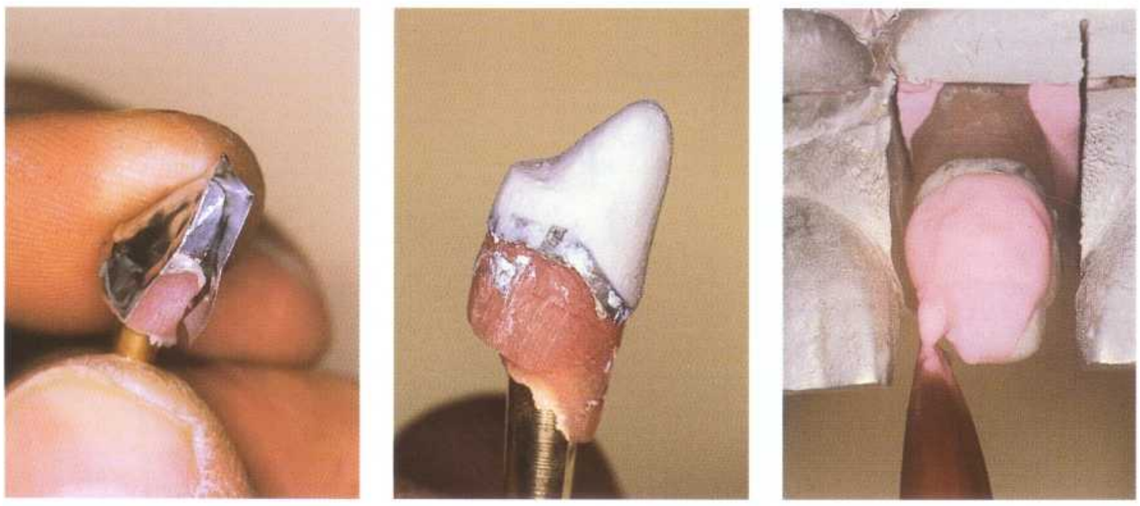
337 Swaged crowns
Today, the gold framework is usually plated electrochemically on a die.

Left: After application of an adhesive mediator, the crown is covered with ceramic masses.

Right: Finished crown.

All-Ceramic Crowns

According to statistics published in 1994, 90% of all cemented restorations are made as metal-ceramic crowns or bridges. However, the all-ceramic products have recently been catching up, which is due to improved strength and outstanding aesthetics. Although the ceramic jacket crown has been available since the beginning of the 20th century and its use has been widely spread, the low fracture resistance has limited its application to anterior teeth, premolars, and molars under low pressure. Contrary to conventional ceramics strenghtened with leucite, the new jacket crowns have significantly improved strength properties because of their reinforcing core. This applies particularly to the products In-Ceram, Procera AllCeram and In-Ceram Spinell. In general, all-ceramic crowns placed on front teeth clearly have better aesthetics than metal-ceramic crowns. Therefore, reinforced ceramics are preferred for manufacturing jacket crowns. However, most of these ceramics are not yet suitable for molars.



338 Pt crowns
Left: McLean first described the aluminia-reinforced Pt crown in 1965. First, a platinum foil is placed and burnished to adapt to the die.

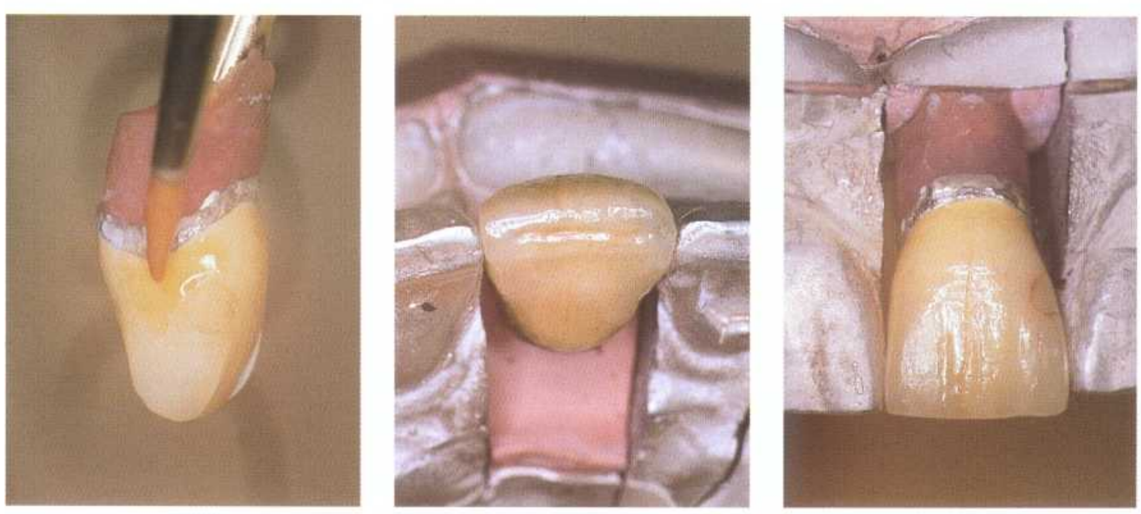
Middle: A layer of very solid alumina ceramic is placed on the platinum foil.

Right: The alumina framework is afterwards covered with feldspar ceramic masses in layers.

339 Lateral layer technique
Left. As McLean showed, an aesthetic restoration can only be achieved with a skillful ceramic layering technique.

Middle: After the dentin mass has been placed, enamel masses of different transparencies are layered.

Right: Effects are placed into the ceramic and not simply placed on the surface using colors for effects.



340 Characterization
Left: Proximal effects can be generated with additional stains.

Middle: Fired and finished Pt crown.

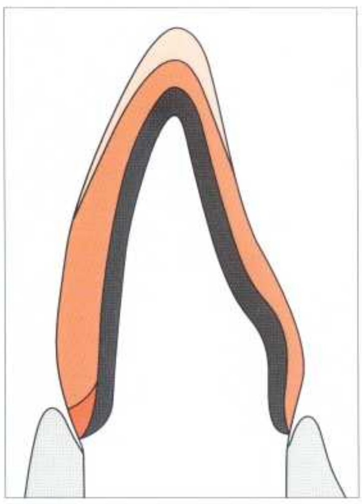
Right: As the finished Pt crown shows, a not too highly fired and subsequently manually polished surface gives a very natural impression.

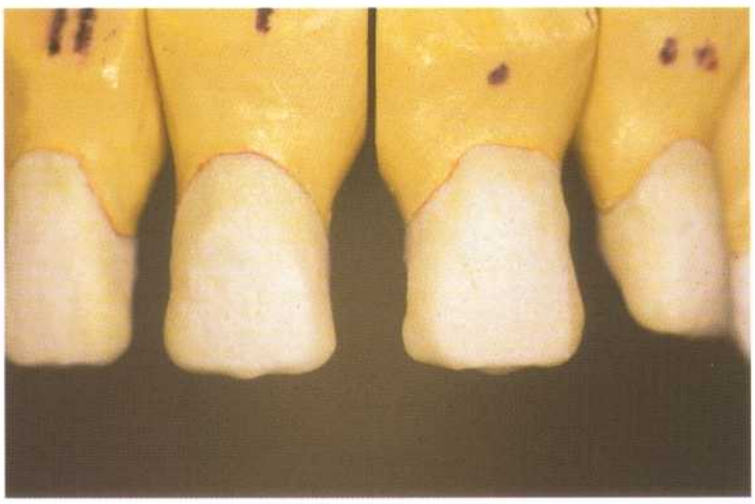
Dental technician: *M. Kedge*

Alumina Ceramic Crowns (Vita Hi-Ceram, Vitadur Alpha)

Before the introduction of the In-Ceram system, alumina ceramics had limited success as cemented restorations because of the low flexural strength and the large shrinkage that occurred during sintering. The *main indications* for alumina-based ceramics are treating front teeth, metal allergies, and where a better aesthetic result is required than that which is achieved with metal-ceramic crowns.

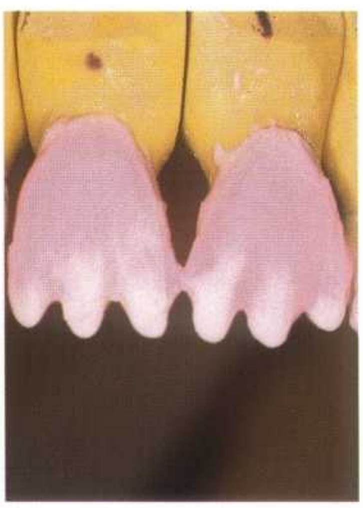
Hi-Ceram crown: The condensed ceramic mass is fired on a platinum foil (Pt crown) or a refractive die material to produce the core. The core is covered with Vitadur Alpha ceramic. Hi-Ceram can be used for inlays and single crowns. Primary indications include front teeth or occlusion-free teeth in the premolar/molar regions. Particularly in the posterior regions the durability is substantially improved if the restoration is bonded with resin cement. Occlusal adjustments take place under water cooling with fine diamonds or smooth stones. The final polish is done with flexible rubber disks or cups, after which it is polished with felt cones and diamond polishing paste.





341 **Hi-Ceram crown**
The alumina core is not processed like the Pt crown on a platinum foil, but produced on a refractory die and then transferred to the master model.

Left. An alumina core is made on a refractory die and covered with different feldspar ceramic masses.



342 **Covering the alumina core**
Even at the raw firing stage the crowns reveal the problem with this technique: the ceramic is very opaque.

Left. The ceramic is built on the alumina core by means of the lateral layering technique.

343 **Glazed and finished crowns**
The ceramic shows only a slight transparency.

Dental technician: A. *Schmidseder*

Dicor Glass Ceramic Crowns

Glass ceramic is molded as a glass and then heat-treated to produce a crystal structure inside the glass structure, a process which is called *"ceramming."* The crystalline particles that are formed by this process prevent cracks from propagating through the material and simultaneously increase strength and hardness. However, since the glass ceramics consist of 55% crystal phase and of 45% glass phase, the ability to block crack growth is limited. The reinforcing effect that is achieved by the crystallization is thus restricted.

Dicor, a glass ceramic, shows outstanding aesthetic results attributed to the *chameleon effect.* The chameleon effect is caused by colors being transferred through the ceramic from both the neighboring teeth and from the colored bonding cement.

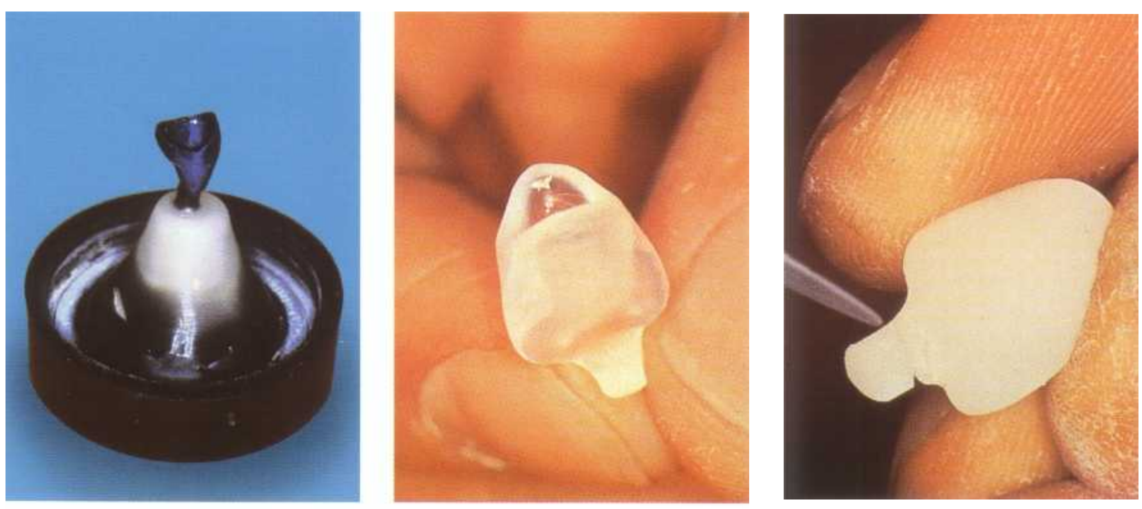
Indications for Dicor glass ceramics are inlays, veneers, and single crowns on anterior teeth. Another indication is the single crown on a posterior tooth exposed to low to medium stress forces.

The Dicor glass ceramic can also be covered with Vitadur Alpha covering ceramics.

A great advantage of Dicor is that the material has very little abrasive ability on the antagonist. This is attributed to the very small crystal size (1-4 um). The advantage is, of course, lost if the crown is painted and characterized with feldspar ceramics.

A resin bonding procedure is recommended with posterior teeth. A higher fracture resistance can be achieved with a dual-curing resin cement.

Occlusal adjustments take place, under water cooling, with fine diamonds or stones with smooth surfaces. The final polish is done with flexible rubber disks or cups, whereupon the surface is polished with felt cones and diamond polishing pastes.

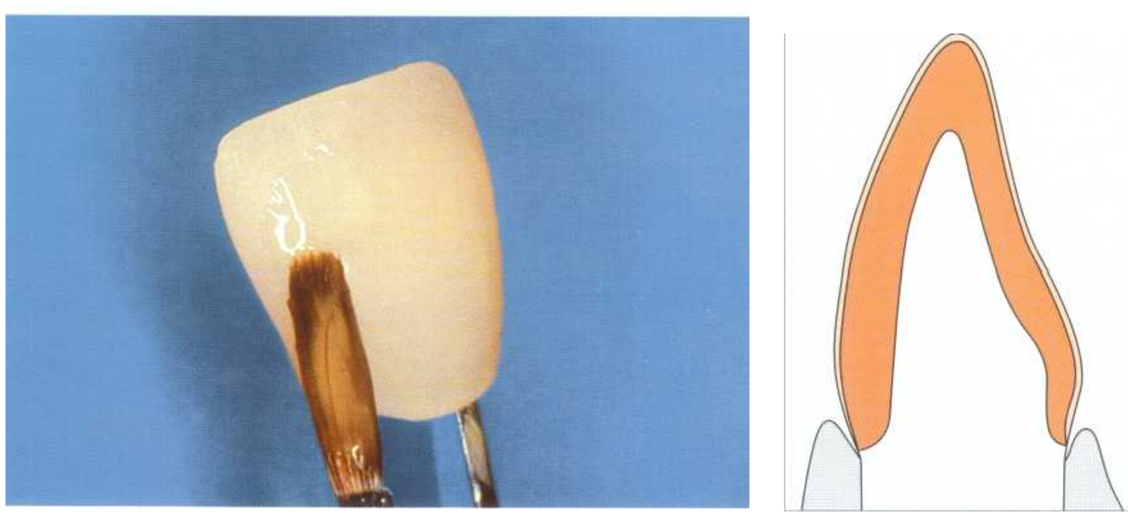


344 Cast glass ceramic crown
Dicor was one of the first commercially available cast glass ceramic systems.

Left: The crown is modeled in wax, embedded, and cast in glass.

Middle: The cast glass crown is crystal clear.

Right: In another step, the crown must be cerammed. Crystallization agents present in the glass enable this.



345 Painting the crown
The cerammed crown is painted afterwards. This has a crucial disadvantage: although industry had promised color stability for 15 to 20 years, a loss of color is possible through abrasion.
As Dicor has thus shown, one should not blindly believe results from in vitro studies.

Right: Dicor has only a superficial color layer on a monochrome ceramic framework.

Leucite Reinforced Ceramics (Optec HSP)

Optec HSP is a leucite reinforced feldspar ceramic that condenses like alumina ceramics and is sintered like traditional feldspar ceramics. The manufacturing process is done on refractive dies. Because of the moderately opaque core, this ceramic is more transparent than crowns made on aluminium oxide cores or with glass/aluminium oxide cores. Because of its being enriched with leucite crystals, Optec HSP is more stable and has a higher modulus of elasticity than conventional feldspar-based ceramics.

The *advantages* are:

-no metallic or opaquing substructure
-excellent transparency
-average flexural strength
-the possibility of malting reconstructions without special laboratory equipment

The *disadvantages* are:

-increased fracture tendency in the posterior tooth region
-possible marginal imperfections due to shrinkage induced during sintering

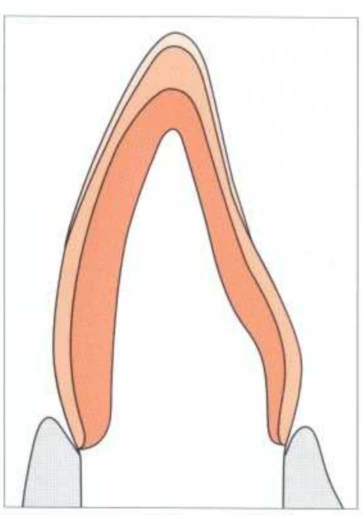
Leucite reinforced ceramics shrink after densification and sintering that occurs during firing. Therefore, the fit of these crowns is not as good as that of metal-ceramic crowns. Optec HSP contains a higher concentration of leucite crystals than feldspar ceramics. Due to the opacity caused by leucite crystals, it is not necessary to apply core ceramics. Before cementing, the restoration is sandblasted to improve the retention with the resin cement. The outer layer consists of conventional ceramics, so that this layer shows a more inferior fracture resistance than the leucite reinforced ceramic core.

Optec HSP can be used for anterior crowns and veneers as well as for inlays, onlays, and crowns in the posterior regions with low pressure. Resin bonding is recommended for the posterior region. However, since a higher fracture resistance can be achieved by dual-curing resin cement, this is recommended.

The occlusal adjustments are done, under water-cooling, with fine diamonds or stones with smooth surfaces. The final polish is done with flexible rubber disks or cups and completed with felt cones and diamond polishing pastes.

346 Leucite reinforced porcelain crown
The Optec HSP System was the first to use leucite reinforced ceramic masses for crowns, inlays, and veneers. Here is a finished Optec HSP incisor crown.

Left: Leucite reinforced ceramic mass used for making veneers.



347 Cross section through an Optec HSP crown
Optec HSP crown cemented with a resin cement on a premolar and a molar. The physical qualities of this technology allow the use of these restorations in the molar regions only if there is no high pressure from chewing (e.g., in contact with a partial denture).

Left. Optec HSP ceramic contains more leucite crystals than conventional feldspar ceramics. The crown is covered with conventional feldspar.

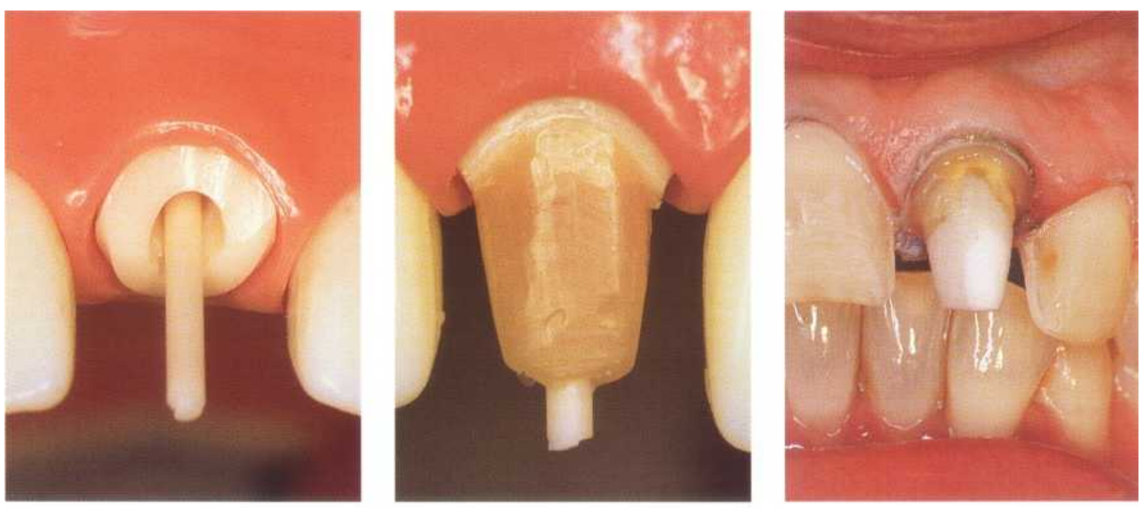
The Cerapress Technique

The patented ceramic pressing method Cerapress has been used for the past 10 years. It was developed by the dental technician A. Schmidseder after a procedure suggested by the Dutch dentist Dr Droge, and is suitable for manufacturing crowns, inlays, onlays, and veneers with high aesthetics and fit, and at a low price. Pressing of ceramic parts has already been used for a long time in industry as a tried and test and simple method. However, industry manufactures mass products, while dental technicians must make a unique component every time. That is why they must create a special form for each individual component.

Compared with the IPS Empress and the OPC methods, the Cerapress method has the following advantages:

- It does not require expensive equipment.
- The procedure can be integrated into any laboratory.
- New ovens and materials are not necessary.
- The manufacturing procedure is very simple.
- The process does not necessitate a highly qualified ceramist. A gold technician can achieve excellent results after little training.
- It is also possible to press layers of ceramics on zirconium oxide posts, and thus to make all-ceramic post-retained constructions.
- One can use all currently available ceramic masses.
- The crucial advantage of this technology is that the ceramic masses are mixed according to the requirements of the tooth and are stacked on the refractory form. An optimal aesthetic can be achieved with inlays, onlays, crowns, and veneers.
- As with the other press methods, additional ceramic can be added to the restoration after the pressing.

Dentists who use all-ceramic crowns frequently require an all-ceramic post-and-core construction in many cases. The procedures available at present include a high-strength post made from zirconium oxide and covered with a composite, or an existing metal build-up covered with an opaque layer. The Cerapress method is the only technique with which it is possible to produce a zirconium oxide post on which a ceramic mass of a suitable color can be pressed to produce a true all-ceramic post-and-core construction.

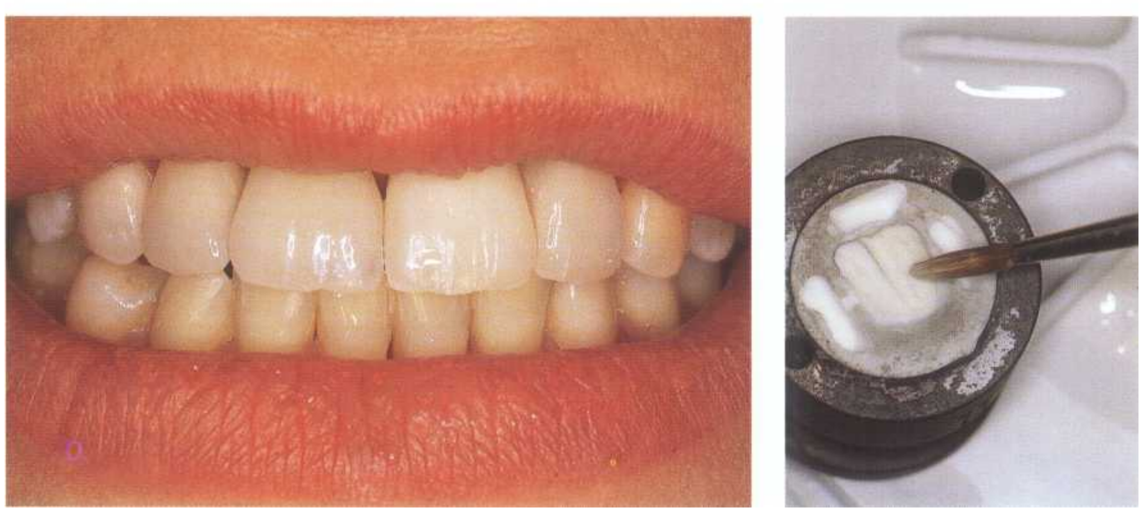


348 Manufacturing an all-ceramic post-and-core construction with the Cerapress system

Left: A zirconium post is adapted to the root canal.

Middle: A wax core is modeled around the post.

Right: Cemented all-ceramic post-and-core construction. After embedding the zirconium post with its attached wax build-up, ceramic masses are pressed around the zirconium post.



349 Aesthetic result

All-ceramic crown (tooth 21) and ceramic veneers (teeth 12, 11, and 22) layered and pressed using the Cerapress method developed by Alfons Schmidseder.

Right: Cerapress is the only procedure for pressing ceramics, in which monochrome ceramics can not only be pressed but also simultaneously layered.

Injection-Molded Glass Ceramic (IPS Empress)

IPS Empress is a precerammed glass ceramic that is heated in a cylindrical form and then pressed into a mold. Like the Optec HSP system, this ceramic contains a higher leucite crystal content, which gives it a better chance of resisting fractures. The shape of the ceramic restoration is achieved by pressing the ceramic ingot into the mold over a time period of 45 minutes under high temperature. This pressed restoration is monochrome and can then be either painted or covered with other ceramics and fired. It is also suitable to cover it with conventional sinter layer technique and use it as a framework for the final restoration.

IPS Empress can be used for crowns and veneers on anterior teeth and for inlays, onlays, and crowns on premolars/ molars exposed to low pressure.

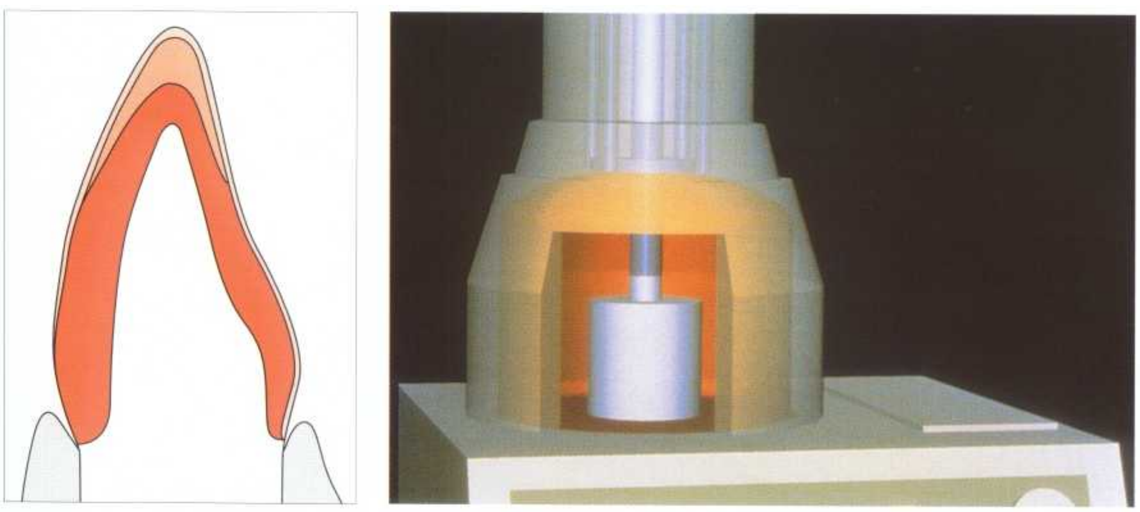
Advantages of this ceramic are the absence of an opaque layer or a metal framework, the excellent fit, and an outstanding aesthetic. Disadvantages include fracture susceptibility when used on posterior teeth and the need to use special, expensive laboratory equipment.

Optec OPC: Optimally Pressable Ceramic

OPC consists of a mixture of leucite crystals ($K_2O \cdot Al_2O_3 \cdot 4 SiO_2$) that comes from a silicate glass. This ceramic is similar to the Optec ceramic, while the glass matrix is tougher. The ceramic contains very fine grains, as is the case with the IPS Empress technique.

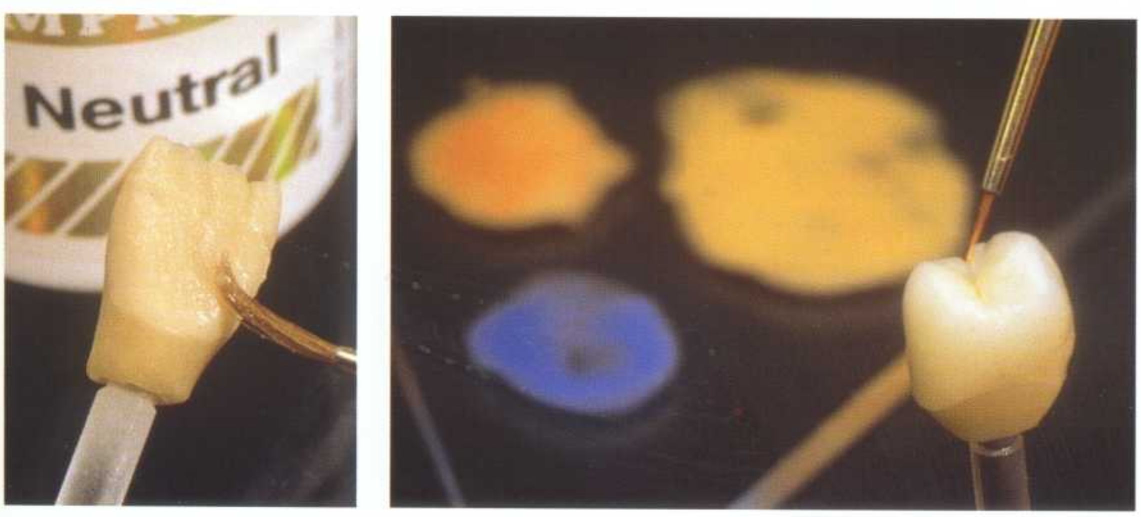
The advantage of the OPC technique in comparison to the IPS Empress technique is the price. The system is complete and represents a challenge for Ivoclar.

The *technique* is similar to that of the IPS Empress:
- The restoration is modeled on the working model.
- The wax model is embedded.
- The muffle is slowly heated to 900'C in the oven.
- Before the pressing procedure, the Optec ceramic pellet is placed into the muffle.
- The ceramic is pressed.
- The restoration is removed from the mold.
- Inlays are individually painted with specific ceramic colors.
- Crowns and veneers can be covered and fired with additional Optec masses.



350 IPS Empress and Jeneric OPC crowns
IPS Empress and Jeneric OPC methods are technologies that rely on pressing all-ceramic crowns and inlays. They assume that a particular ceramic oven is used for the pressing step. The oven is also used for other worl< with ceramic.

Left: The pressed all-ceramic core is covered with conventional ceramic masses and fired.



351 Individual characterization
All-ceramic crowns used in the premolar regions must not necessarily, as declared by the manufacturers, be layered. It is sufficient to paint their surfaces. In the author's opinion, IPS Empress and Jeneric OPC are not suitable for use as crowns in the molar regions, since they do not have sufficient flexure strength.

Left: An all-ceramic anterior crown is first cut back and then refired.

Procera AllCeram

This system is based on an alumina ceramic core mass that is processed by pressure injection. A density of approximately 99.5% and a flexural strength of approximately 600 MPa is achieved with this method. The crowns can be used on anterior teeth for all single tooth restorations as well as for inlays, onlays, and veneers.

Any cement is suitable for its cementation. However, a resin-based bonding procedure, with which a higher fracture resistance can be achieved, is recommended for the posterior region. Since the base material of the core consists of *one* Al_2O_3 *phase,* no significant etching of the ceramics can be achieved. Other with leucite-enriched ceramics contain two or more phases and consequently provide better mechanical retention with a resin cement after etching.

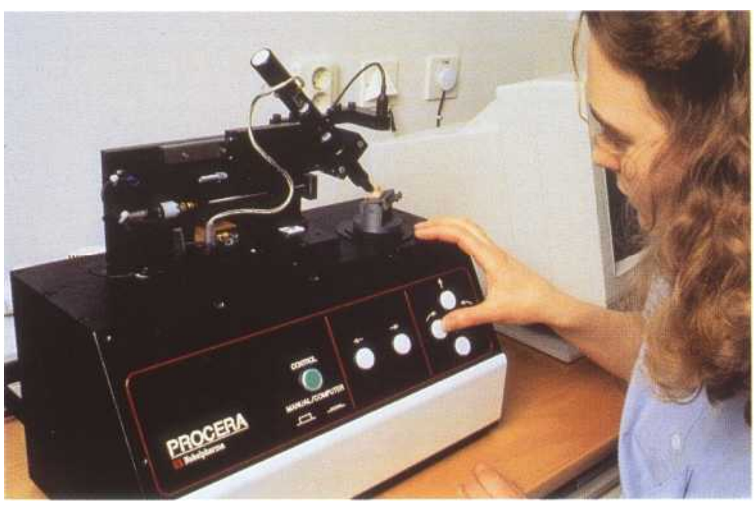
Occlusal adjustments are done, under water-cooling, with fine-grained diamonds or stones with smooth surfaces. The final polish is done with flexible rubber disks or cups, whereupon the surface is polished with felt cones and diamond polishing paste.

Glass Infiltrated Alumina Ceramic (In-Ceram)

The glass infiltrated, sintered alumina ceramic has outstanding fracture strength values. The In-Ceram crowns are used with single crowns in the anterior and the posterior regions. According to manufacturer, three-unit anterior bridges are also possible at low chewing forces. Dentists, dental technicians, and patients should be aware of the fracture risk of the bridges and how difficult it is to remove bonded bridges. For treatments with short bridges, it is imperative, however, that the alumina framework is shaped sufficiently solidly in the proximal contact regions.

The slip mass consists of alumina and is slip-casted on an absorbing refractory die which is then fired to reach a point when the particles sinter. The lightly sintered ceramic core is then infiltrated with glass and fired for four hours at 1100°C in order to eliminate any porosity and to reinforce the core. The sintering process causes the particles to stick together only in small areas and therefore leads to only little shrinkage. Because of this, the marginal adaptation and the fit of the restoration are outstanding.

Beside the fracture toughness, the *flexural strength is* an important quality of ceramic materials. The following flexural strength values are not very precise, due to the dependence on the manufacturing technique, the roughness of the surfaces, and the load rate:



352 Procera system
The die is mechanically scanned and the data stored in a computer.

353 Procera scanning computer
Right: Completed Procera crown.

Courtesy of *Nobelphormo*

- Procera AllCeram: 600 MPa
- In-Ceram: 450 MPa
- In-Ceram Spinell: 350 MPa
- Dicor, Optec HSP, Cerapress, OPC, and IPS Empress: 110-150 MPa

Advantages of the glass infiltrated material: The metal base is not necessary and it has very high flexural strength and outstanding fit.

Disadvantages: The opacity of the core can affect the aesthetic appearance, the acid resistance of the core makes conventional acid etching of the core inefficient, and special laboratory equipment is necessary to make the crown.

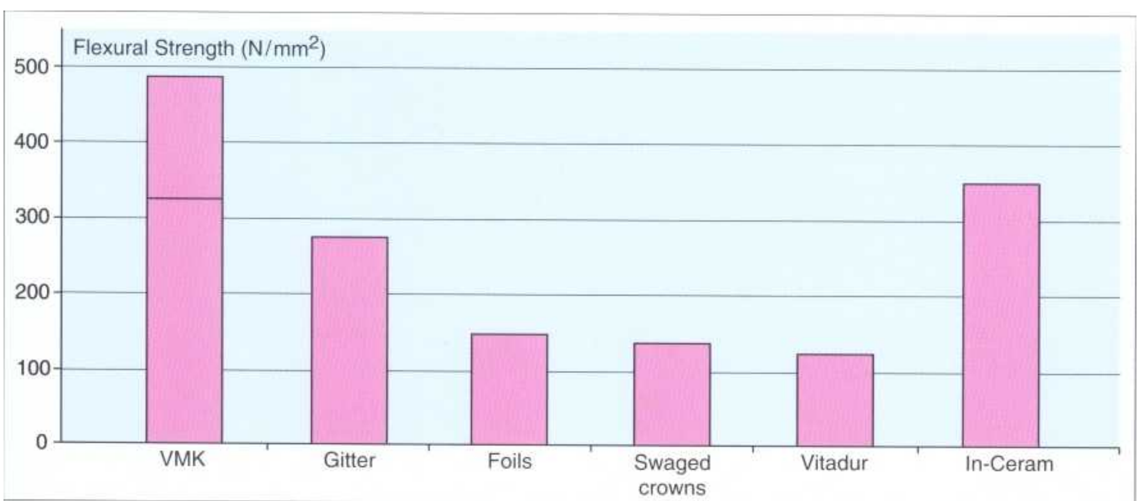
The alumina core of the In-Ceram construction is covered with Vitadur Alpha. According to the manufacturer, any luting agent can be used. However, resin bonding is advisable because of the higher fracture resistance of such a procedure.

The large amount of alumina in the core prevents successful etching, while it is possible to etch other ceramic materials containing a sufficient amount of glass phase, such as Dicor or leucite reinforced materials, to achieve an etch pattern which enables mechanical bonding with the resin cement. With the In-Ceram system, the surface must be sandblasted with Al_{203} (50 pm) in order to achieve micromechanical retention. Zinc phosphate, glass ionomer cement and light-curing, resin-based composite cements are suitable for cementation, although Panavia 21 is particularly recommended. Compomer cements are not suitable since they can expand.

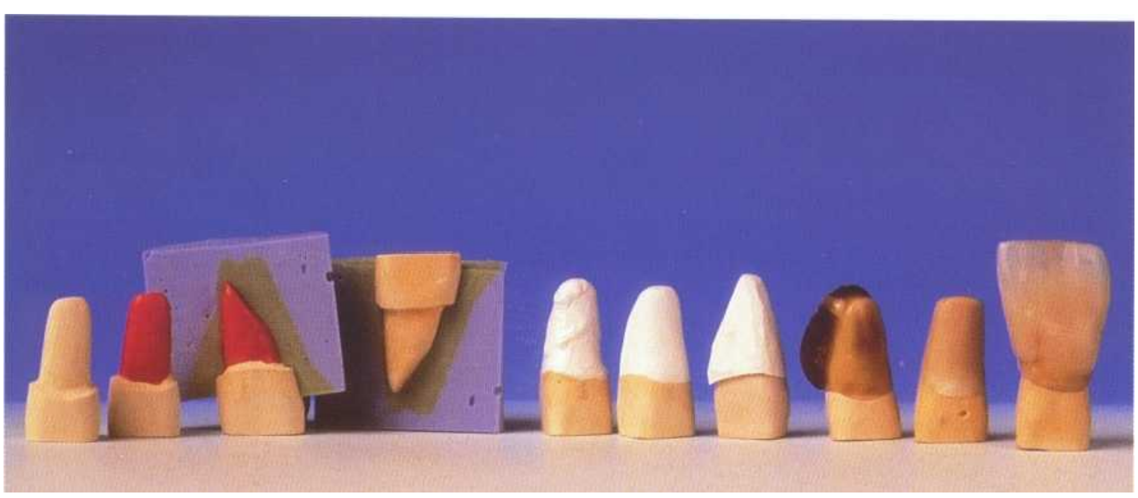
Occlusal adjustments are done, under water cooling, with finely grained diamonds or stones with smooth surfaces. The final polish is done with flexible rubber disks or cups, whereupon the finish is completed with felt cones and diamond polishing paste.

In-Ceram Spinell

One of the major disadvantages of In-Ceram is its high opacity. That is why In-Ceram Spinell, which has a higher translucency, was developed. The manufacturing process resembles that of In-Ceram, with the exception that the core is made of a glass infiltrated magnesium alumina (spinel, $MgAl2O4$). However, the crowns are more susceptible to fracture than the In-Ceram crowns. The reason is the approximately 100 MPa lower flexural strength. The indication for In-Ceram Spinell crowns exists only for anterior, single crowns, when more translucency is desired. In-Ceram Spinell crowns are cemented and adjusted in the same way as the In-Ceram crowns.

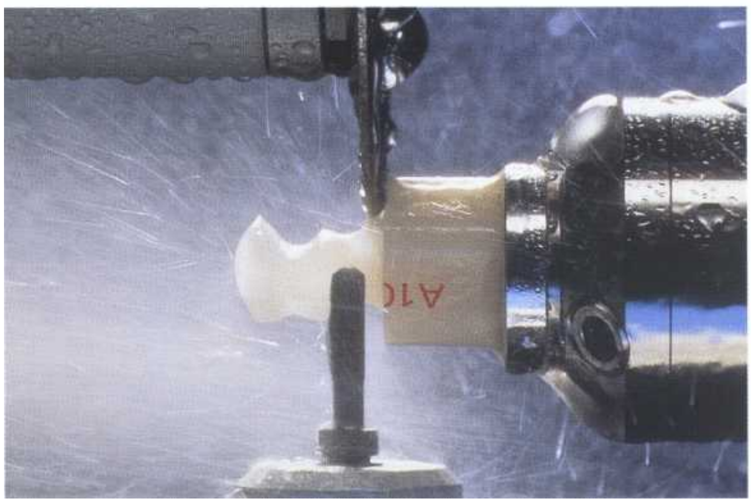


354 Flexural strength of anterior crowns
At present, Procera (not included in **these** statistics) and In-Ceram are the crown systems with the highest flexural strength.



355 Manufacturing an In-Ceram crown
A refractory die is produced after duplication of the model. This is coated with alumina ceramic and later infiltrated with glass. The highly stable alumina ceramic core has great flexural strength. It is then covered with feldspar ceramics.

356 Cerec computers
Numerous CAD/CAM systems for manufacturing dental prostheses are being developed. The Cerec system was one of the first systems on the market.



357 **The Cerec system**
The Cerec system is suitable for manufacturing single inlays (shown here), onlays, and veneers.

CAD/CAM Systems

Mormann and Brandestini (1989) introduced the first CAD/CAM system-Cerec 1-for use in computer-aided production of ceramic inlays. It is based on an optical impression. The preparation is shown on the screen. The inlay is designed with the help of a trackball that allows the inlay to be constructed on the screen.

Through a further development of the milling unit (six instead of three axes) and a camera with higher resolution it has been possible to improve the fit of restorations manufactured with the Cerec 2 system. The marginal fit of inlays produced in vitro has been reduced from 84 ± 38 pm to 56 ± 27 um. However, this assumes a perfect Cerec preparation (Schlug and Mormann 1995). Cerec 2 also has the ability to give the inlay an automatic, anatomically adapted occlusion. It is also possible to manufacture onlays.

In the years ahead, miscellaneous CAD/CAM systems will continue to be manufactured and be brought onto the market. However, it will probably be impossible, within a foreseeable future, to leave the design of anatomy, function, and aesthetic to a machine.

Summary

There is no all-ceramic material that can be used for all clinical situations. Available ceramics with high strength and fracture resistance have only restricted transparency.

All-ceramics must be treated very carefully as far as the processing techniques are concerned, since even a small technical deviation can strongly influence the fracture resistance or the aesthetic of the final restoration.

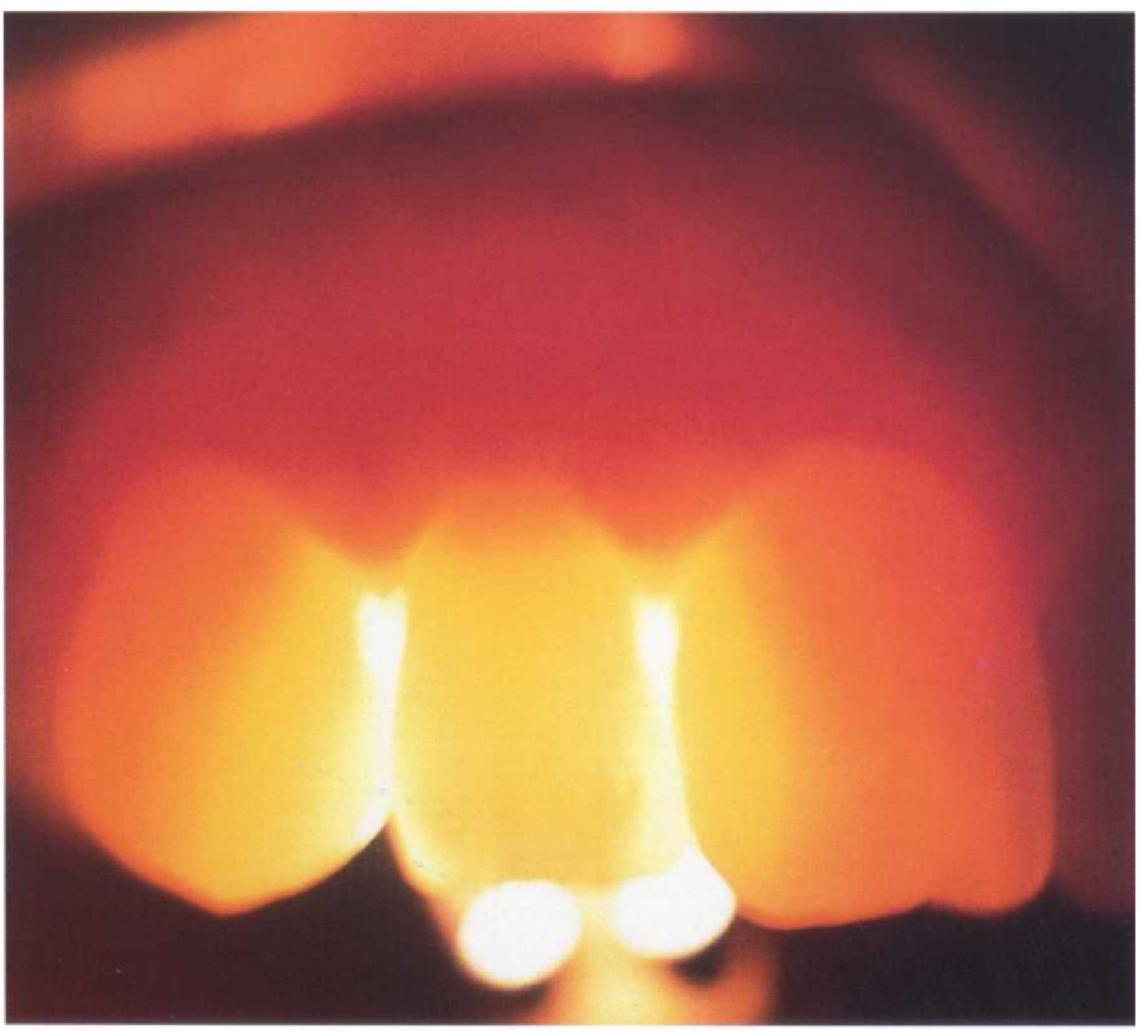
It is obvious that all-ceramic units, particularly in the anterior regions, where the aesthetic appearance plays a significant role, show very satisfying permanent results. However, for the posterior regions it seems that, when compared with metal-ceramic crowns, the purely aesthetic advantage of the all-ceramic crowns may not necessarily be enough to justify their usage.

With the exception of Procera AllCeram, In-Ceram, and possibly In-Ceram Spinell, all-ceramic crowns used in the posterior tooth regions show a significantly higher risk of fracture.

All-Ceramic Systems-Clinical Aspects of the All-Ceramic Crown

Since the introduction of the porcelain jacket crown at the beginning of the 20th century, the all-ceramic crown has been the most aesthetic of all restorations. However, the demands made of it have always been high: The dentist must be able to prepare a circular shoulder and the dental technician must not only master a very complicated procedure but also possess the skill needed to reproduce natural-looking teeth. The technology used to make an all-ceramic crown has in fact been simplified, but great skill is still necessary to make beautiful, matching, and functional reconstructions.

Some clinical aspects that can contribute decisively to the success of a restoration are discussed in this section. One can produce aesthetically perfect anterior tooth restorations with all-ceramic crowns and ceramic veneers. Such restorations are successful only when every step in the treat ment process, from planning to completed, correctly bonded, and adjusted restoration, is carried out equally well.



358 Translucency of all-ceramic crowns
All-ceramic crowns are as translucent as natural teeth, which is an advantage when creating aesthetic front teeth.

Indications and Contraindications

Although all currently available all-ceramic systems have excellent mechanical properties, the existing indications and contraindications of the all-ceramic crowns are comparable to those of the conventional alumina ceramic crown (McLean's Pt crown). In fact, the flexural strength is a contentious issue when comparisons are being made. On the basis of the metal content, the metal-ceramic crown has a very high fracture strength that none of the all-ceramic crowns has reached.

In addition, the durability of the all-ceramic crown depends of many factors: treatment planning and patient education (hygiene phase), preparation of the tooth, making the impression, dental technical processing (many mistakes are possible), selection of cement and cementation technique, finishing, adjustments, and maintenance.

Indications for an all-ceramic crown:

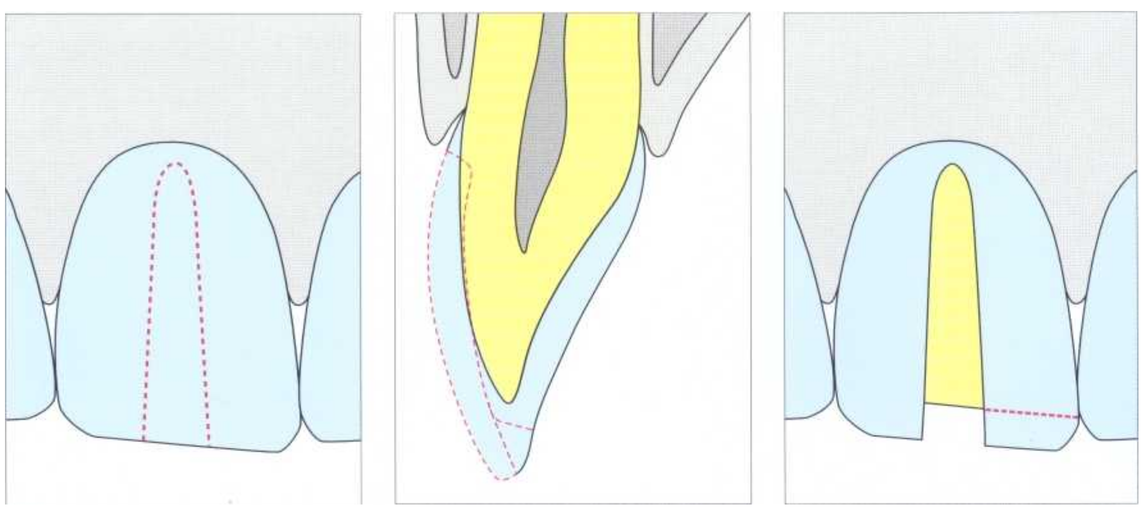
- Front teeth that are destroyed, fractured, discolored, abraded, or are in a faulty position.
- Under favorable occlusal conditions, they can also be used to rebuild posterior teeth. However, the first choice regarding the use of treatment options for posterior teeth should remain the metal-ceramic crown until sufficient long-term results are available regarding the performance of all-ceramics in the molar regions.

Contraindications are:

- too conical preparation
- insufficient lingual thickness of porcelain (<0.8 mm)
- deep bite
- short clinical crown that would only offer minimal retention after preparation
- parafunctions, for example, heavy bruxism

The principles of the tooth preparation for treatment with an all-ceramic crown are therefore:

- Virtually parallel mesial and distal axial walls, so that the proximal spaces are equally large.
- The length of the prepared tooth must be to at least two thirds of the incisal-cervical length of the restoration. A shorter preparation can increase the surface stress and lead to fractures.
- The incisal preparation must be rounded off.
- A uniform width (approx. 0.8-1.0 mm) of the cervical margin at an angle of close to 90' is important in order to resist pressure.
- All sharp angles and corners should be rounded off, in order to avoid concentrations of stress.

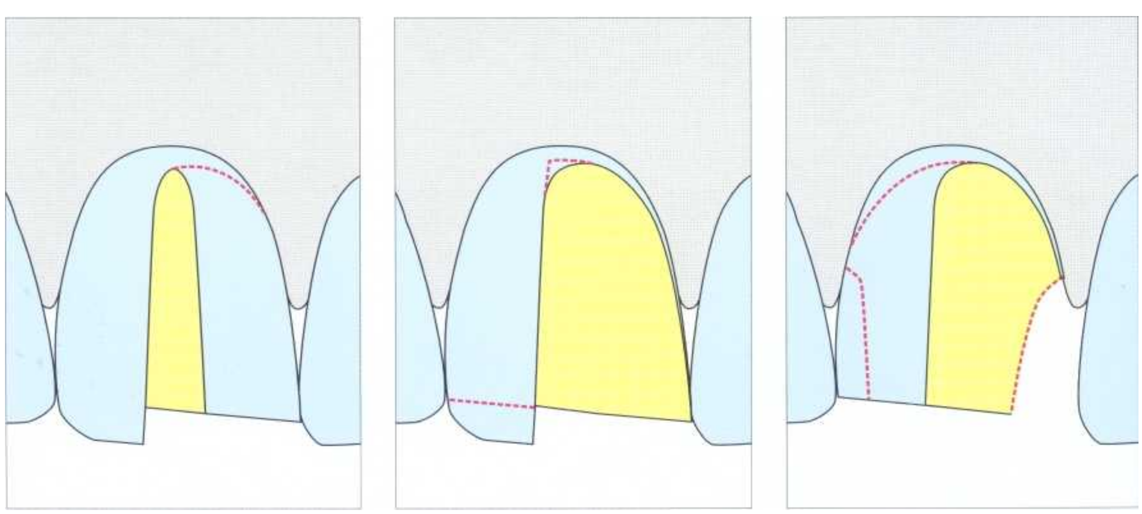


359 **Preparing an all-ceramic crown**
A depth cut is prepared to improve orientation. Layers in all-ceramic crowns must be at least 1.5-Z mm thick.

Left: Preparing a depth cut.

Middle: Cross section through the tooth with depth cut and incisal preparation.

Right. Incisal preparation



360 **Step-wise preparation of half a tooth**
After the depth cut is placed, the incisal edge is shortened accordingly, and one half of the crown is prepared. This approach enables control of the thickness of the layer of tooth substance removed.

Left. Preparation of half a tooth.

Middle: Incisal preparation of the second half a tooth.

Right: Residual preparation.

Preparatory Steps

1. Depth cuts: The depth cuts are cut on the facial surface and the incisal edge. The cuts are 1.0 mm deep facially and 2.0 mm deep incisally. One to three cuts are prepared facially parallel to the cervical first third of the facial surface. Then one prepares two cuts parallel to the incisal two thirds, and also two cuts 2 mm deep, positioned along the incisal edge.

2. Incisal and facial reduction: The incisal reduction is done parallel to the incisal edge of the crown. The facial surface is reduced in accordance with the appropriate cuts. An even reduction is imperative in order to get a smooth tooth structure. The prepared facial surface is finished and extended into the proximal areas.

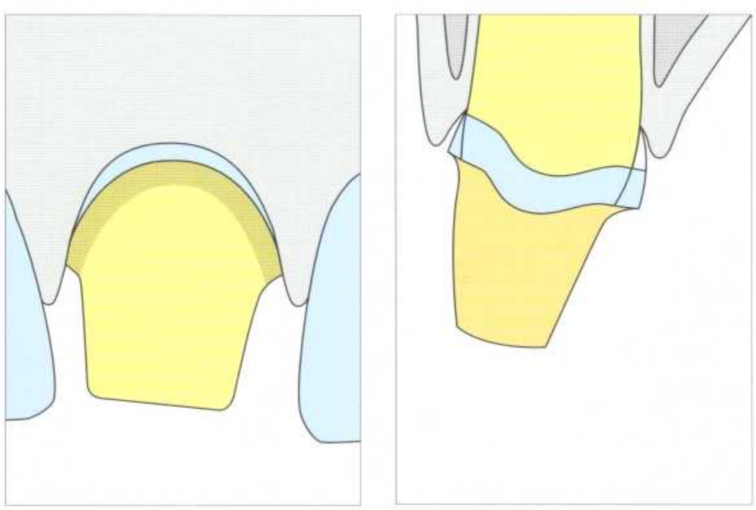
3. Proximal reduction: The mesial and distal proximal walls are cut as parallel as possible. One should be careful that one does not prepare the proximal surfaces too profoundly and destroy the papillae by doing so. This could lead to unsightly interdental conditions.

4. Lingual-axial reduction: The reduction of the lingual-axial surface takes place to form a pointed angle of 5-6 ° to the cervical first third of the facial surface.

5. Preparation of the lingual concavity: The lingual surface is prepared so that between the lingual vault and the tooth surface there is a gap of 1.0 mm.

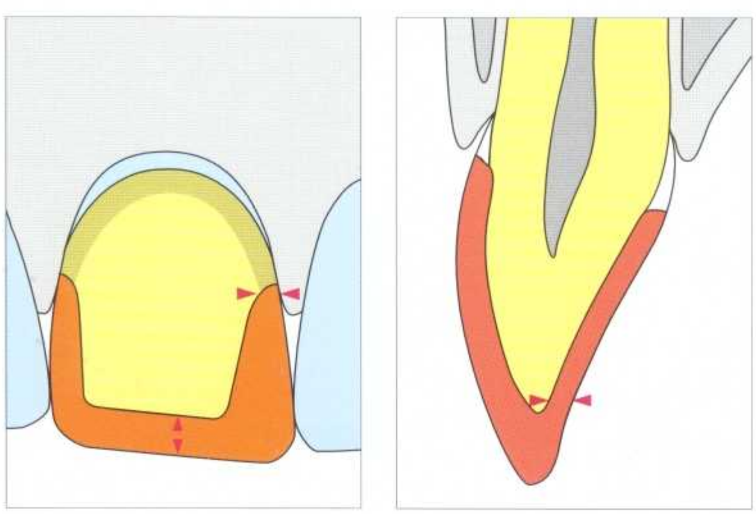
6. Finishing the marginal shoulder: The width of the shoulder on the facial and lingual surface should be 0.8-1.0 mm, and 0.6-0.8 mm on the mesial and distal surfaces. The shoulder must be shaped flat all around and the transitions between facial, mesial, lingual, and distal surfaces must be smooth. A right-angled rounded shoulder is preferred.

7. Rounding off all sharp corners and edges: All rounded-off surfaces should preferably be created with a low-torque FG diamond.



361 **Preparation of the second half of the crown**
Left: After one half of the crown has been prepared, the remaining tooth substance can be removed very easily. This procedure makes it possible to remove an even layer.

Right: The prepared crown in cross section.



362 **Finished preparation**
Note that sufficient tooth substance is removed to achieve sufficient thickness and strength of the crown.

Left. With all-ceramic crowns, a rounded shoulder or heavy chamfer is necessary. The ceramics should not be thicker than 2 mm incisally (risk of fracture).

Right: Cross section through preparation for an all-ceramic crown.

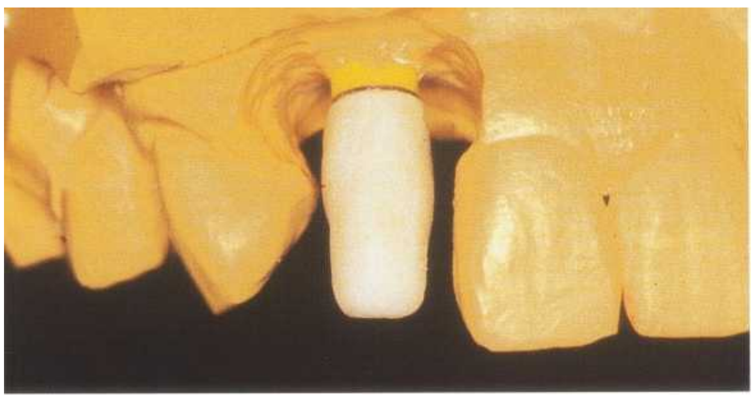
Quality of Materials for All-Ceramic Systems

-The material should be selected so that it resists the occlusalforce.
-The material should be sufficiently transparent and adapt to different lighting conditions.
-The margins of the crown material should fit well.
-When the ceramic is built up the material should facilitate layering the right colors.
-At the try-in session, it should be possible to change contour and color.

Of all the current all-ceramic systems, In-Ceram best fulfills the requirements. It has the best available mechanical properties (approx. three times the flexural strength compared to other all-ceramic systems, except for Procera). The spinell core, consisting of $MgAl_2O_3$, has the translucency of the natural tooth. The margins of In-Ceram crowns fit very well (marginal gap width 10-40 um). The transparency of the core is able to even cover unfavorable dark reflections from the oral cavity.

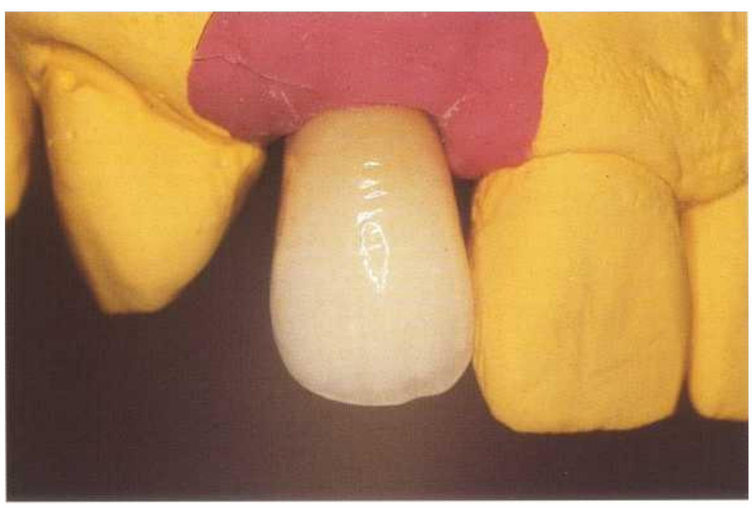
The drawback when using the In-Ceram system is that it requires special equipment.

363 All-ceramic constructions on implants
The Celay system is ideal for manufacturing high-strength constructions in alumina ceramics. An all-ceramic construction is milled from an alumina block, which is then infiltrated with glass.

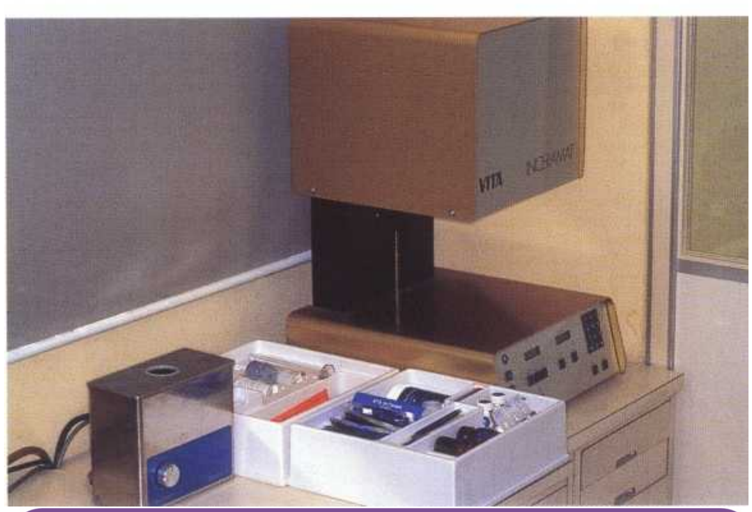


364 Completed all-ceramic crown on the implant
An all-ceramic crown is produced on the all-ceramic core construction. With the Celay technique an In-Ceram core is milled and then coated with Vitadur Alpha ceramic.

Right. All-ceramic crown on analog implant.



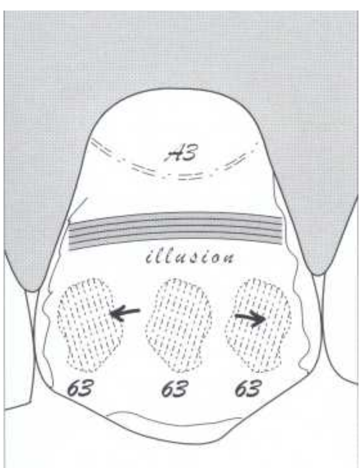
365 In-Ceram oven
The In-Ceram technique requires a special oven. Such an oven is not necessary if the alumina framework is milled using the Celay technique.



Tasks for the Dentist

1. Hygiene phase and plan treatment.
2. Prepare situation models.
3. Simple functional analysis.
4. Documentation.
5. Discuss with the patient which procedures and which materials are desirable.
6. Select the suitable procedure.
7. Preparation, as described on page 185.
8. Impression with an elastomeric impression material: A-silicone or polyether.
9. Temporary restoration.
10. Select tooth color: The In-Ceram Spinell core is available in four colors (S1 to S4), which correspond to the Vita colors.
11. With the patient decide on a color layering plan.
12. Communicate with the laboratory.

366 **Color selection**
Labial view of a lateral incisor. The tooth color should not only be decided by determining the color of the tooth to be prepared and its adjacent teeth, but also by considering the color of the opposite lateral incisor.



367 **Determining the core color**
The In-Ceram Spinell core can be produced in four different colors. It is important to take the color of the core into account during color selection.

Left: Layering plan.

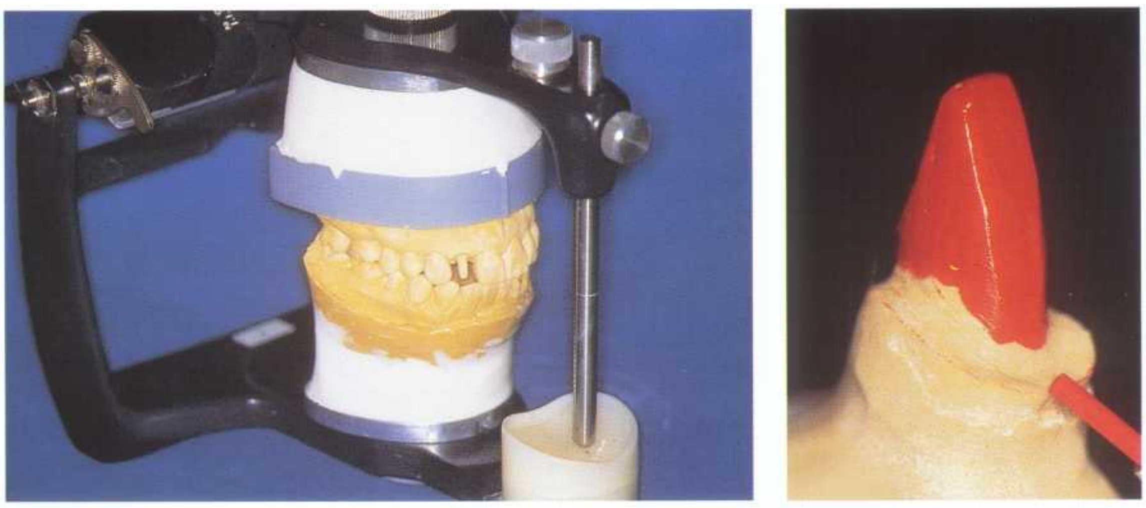
368 **Prepared tooth** 12
The preparation of the tooth is finished and the gingiva is retracted ready for making the dental impression.

Making an In-Ceram Spinell Crown

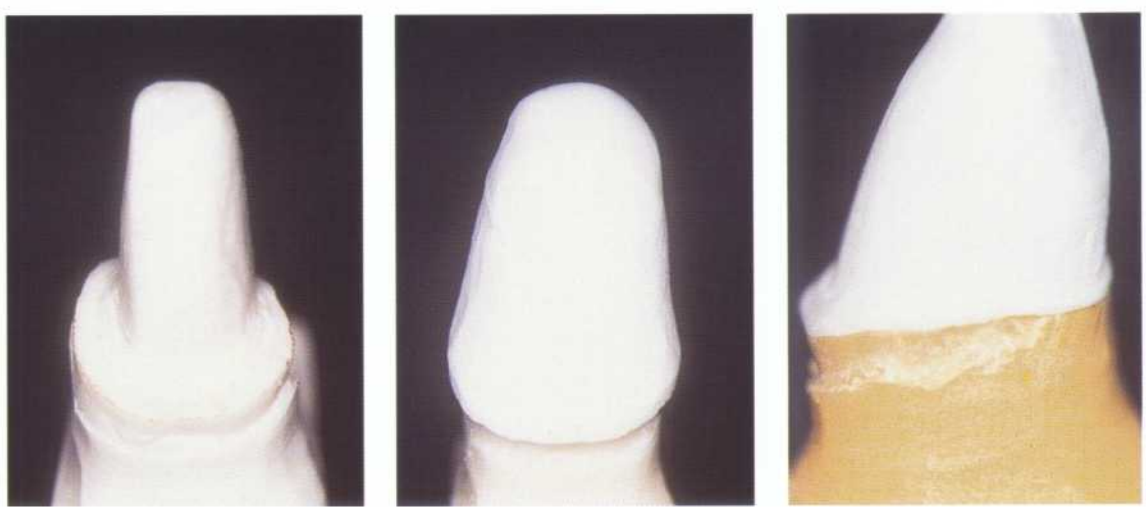
1. *Production of the working model and the refractory dies:* A working model is produced by means of a silicone impression. The complete reproduction of both jaws is appropriate in order to make it possible to take functional parameters into account. The models should be mounted axis-oriented in an articulator.

A sufficiently thick layer of a die spacer must be placed on the working die. This is very important for the cementation. All cements require a minimum film thickness. More than other cements, resin cements need a certain thickness for achieving a sufficient tensile bond strength value. Then the working die is duplicated with a silicone impression material and a refractory die is made.

2. *Slip-Casting and Sintering:* The thick slip is a mixture of Spinell powder and its mixing liquid. Both should be mixed in correct proportions and be condensed using ultrasound (Vita Sonic 11). The slip-casting is achieved by immersing the refractory die into the slip mixture. The slip-casted framework should be approximately 0.5 mm thick. Any surplus slip mass is removed from the margins with a sharp knife. Then, sintering takes place and the sintered shell is



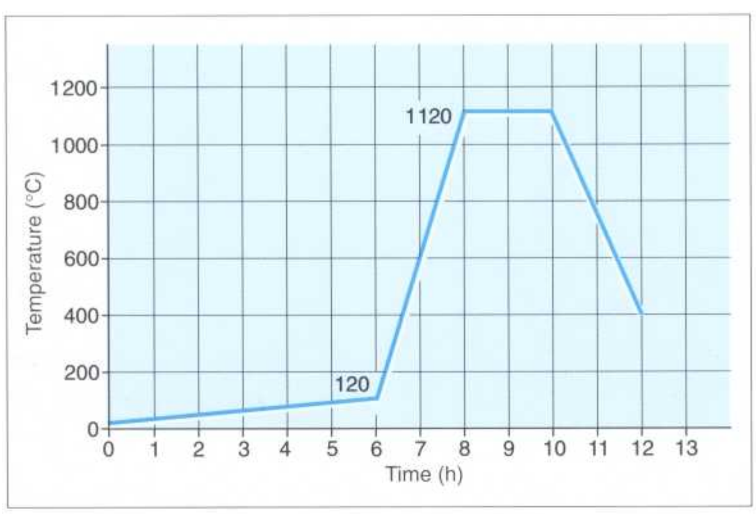
369 Working models mounted in the articulator
The working model has been mounted in the articulator. For this purpose, a quick transfer is sufficient. By making the crown in the articulator, it is possible to consider the movements of the front teeth during the construction of the crown.
Right: The die is covered with a sufficiently thick layer (40-60 pm) of a die-spacer. It is is important to be aware that resin cements require a minimum thickness of the layers.



370 Manufacturing the alumina core
Left: A refractory die has been produced.

Middle: The alumina core is slip-casted on the die.

Right. Completed alumina ceramic core.

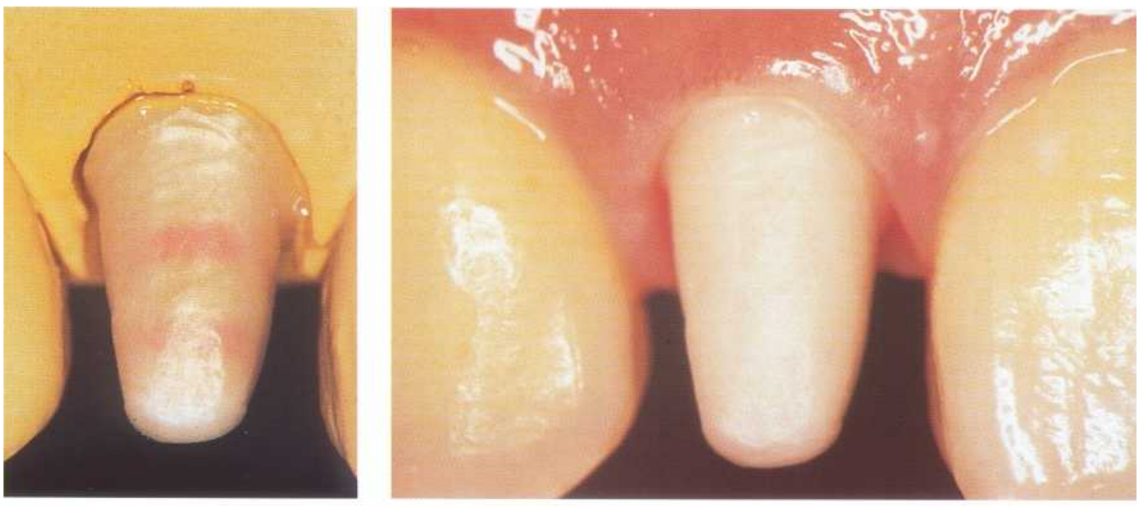


371 Firing schedule of the In-Ceram Spinell framework
It is necessary to use a special furnace for the very lengthy, precisely controlled firing protocol in order to produce the high-strength alumina core.

subsequently removed from the refractory die and adapted to the working die.

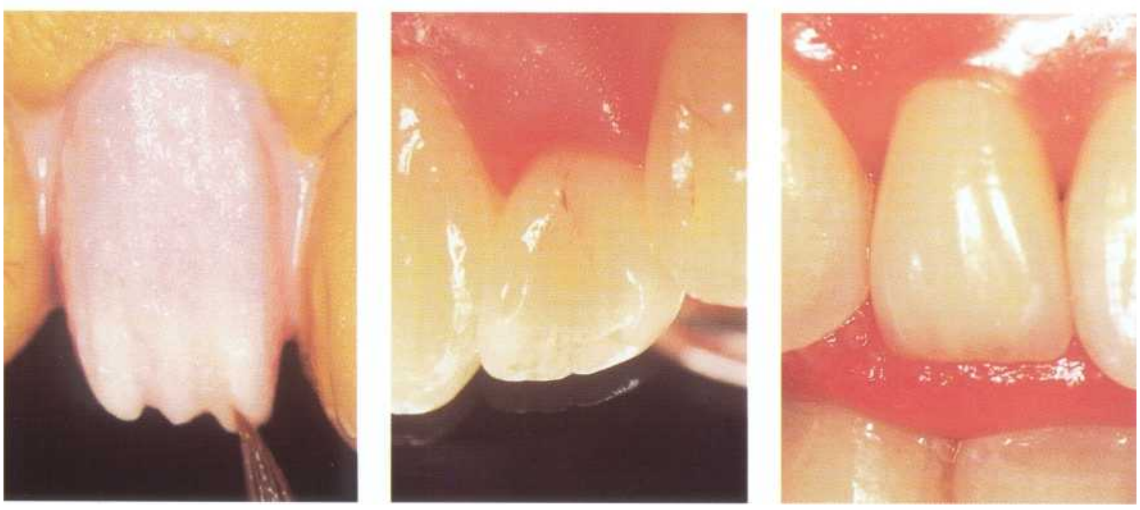
3. Placement of the spinell glass powder and firing: The glass powder is mixed with distilled water and placed on the alumina framework up to around 1 mm away from the incisal edge. The most suitable color of the glass is used. The firing process takes place in a vacuum. Subsequently, the surface is sandblasted with alumina powder (50 ltm particles). The In-Ceram framework achieves its typical optical quality through the firing procedure. The framework is fitted onto the model.

4. Crown reconstruction: The crown is stacked on the framework with Vitadur Alpha mass and fired in accordance with the layering plan determined beforehand. It is helpful to lace a silver powder on the surface of the crown and the master model in order to make the surface structure of the tooth visible. The right surface structure is just as important for the aesthetic appearance as is anatomy, color, and layering. Finally, glaze firing is carried out. It is important that firing is not executed at too high a temperature as this will destroy the surface completely. The crown can also be polished instead of being glaze fired.



372 Semitransparent In-Ceram Spinell core
Fitting the Spinell core.

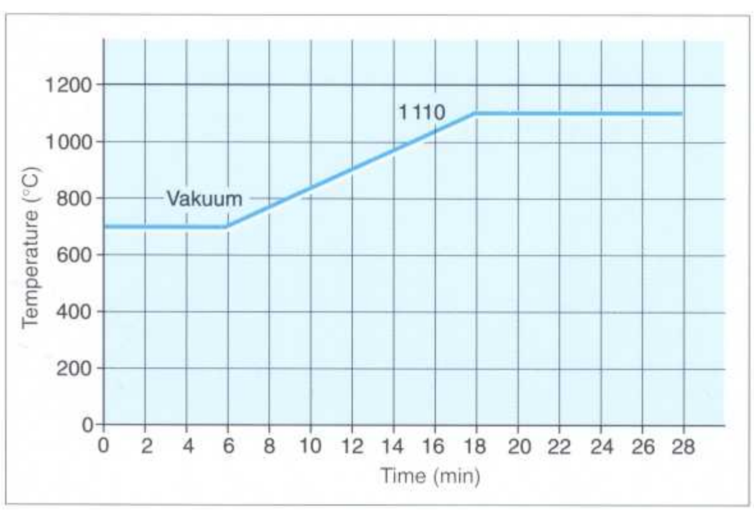
Left: The alumina core is infiltrated with glass and acquires its necessary physical properties. It is more transparent than a framework made from a non-spinell-based In-Ceram core material.



373 Covering the Spinell framework
Left: The Spinell core is covered in layers.

Middle: Finished crown seen from its lingual surface.

Right: Finished crown seen labially.



374 Firing schedule for the glass infiltration
The rather short firing schedule of the glass-infiltrate which is conducted in a vacuum is also done in the In-Ceram oven. If the framework has been produced with the Celay technique, the glass infiltration can be done in a conventional ceramic oven.

Manufacturing a Cerapress Crown

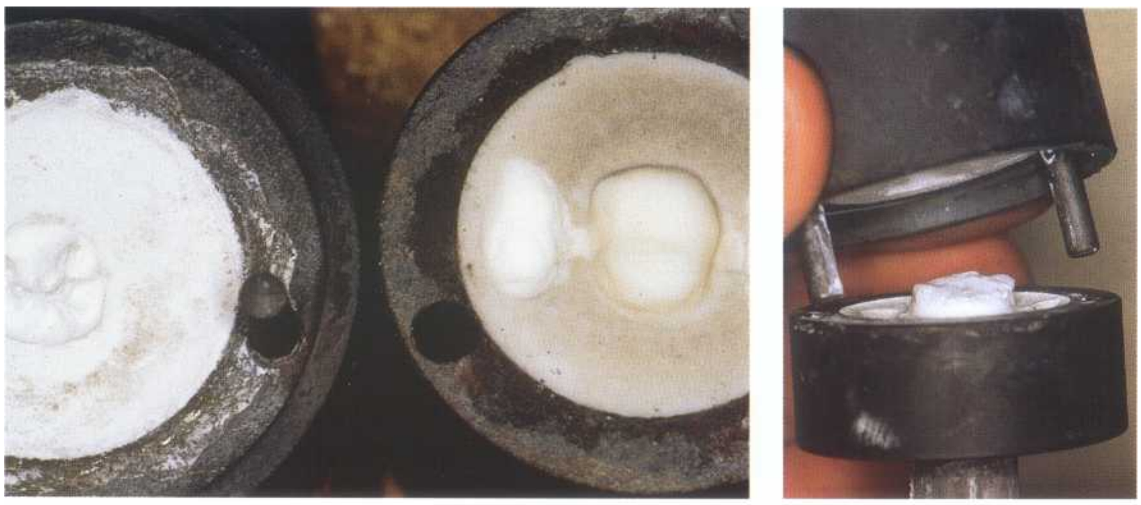
The Cerapress technique is a very simple technique for making crowns. Some steps are identical for all technologies:

- The preparation must suit the material (p. 185).
- A sufficiently thick die spacer layer must be placed on the working die.
- A refractory die is produced.

The crown is modeled in wax on the working model and then transferred to the refractory die. Both the die and the wax pattern are embedded. The ceramic is layered inside this form. The big advantage of this technique is that the dental technician mixes the ceramic mass and layers as requested in each individual case.

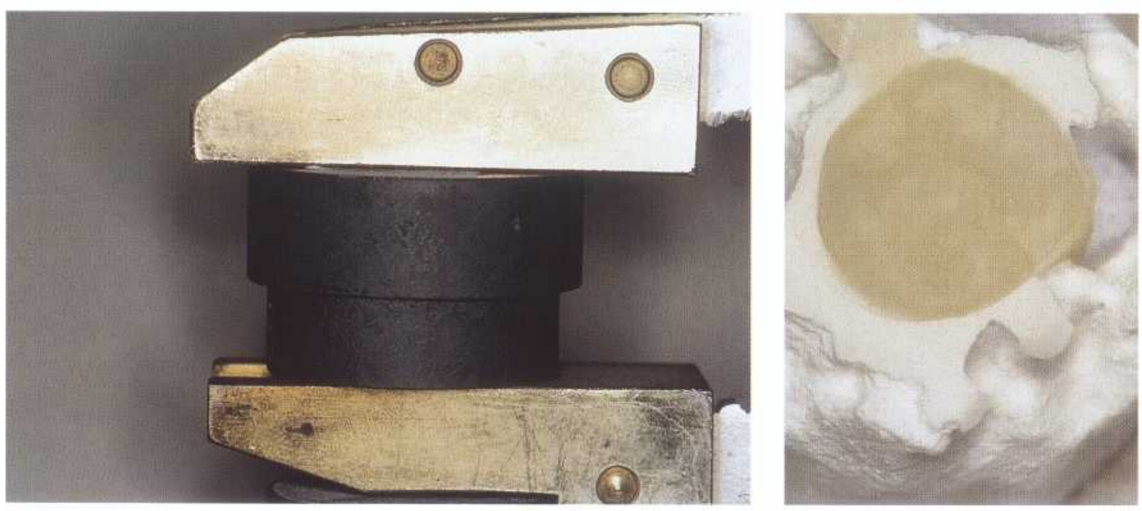
After the crown is fired, it can, as with the other press ceramic procedures, be layered and fired again.

The Cerapress technique is suitable for anterior teeth and for posterior teeth exposed to low pressure. Before cementation, the crown can be etched and silanized.



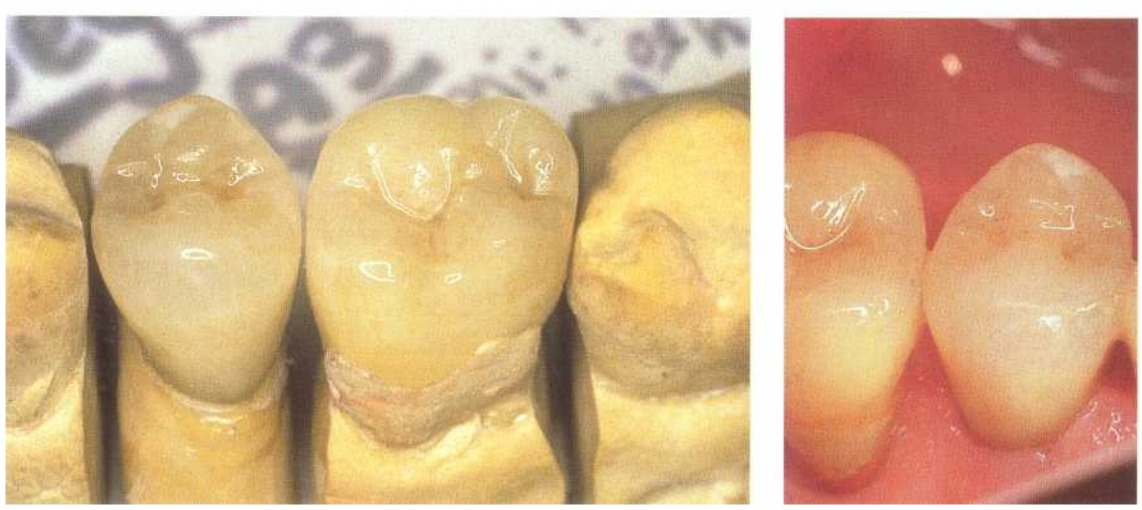
375 Making all-ceramic crowns using the Cerapress technique
The crown is modeled in wax, embedded in a particular flask, and the ceramic masses (preferably Optec HSP ceramic) are placed in layers. Since the ceramic shrinks, excess material made from clear porcelain must be placed and pressed into the mold to compensate for the lost volume.

Right: The two flask halves are lined up and connected before the firing.



376 Pressing the crowns
As soon as the ceramic is sufficiently plastic, both flask halves are pressed together outside the oven with special tongs.

Right: The all-ceramic crown is removed from the embedding material with the help of a glass powder blaster.



377 Manufacturing all-ceramic crowns
An all-ceramic crown on tooth 25 and an all-ceramic partial crown on tooth 26.

Right. The same crowns after cementation. The Cerapress technique should only be used for posterior teeth if there are small chewing forces.

IPS Empress and OPC Technique

The two technologies are virtually identical. The only significant difference is the price of the system and the ceramic pellets.

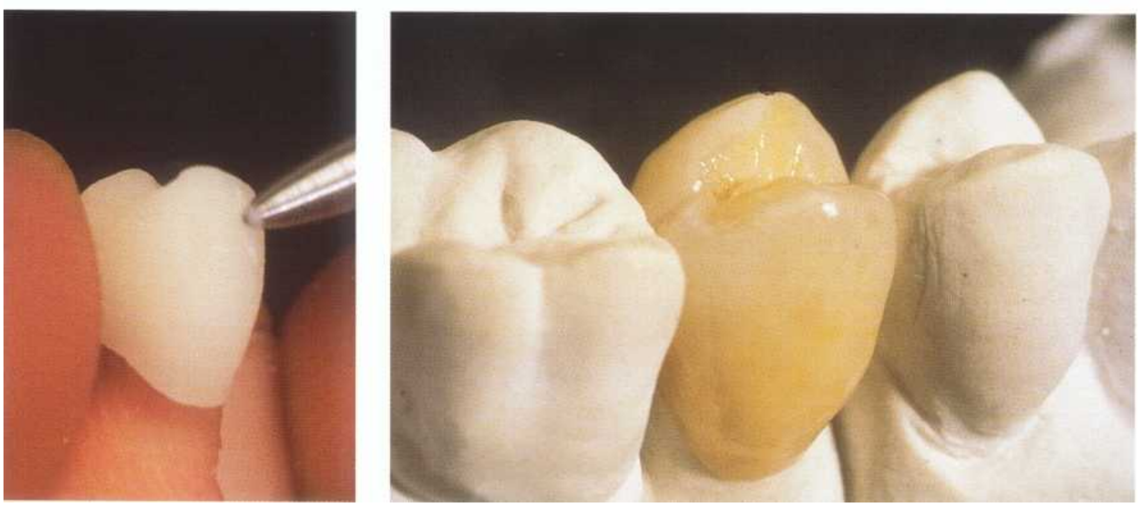
The wax crown, modeled on the master model, is embedded. A leucite reinforced ceramic is pressed into this form. The framework is monochrome and is masked later.

Since the cap (the framework) has a flexure strength of only approximately 160 MPa, the technique should be restricted to anterior teeth, or posterior teeth exposed to low occlusal force. Excellent aesthetic results can be achieved with the IPS Empress and OPC techniques.

Adhesive cementing is carried out. Before the cement is placed, the inside of the all-ceramic crown should be etched with hydrofluoric acid and silanized.

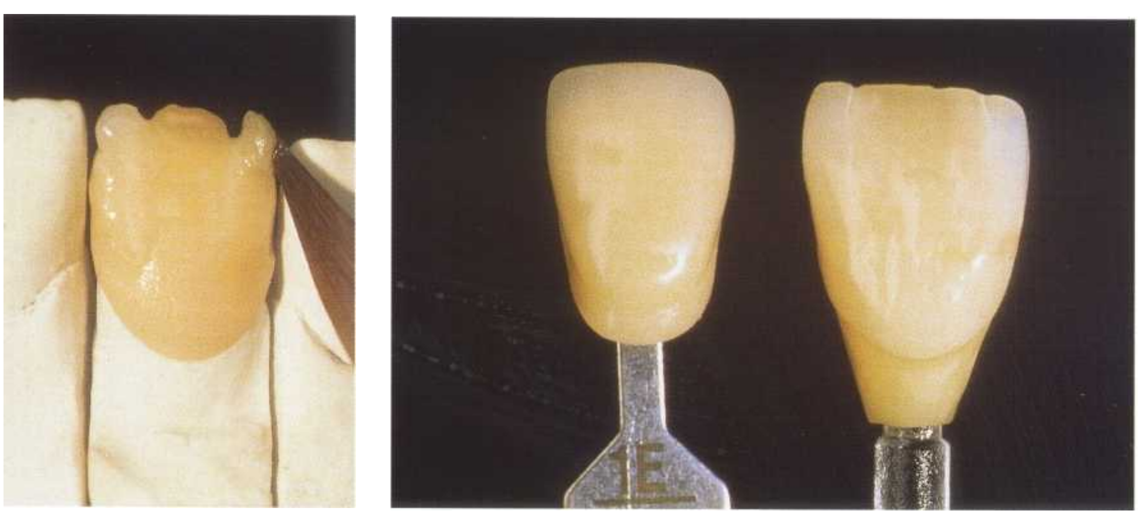
Advantages of these technologies are: simplicity, standardized procedure, and extensive scientific documentation.

378 Manufacturing an all-ceramic crown with the IPS Empress or the OPC System
The crown is modeled in wax and then embedded. The ceramic is afterwards pressed in a special oven.



379 Pressed crown for the posterior region
Right: According to the manufacturers, it is sufficient to paint all-ceramic posterior crowns only with a thin layer.

Left: Finished pressed all-ceramic crown. The IPS Empress and the OPC techniques should be used in the posterior regions only when exposed to low chewing pressure.



380 Pressed crown in the front tooth region
Completed all-ceramic crown.

Left: The all-ceramic incisor crown is cut back and over-layed.

Courtesy of Ivoclar

381 Advantages and disadvantages with all-ceramic crown systems

System	Aesthetics	Strength	Marginal Adaptation	Equipment and Cost	Suitable for bridges
Conventional Jacket Crown	Excellent	Low to medium	Good	Low (platinum foil or refractory die material)	No
Pt crown	Excellent	Medium (higher than jacket crown)	Good	Low	No
Hi-Ceram	Good	Medium (higher than Pt crown)	Good	Low	No
In-Ceram	Aluminium oxide kernel very opaque	High	Very good	Expensive equipment, high manufacturing cost	Restrict to particular indications
AllCeram	Outstanding	High	Very good	Expensive equipment, high manufacturing cost	No
Optec	Good (no opaque kernel)	Medium	Good	Low (refractory die material)	Restrict to particular indications
Empress and Jeneric OPC	Good	Medium	Very good	Expensive equipment, high manufacturing cost	No
Cerapress	Good to very good	Medium	Good	No particular equipment necessary, low manufacturing cost	No
Dicor	Very transparent, requires surface painting	Medium	Good	Expensive equipment, high manufacturing cost	No

382 Overview of different all-ceramic systems

Sytem	Type of Ceramics	Factors Influencing Strength
Hi-Ceram	Alumina core, alumina-reinforced ceramic	Dispersion strengthening by mixing two ceramics
In-Cream	Glass infiltrated alumina ceramic	An alumina core is infiltrated with a low melting glass, dispersion strengthening through glass infiltration
AllCeram	Nonshrinking alumina ceramic	Dispersion strengthening through magnesium–alumina spinell
Optec	Leucite-reinforced ceramic	Dispersion strengthening through leucite crystals
Empress and Jeneric OPC	Pressed leucite-reinforced ceramic	Dispersion strengthening through leucite crystals
Cerapress	At will	Used ceramics are consolidated by the pressing process. Leucite-reinforced ceramics can be used
Dicor	Cast glass ceramic	Conversion of glass to crystalline phase through ceramming

Overview

Porcelain inlays were already being produced in the 19th century. Unfortunately, both fit and cementation were very unsatisfactory. In 1908, the tooth-colored silicate cement was introduced that would become the most widely used anterior filling material for many years. After 1946, silicate restorations were slowly replaced by resin restorations.

Since the 1980s, tooth-colored materials have become available for use in the posterior regions. However, it is only since the ceramics and composites can be firmly bonded to the tooth that tooth-colored posterior restorations have worked with direct or indirect methods.

For the treatment of posterior teeth, numerous tooth-colored filling materials are available today:

- direct glass ionomer fillings
- direct resin-modified glass ionomer fillings
- compomer fillings
- direct composite fillings
- composite inlays manufactured directly in the mouth
- composite inlays manufactured indirectly, but immediately chair-side
- laboratory processed composite inlays
- sintered ceramic inlays
- cast glass ceramic inlays
- pressed glass ceramic inlays
- pressed ceramic inlays
- CAD/CAM processed inlays from ceramics and composites

The classic glass ionomer fillings were replaced by the resin-modified glass ionomers (e.g., Fuji II LCS, Vitremer, etc.). The indication for compomer fillings is limited to pedodontics and cervical cavities in active caries dentitions. The direct composite filling is the ideal restoration for small, incipient carious lesions. If existing extensive amalgam fillings are to be substituted, indirect methods are still preferred.

Ceramic inlay techniques are described in the following sections. The details concerning preparation, cementation, and finishing are not extensive because these topics have already been dealt with extensively in context of composite inlays (p. 152 ff.). However, differences in placing them will be accentuated.

385 Prerequisites, indications, and contraindications for all-ceramic inlays

Indications and Prerequisites	Contraindications
• High aesthetic requirements on the part of the patient.	• Allergies against components of the composite cement with which ceramic inlays must be cemented.
• The laboratory must be able to produce strong and well-fitting inlays.	• High caries activity.
• The dentist must master the adhesive bonding technique.	• Insufficient tooth substance.
• Size and number of restorations: ceramic needs more space than composites.	• Too strong discolorations.
• Large occlusal reconstructions are best made from ceramic if gold is excluded for aesthetic reasons.	• Margins are located too far subgingivally, impeding the use of a dry field during cementation.
• Numbers and duration of the treatments: ceramic inlays necessitate two sessions to place one inlay (with the exception of Cerec). Each session is time-consuming and requires cooperative patients. Immediate inlays are manufactured from composites and can be a good alternative.	

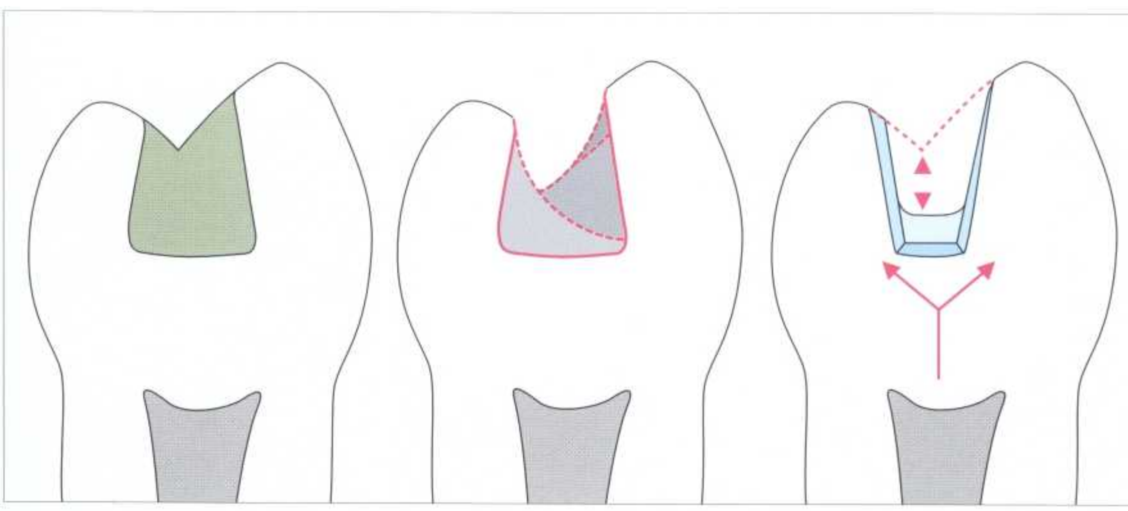
Principles of Preparation

Ceramic inlays require a large amount of space. The material should not be less than 1-1.5 mm thick. If the dental technician has less than 1.5 mm space for manufacturing an inlay, it would be difficult to make a well-fitting inlay that does not break during manufacturing in the laboratory. Also, the risk of fracturing an inlay during cementation should not be underestimated, particularly when thin inlays are cemented.

The typical preparation of a gold inlay and that of a ceramic inlay differ as follows:

- The ceramic inlay should have no feather edges, since these will break off.
- It should be prepared with a divergence greater than the gold inlay (approx. 6°) in order to facilitate sealing the inlay.
- The ceramic inlay should have no sharp internal angles. If this is, nevertheless, the case, they can easily be blocked by the dental technician with the die-spacer.
- With onlays, the cusps should not be embraced as is the case with gold inlays, but only beveled.

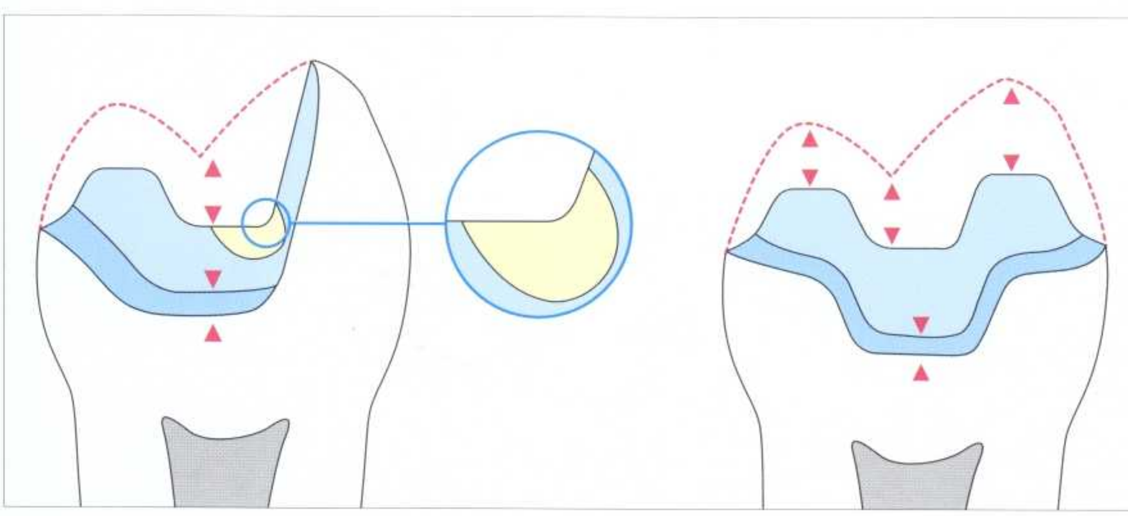
386 Principles of preparation
The preparation should have no undercuts and be more diverging than gold inlays. Cusps should not be embraced.



387 Importance of build-up and base
Left: After removing the old restoration, a large defect is usually present.

Middle: A preparation is chosen that does not have regions with large undercuts, because this usually leads to extensive restorations.

Right. Build-up and base filling serve to conserve tooth structure during preparation and to protect the dentin and the pulp.



388 Preparation of all-ceramic inlays and onlays
One should make sure that 1.5-2-mm space exists in all planes. Sharp inside line angles and small undercuts are not desirable and can be blocked by the dental technician with some die spacer. Large undercuts should be blocked before the impression is made with a buildup filling.

Color Selection, Impression, and Temporary Restoration

Color Selection

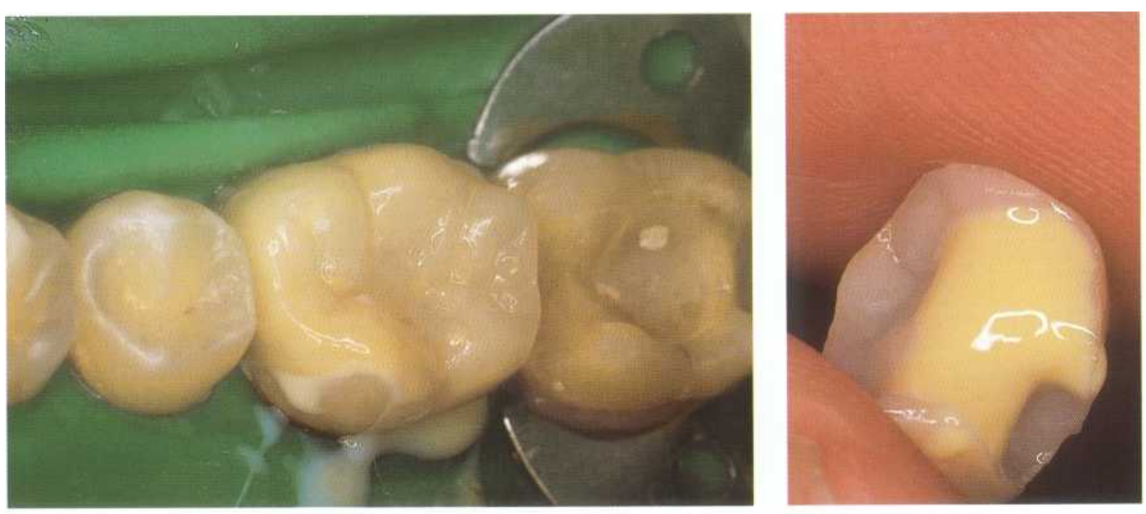
Colors should be selected before the rubber dam is placed. Discolorations that shine through a great deal from old restoration and carious lesions are to be removed with the rubber dam in place. Color selection can take place before the temporary restoration is placed.

The fact that the tooth color can change significantly during the treatment because of dehydration should be taken into account.

Depending on the technique used, patients are reminded that they will receive a tooth-colored inlay. A difference in color between inlay and the patient's own tooth is possible. Inlays made from IPS Empress, OPC, Celay, and Cerec techniques are produced from monochrome blocks and are subsequently painted. The colors are not always perfectly matched. In the case of onlays, a perfect color match is often difficult on the buccal surface of the onlay. It is, therefore, important to remember that this is where finishing and polishing is done. A line layer of color is often lost if care is not taken.

Surprisingly, with many inlay techniques it is not so important to select the exact color and color stratification. Through the chameleon effect of a transparent ceramic and the translucency of the cement, the margins are more often invisible with inlays than with onlays. Patients should already know this before starting the treatment plan. If they desire an invisible inlay, sintered ceramic is the best alternative. Then one must take the higher laboratory costs and the higher dental fees into account during the treatment planning.

However, the patient must also be informed that the physical properties of the sintered ceramic inlay are not as good as most other materials.



389 **Selecting the suitable color of the cement**
Left. Adapt the inlay on the tooth. Small corrections to the color, particularly at the buccal transition of onlays, are thus possible.

Right. The inlay is coated with the try-in paste.

390 **Impression**
The impression can be made with any addition-polymerized silicone or polyether impression material. A combination of hydrocolloide and alginate is also possible. The picture shows a combined hydrocolloid/alginate impression.

Making a Dental Impression

Usually, the impression is made with an addition silicone or a polyether impression material. Also, the classic hydrocolloid impression material (two impressions are required) is suitable for this. The dental technician should always make two working models. The contact points are adjusted after completion of the inlays on an uncut model. This makes it much easier to insert the inlays.

Temporary Restoration

Page 156 (Composite Inlays) describes a simple technique for malting temporary restorations. The technique is also used here. If complex onlays and partial crowns are made, indirect techniques are preferred. Temporary restorations prepared in the mouth or on a model are made extraorally, where they also are polished. Afterwards they are cemented with a temporary cement.

Restoration Material	Color	Longevity	Number of Visits	Cost	Optimal Restoration Size	Present State of Knowledge	Frequency of Use
Amalgam	Silvery	Medium to long	1	Low	Small, medium	Extensive	High
Gold, cast	Gold	Long	2	High	Medium, large	Extensive	Low to medium
Ceramics, cast	Tooth-colored	Medium	2	High	Medium, large	Medium	Low
Ceramics, fired	Tooth-colored	Medium to long	2	High	Medium, large	Medium	Low
Cerapress IPS OPC	Tooth-colored	Medium (possibly longer)	2	High	Medium, large	Little to longer	Low
Composite (directly placed)	Tooth-colored	Medium to long	1	Low to medium	Small, medium	Extensive	Medium to high
Composite (directly made inlay)	Tooth-colored	Medium to long	1	Medium	Medium, large	Medium	Low
Composite (direct/ indirect)	Tooth-colored	Medium to long	1	Medium	Medium, large	Medium	Medium
Composite (indirect)	Tooth-colored	Medium to long	2	High	Medium, large	Medium	Medium
CAD/CAM	Tooth-colored	Medium (possibly long)	1	High	Medium, large	Medium	Low
Celay	Tooth-colored	Medium (possibly long)	1 (long) or 2	High	Medium, large	Little to medium	Low

391 Possibilities for substituting amalgam with direct and indirect methods

The possibility for substituting amalgams with direct and indirect methods is an important topic in many countries. If a patient wishes to have a tooth-colored restoration, the patient should be informed about advantages and disadvantages of different techniques. Therefore, the dentist must master all available techniques to be able to propose the ideal technique for an existing defect. In the case of small defects, composites are preferred to ceramics because less healthy tooth substance needs to be removed. However, with large restorations affecting occlusion, strong ceramics (e.g., made with the Celay technique) and sintered ceramics may be advantageous. In cases when visual appearance is of less importance (second molars) and where gold restorations are aesthetically acceptable, these restorations should be considered as an alternative to tooth-colored restorations.

Ceramic Inlay Systems

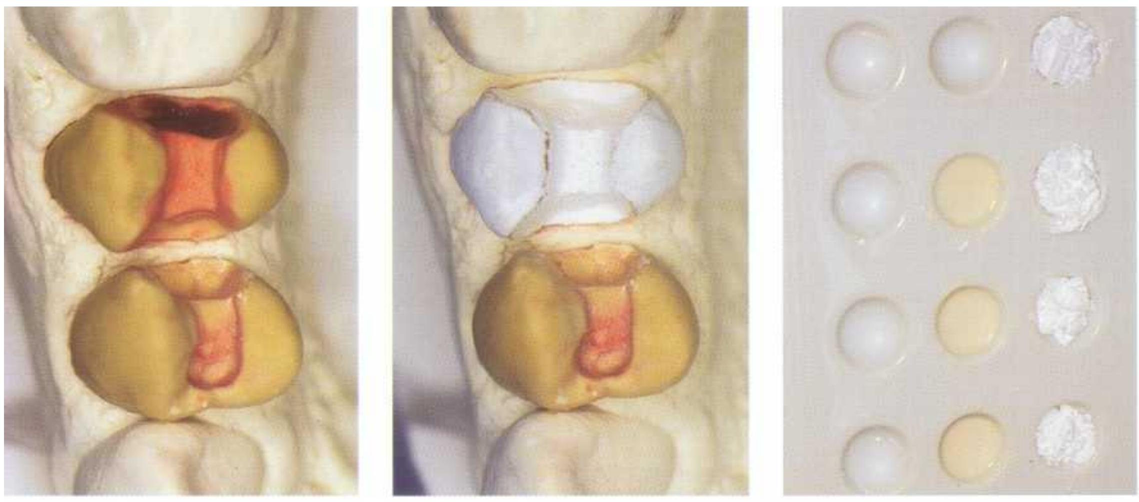
Sintered Ceramics

Classic sintered ceramics made on refractory dies still give the most beautiful results although they require a highly qualified dental technician.

The die is blocked as usually and the inside surface is coated with a die spacer. It must be duplicated afterwards with a silicone impression and filled with a refractory die material.

Repositioning the refractory die into the master model is problematic. A number of techniques are available for accomplishing this, although none is perfect. Therefore, it is important to transfer the inlay to a second uncut model after completion and to adjust the contact points.

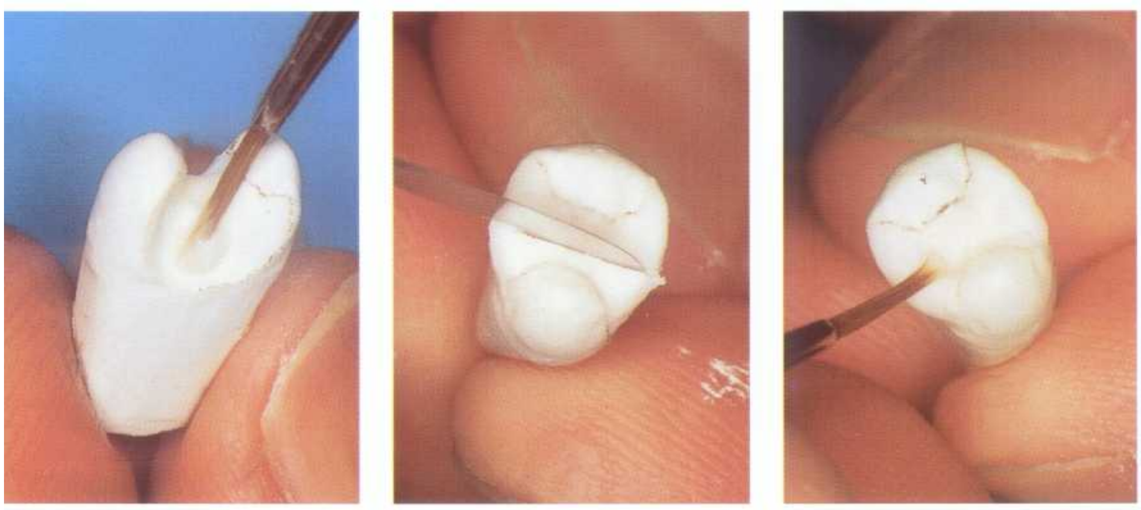
The ceramic is put on the refractory die in layers and is fired several times. The refractory die must first be destroyed before the inlay can be transferred to the master model. Corrections are still possible, but require a new die or the use of a low melting ceramic.



392 Making a sintered ceramic inlay
Left: Initial situation is a prepared tooth 15. A ceramic inlay is to be made on this tooth. (A composite inlay is to be made on tooth 14.)

Middle: The previous stone die has been replaced with a refractory die.

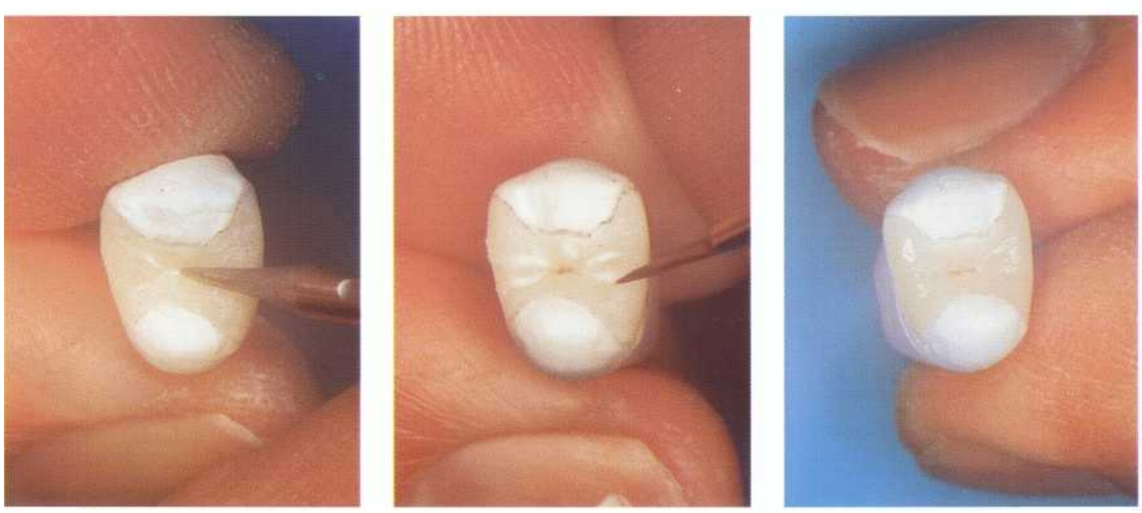
Right. The ceramic masses are mixed.



393 Building the ceramic
Left: Some opaque core mass is first placed and then the inlay is built up in layers.

Middle: Through contraction of the ceramic masses, tensile stresses are formed in the ceramic that can possibly break the inlay. Therefore, an intentional break is prepared.

Right. After firing, the intentional break is rebuilt with ceramic masses and the inlay is refired.



394 Shaping the sintered inlay
Left: The occlusal anatomy is shaped using a diamond.

Middle: The occlusal anatomy can in addition be characterized with ceramic stains.

Right: Completed sintered ceramic inlay.

Dental technician: *A. Schubert*

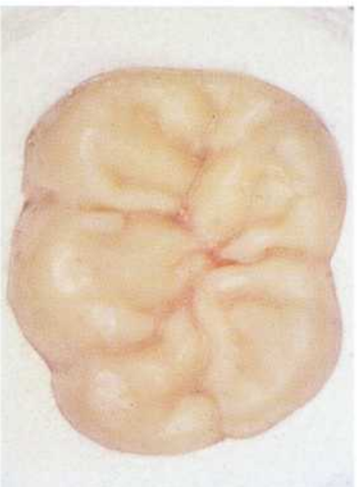
Cerapress Technique

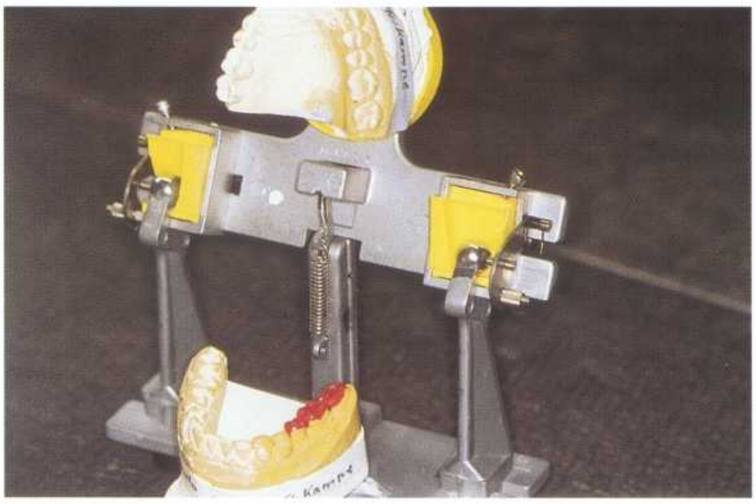
The Cerapress technique does away with the need to transfer the refractory die into the master model. The wax pattern produced on the master model is moved to the refractory die, which is then embedded in a flask with a special embedding material together with the wax pattern.

After the two embedding material masses have set, the wax is removed in a water bath or burned out in the preheating oven. Since the ceramic contracts, the mold must be overfilled and a drain furrow placed in the lower flask for the excess.

The advantage of this technique becomes clear as soon as the ceramic is inserted: a ceramist can mix the necessary masses individually and place them in layers. All ceramic masses are available to the ceramist. Leucite-reinforced ceramic such as Optec seems to be the strongest.

The two flasks are placed on top of each other and fired in the oven. At the end of the firing process, both flasks are pressed firmly together with special tongs. After cooling, the inlay is removed and finally shaped.





395 **Manufacturing a Cerapress inlay**
The restoration is modeled in wax on the master model.

Left: The wax pattern is transferred to a refractory die that is then embedded in a special flask.

396 **Pressing the all-ceramic inlay**
All-ceramic partial crowns pressed and placed on the model.

Left: The ceramic masses are placed in a special flask in layers. The excess which is to be modeled is selected in the "clear" color and then pressed into the lost wax model.

397 **Finished Cerapress partial crowns**
Inlays cemented in the mouth.

Left: The fit of the pressed inlays is virtually perfect.

Dental technician: A. *Schmidseder*

IPS Empress and OPC Technique

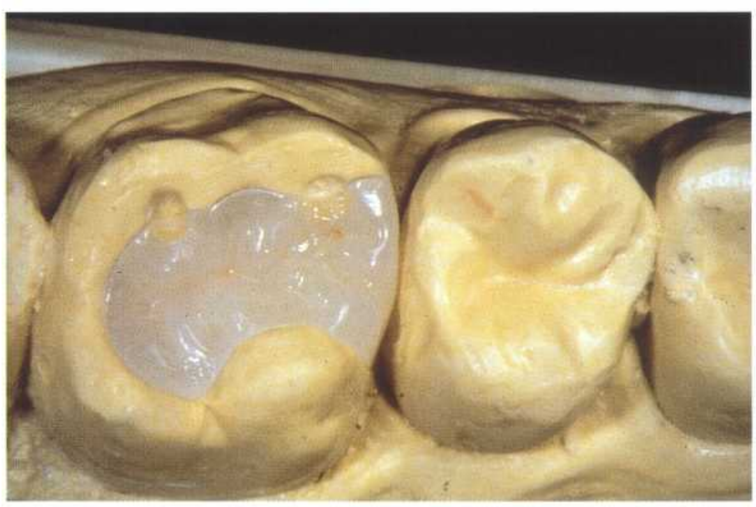
The two techniques are virtually identical and differ most of all in terms of price. Their advantage in comparison to the Cerapress method is that these techniques improve standardization and therefore become less technique-sensitive. The making of a refractory duplicate die is not necessary. The wax pattern is directly embedded. This process hardly differs from the gold-casting technique.

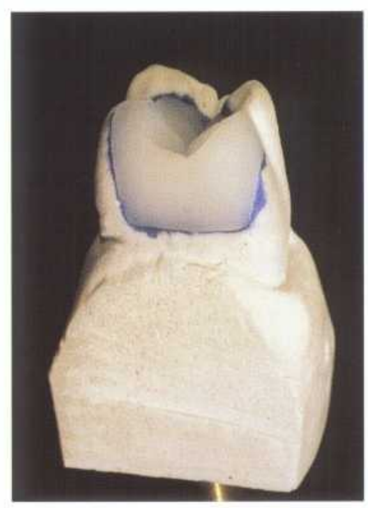
A ceramic pellet is placed in the mold after a preheating phase. With the OPC system, these pellets are partially sintered, while with the IPS Empress system they are completely presintered. When the ceramic has reached a specific temperature, it is forced under pressure into the inlay mold. After it has been pressed, the inlay is a monochrome block, which can be superficially stained.

The aesthetic result of the inlay is often stunningly impressive. With onlays and partial crowns, optimal coloration is usually most difficult to achieve at the transition to the natural tooth. The superficial layer of color is lost not only during finishing, but also over time due to normal abrasion. The patient should be made aware of this.

Manufacturing a pressed ceramic inlay using the IPS Empress or OPC technique

398 Modeling the inlay in wax
Right. **The wax pattern is embedded like a gold inlay.**





399 Pressed inlay
The pressed inlay is a monochrome block that is painted on the surface. The transparency of the ceramic mass results in aesthetic restorations because of the chameleon effect.

Right. **The pressed inlay fits very well.**

400 Finishing a cemented pressed ceramic inlay
All-ceramic inlays must be adhesively bonded.

Try-in

The teeth must be cleaned well after the temporary restoration has been removed. A fluoride-free polishing paste (e.g., Pellex) or fine pumice should be used for this purpose.

Before placing the rubber dam, the tooth color should be checked. Tooth and inlay should be moist when this is done.

The proximal contacts must be checked with dental floss. One must proceed very carefully, in order to avoid a possible fracture of the inlay. The contact points are adjusted in the laboratory on the second, uncut model and if a well-fitting temporary restoration has been used, this process should usually not represent any significant problems. If the contact point is too loose, this must be corrected in the laboratory. If it is too tight, it can be loosened easily with a white ceramic polishing stone.

Fit

The edges of ceramic inlays can and should fit as precisely as gold inlays. Ceramic inlays are usually simple to place. The cement requires space, however. Lack of space for the cement leads to reduced bonding ability and increases the risk of fracture. Therefore, the entire preparation on the model (up to just below the preparation margin) must be coated with a die spacer 40-60 pm thick. It is important that the dentist keeps an eye on this coating and discusses this point with the laboratory, since the consequence of forgetting the coating could be a fracture of the inlay at a later time. If the laboratory guarantee has expired when such a fracture happens, the dentist may have the legal or moral obligation to remake the inlay.

The occlusion cannot be tested until after cementation. The inside surfaces of the inlay must be checked. The inlay is etched sufficiently with phosphoric acid (frosty surface after blow-drying) and must be cleaned before silanization is carried out. If there are any doubts regarding the etch pattern, the inlay is reetched with a hydrofluoric acid gel. Only after the phosphoric acid, or if necessary after the hydrofluoric acid has been rinsed away, is the ceramic silanized.

401 Cleaning the preparation before the try-in
It is important that the tooth surfaces are thoroughly cleaned with pumice before try-in of the inlay.

402 Try-in of the pressed ceramic inlay

Bonding Ceramic Inlays with Composite Cements

Ceramic inlays must be cemented with composite cements. If this is not done, there is a high risk of fracture. Like ceramic veneers, ceramic inlays can also last for a very long time if they are bonded correctly.

However, in order to avoid problems, the dentist should be aware of the differences between the different ceramic materials. Most ceramics can be etched well with hydrofluoric acid and, after silane treatment, form a reliable micromechanical and chemical bond to the adhesive and the composite cement.

However, the techniques that are suitable for the conventional dental ceramics do not work well with a glass infiltrated aluminium oxide ceramic (In-Ceram). The reason is that hydrofluoric acid does not generate a suitable etch pattern on alumina-based ceramics.

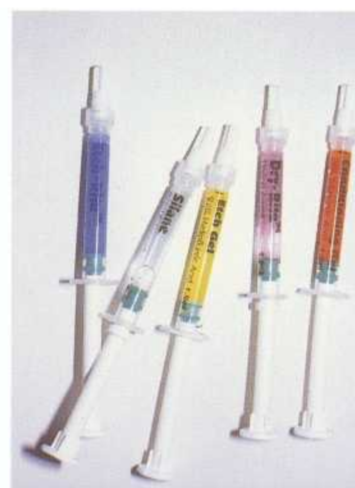
At the present state of knowledge we know that correctly executed bonding between an etched ceramic surface and a composite is a reliable connection. If, for example, orthodontic ceramic brackets are used, the strong bond considerably impedes removal of the brackets.

Selecting a Suitable Cement

Small, particularly transparent, inlays can be best bonded with a purely light-curable cementing system (e.g., Scotchbond MP and paste A of the opalescent bonding cement by 3M). This approach significantly facilitates cementation.

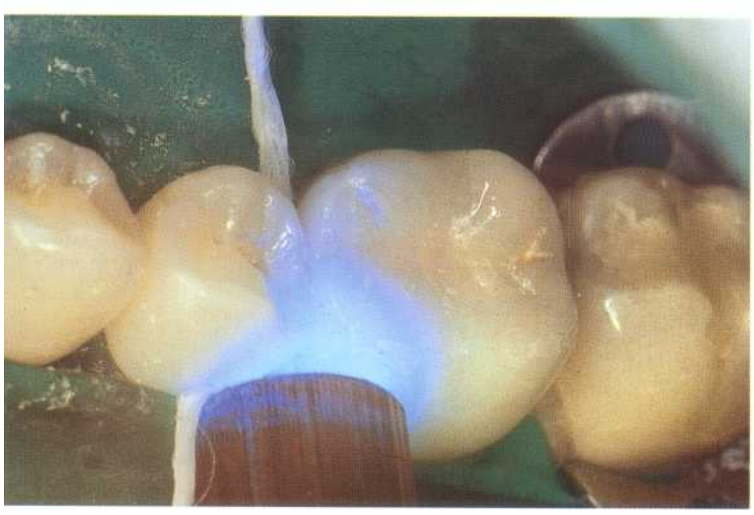
However, large inlays and onlays with more distinctive opacity must be cemented with a chemically or dual-cured cement. Be aware that not only the cement is chemically or dual-curing, but also the adhesive bonding agent (e.g., Scotchbond MP Plus). If a purely light-cured bonding agent or adhesive is used, the substance under an inlay or onlay may not completely hardened. The consequence is insufficient bonding with increased fracture risk, possible leakage with postoperative sensitivity, and irritation of the pulp due to free leakage of monomers.

It is important that dentists either select a bonding system that allows them to cement purely light-curing systems (primer, bonding agent, and cement), or a system that exists as a purely dual-cured system (primer and bonding agent as well).



403 Adhesive cementation of all-ceramic inlays
All-ceramic inlays must be cemented adhesively (see checklist, p. 204). A solid connection form which gives the inlay maximum stability can only be achieved by means of a perfect bonding technique.

Right: Before the all-ceramic inlay is cemented, the ceramic surface must be conditioned, i.e., etched with hydrofluoric acid and silanized.



404 Polymerization of the cement and the adhesive
If one uses purely light-cured resin cements, these cements must be sufficiently polymerized. However, if one uses dual-cured cements, the adhesive must also contain a chemical hardening component (e.g., Scotchbond MP Plus).

Right. An intense polymerization lamp and light-cured cement can be used to cement an inlay that is sufficentlytransparent and is not too bull<y.

Adhesive Bonding

In order to cement a reconstruction, the enamel, the dentin and the build-up filling are etched for 30 seconds with 30-35% phosphoric acid. Care must be taken that the dentin surfaces should not be etched for longer than 15 seconds if possible.

After the tooth has been conditioned with phosphoric acid, the primer is taken from the bottle and immediately placed on the entire, prepared tooth surface. It is important that the manufacturer's instructions are followed. Some manufacturers recommend that several layers of the primer are placed. After the primer follows the adhesive, and the inlay is coated with resin cement. Before the etched and silanized inlay are covered with the resin cement, some bonding agent is placed and blown not too thinly.

Up until now it has not been clearly proved whether fifth-generation dentin adhesives are suitable for this technique. All the systems available on the market at present are light-curable systems. So long as there are so many open questions that have not yet been clarified regarding these dentin adhesives (e.g., the bond strength values to ceramics and other materials, thickness of film, and bonding ability to different cements), one should continue using the fourth-generation, three-component systems.

After preparation of the inlay and the tooth, the inlay is bonded with the resin cement. Subsequent steps (bonding, polymerization, trimming, and finishing) follow the pattern described for composite inlays.

405 Trimming all-ceramic inlays and onlays
The buccal surface of an all-ceramic onlay can be processed very well with ceramic rubber wheels. Disks and fine diamonds are also suitable.

406 Trimming and adjusting the occlusion
The occlusion is adjusted with superfine finishing diamonds, which are also used for removing excess resin.

Dental technician: A. *Schmidseder*

Checklist—Ceramic Inlays

For the Dentist

Treatment Planning

- Needs of the patient (aesthetics, cost, number of sessions)
- Size of the defect (suitable material for the existing defect)
- Oral hygiene and caries activity (pretreatment during the hygiene phase)
- Determining the treatment goal (color selection, color of all teeth, possibly bleaching before the treatment starts)

Preparation

- Removal of old restoration, underfilling, and caries
- Construction of underfilling (total etch technique to protect the pulp and to seal off the dentin; build-up filling made with composites)
- Tooth conserving design, smallest possible preparation (inlay preparation with rounded off transitions)
- Selection of suitable material (composite, ceramic)
- Impression
- Temporary restoration
- Instructions to dental laboratory/technician

Cementation

- Anesthesia
- Removal of the temporary restoration and cleaning of the cavity
- Try-in (color, contact points)
- Rubber dam, renewed cleaning of the cavity, sandblasting (Microetcher, KCP, etc.) of the base if present, normally slight roughening with diamonds
- Etch ceramic inlays with hydrofluoric acid, rinse, dry, and treat surface with silane. Sandblast composite inlays
- Use total etch technique for the entire cavity, place primer and bonding agent on tooth surface
- Place bonding agent on inlay, air-thin lightly; cover inside of inlay with light-curing resin cement (clear color if the inlay color is correct)
- Insert the inlay
- Remove gross excess (proximal excess is removed with dental floss)
- Polymerize at a few points (5 seconds)
- Remove further excess
- Polymerize (3 minutes per tooth with polymerization lamp $>450\ mW/cm^2$, check light performance)
- Adjust margins and occlusion
- Recall for check-up after 2 weeks to check for possible resin remains that need to be removed

Follow-up

- Medicine carrier, if there is caries activity (like bleaching tray) suitable for fluoride application
- Regular maintenance visits (2–4 times per year)
- Oral hygiene instructions

For the Dental Assistant at the Recall

- Avoid using chlorohexidine for plaque control if possible
- Identify inlay margins and do not touch them with ultrasonic instrument or during air-abrasion
- Do not damage the inlay margins with curettes
- Do not use highly abrasive polishing pastes on the inlays
- Sodium fluoride with neutral pH containing varnishes and gels are preferred to slightly acidic amine or stannous fluoride gels
- Regular bite-wing radiographs (annually)

For the Patient

- Come regularly for check-ups
- Use a suitable, soft toothbrush (a power toothbrush is better)
- Clean interproximal spaces with dental floss
- Use toothpastes with neutral pH and low abrasive capacity
- Use sodium fluorides rather than amine or stannous fluorides

Veneers-From Planning to Recall

The term "Hollywood smile" was coined by Dr. Charles Pincus during the 1930s. At the 1937 meeting of the California State Dental Association he said: "The average dentist always considers articulation and function, while only very few consider aesthetics. We should not forget, however, that we are dealing with an organ that characterizes and can change an individual's entire personality. A beaming smile, a straight row of natural white teeth is an important component of a characteristic of a personality that is very difficult to understand." To help movie stars to get a beaming white smile, Dr. Pincus invented the veneer technique-wafer-thin ceramic shells that were glued onto teeth. It was a very expensive method that was affordable to only a few. The technique was not further developed until new bonding methods became available, and it has been successfully used since 1985 (Calamia 1985).

The Advantages of Veneers

Veneers are labial partial crowns. Their advantages compared to crowns are so major that they should be preferred to crowns in almost all cases.

Color and Aesthetics

It is only occasionally possible to achieve a similarly perfect aesthetic result with crowns as with veneers. Color, form, surface, individual characterization through internal and external staining, color corrections during cementation with special cement colors, and the contact lens effect, which makes these restorations invisible-all these factors lead to a perfect restoration.

Durability and Tooth Conservation

Ceramic veneers have high abrasion and color stability. With the new bonding methods, the risk of fracturing veneers is presumably smaller than that of metal or all-ceramic crowns.

Only little tooth substance is removed (0.5-0.75 mm) during veneer preparation.

Function

Since the veneer itself is in most cases limited to the labial surface and the incisal part of the clinical crown, postoperative functional complications can also be avoided. Particularly in patients with deep bites there is rarely sufficient space on the lingual side for conventional crown preparations. Also, lower front teeth can only in rare cases be treated with traditional crown techniques and be aesthetic, retain functionality, and simultaneously protect the pulp. Veneers are, therefore, far superior to crowns.

Strength

The new generation of dentin adhesives and cementation materials makes it possible to extend the list of indications for veneers. It is no longer necessary that all cut margins are in the enamel. The strength of the bond of etched and silanized porcelain, adhesively bonded with the new bonding materials to enamel and dentin, has opened a new era. The bond strength values of etched porcelain bonded with composite cement are as high as systems consisting of composites bonded to etched enamel.

407 **Shortened upper incisors**
Acid erosion, toothbrush abrasion, and bruxism have led to a significant loss in coronal length of this patient's upper front teeth.

408 **Reconstruction using veneers**
Aesthetics and function of the upper incisors were restored with veneers.

Dental technician: *R. Schubert*

Furthermore, the coefficient of thermal expansion of the veneers is comparable with that of the natural tooth structure. No other restoration is as stable and durable. This is astonishing, because in the unbonded condition the veneer is very fragile. However, as soon as it is adhesively bonded to the tooth, it develops an extremely high tensile and flexural strength.

Periodontium

It is not necessary to hide the veneer margin under the gingiva as is the case with front crown margins. Since they are invisible, the margins are supragingivally or slighly subgingivally placed and sealed with insoluble composite cement, resulting in gingival health conditions that are usually better than with crowns. However, finishing the veneer margin is a very difficult and demanding task.

The Disadvantages of Veneers

Irreversibility

Tooth substance must be removed. The restorations can not be tried-in and be cemented temporarily. If the veneer is put in and attached, it is not possible to correct it later. However, a veneer can be removed (this is only possible through grinding) and replace it with a new veneer or crown.

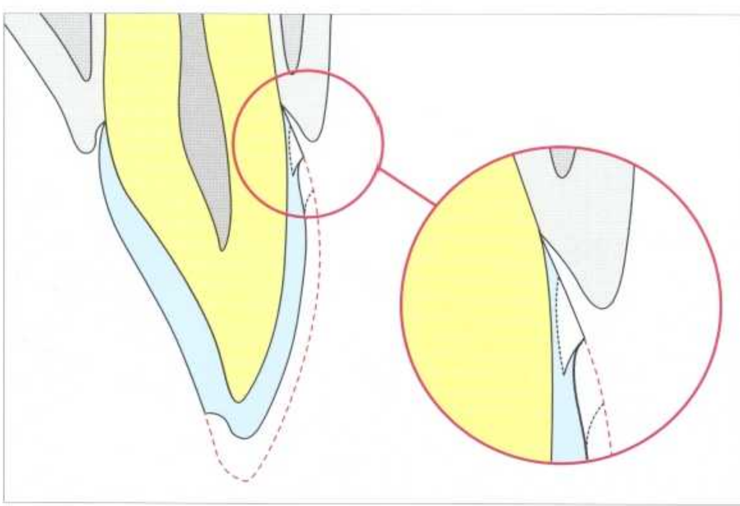
Cost

Placing a veneer is a very demanding dental activity. For the ceramist in the laboratory, it is also a big challenge again and again to accommodate color, form, surface structure and individual characteristics on small areas. All this leads to relatively high costs.

Test group	Etching	Silanization	Tensile strength (MPa ± standard deviation)
A	Yes	No	2907 ± 165
B	Yes	Yes	3485 ± 340
C	No	No	564 ± 140
D	No	Yes	987 ± 390

409 Effect of conditioning used on the ceramic surface on the tensile strength of the restoration
The surfaces of all-ceramic restorations should be conditioned before cementing: etch with hydrofluoric acid and silanate (exception: In-Ceram). The combined treatment (group B) increases the tensile strength when compared to the untreated control surfaces (group C) by a factor of approx. 6.

(Adapted from Hsu et al. 1989)



410 Cervical margin
The margins of veneers do not need to be hidden below the gingival margin as is the case with crown margins. They can end at the gingival margin or finish slightly supragingivally. The veneer margins are not visible in the mouth because of the contact lens effect: like a contact lens, the edges of a veneer cannot be recognized in the moist environment of the oral cavity.

Indications and Contraindications

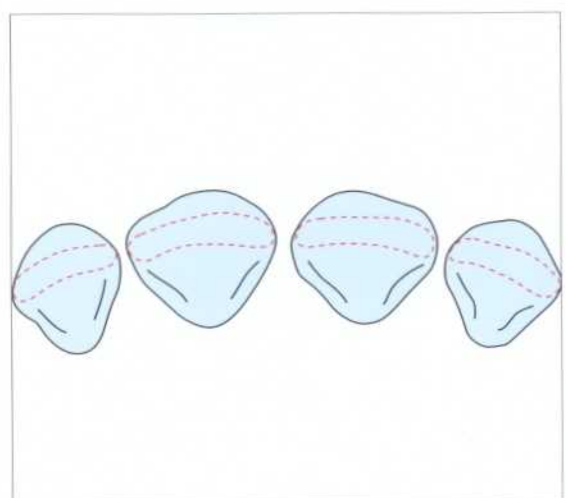
Special indications:
- -Tooth fractures in teenagers.
- -Single and strongly discolored nonvital teeth.
- -Large labial erosions and front teeth with extensive cervical restorations.
- -Strong discolorations that cannot be removed by bleaching or through micro abrasion.
- -Extensive enamel defects.
- -Occlusal and incisal overlays in the anterior and posterior regions caused by acid erosion (bulimia, anorexia nervosa).
- -Deep bite with or without contact.
- -On lower front teeth instead of crowns.
- -Closing a diastema.
- -Correcting minor malaligaments.

Contraindications:
- -Extreme bruxism
- -Front teeth with too extensive composite restorations and with too large destructions
- -High caries activity, lack of dental awareness
- -Poor oral hygiene


411 Extensive cervical defects
Left: During puberty many teenagers have high caries activity that frequently results in large cervical cavities.

Right. The teeth have been restored very aesthetically with veneers.

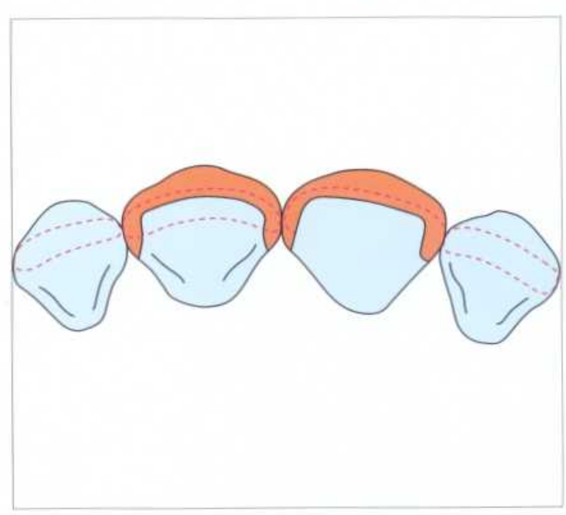
Dental technician: A. *Schmidseder*

412 Diastema between the upper incisors
A diastema cannot only be closed with direct composites, but also very aesthetically with ceramic veneers.

Left: Situation before treatment.

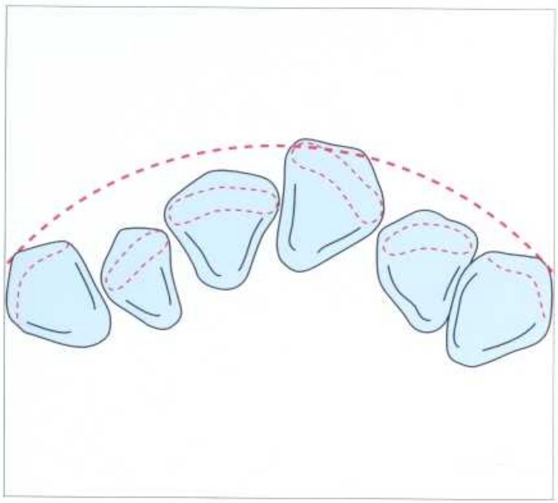
Right: Graphic representation.

413 Situation after restoration with veneers
Left: Cemented veneers.

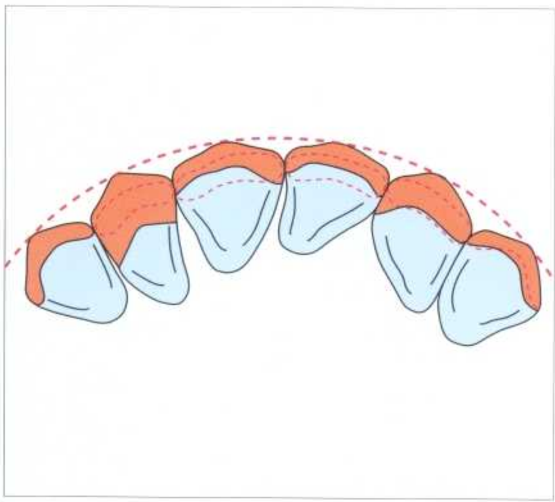
Right: The preparations are cut through to the palatal surface so that the proximal spaces can be closed with the ceramic veneers.

Dental technician: *R. Schubert*




414 Veneers instead of orthodontics
Many adults have already been treated orthodontically and do not wish any further orthodontic treatment. Slightly malpositioned teeth can alternatively be treated with veneers. The resuls are very good.
Left: The labial surfaces of teeth 12, 11, and 22 must be moved forward, while 21 needs to be moved backwards in order to achieve a symmetrical front.

Right: Preoperative situation.

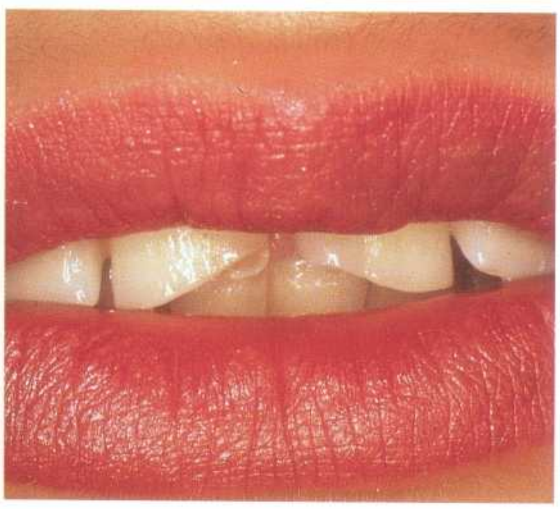
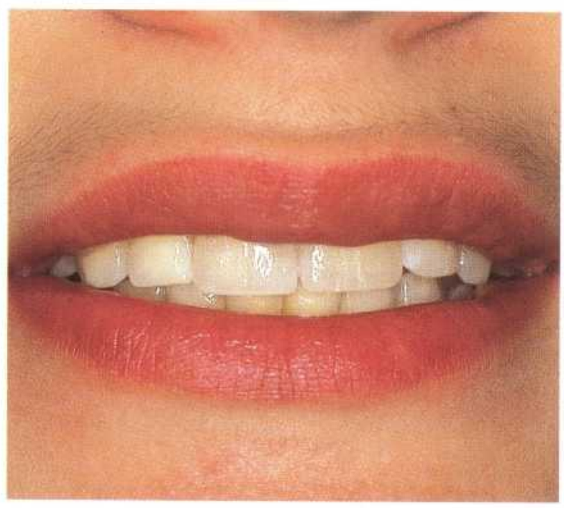



415 After reconstruction
After the wax build-up, it was clear that the teeth could be reconstructed with veneers very well.

Left: Planned correction of malpositioned teeth treated with veneers.

Right: Situation after treatment.

Dental technician: *R. Schubert*

416 Reconstruction of fractured front teeth
It is especially important that crowns should not be used to reconstruct teenagers' fractured front teeth, as appearance is highly valued in this age group and is important for self-esteem. All-ceramic veneers are an ideal solution.

Left: A 13-year-old girl with fractured incisors.

Right: Veneers have been used to reconstruct the fractured incisors.


417 Reconstruction of the lower incisors
Defects on lower incisors are not easily reconstructed aesthetically with crowns. All-ceramic veneers withstand high pressure and they are therefore suitable for reconstructing lower front teeth.

Left. Defective and tightly spaced lower incisors.

Right: Reconstruction with veneers.

Dental technician: *A. Schmidseder*

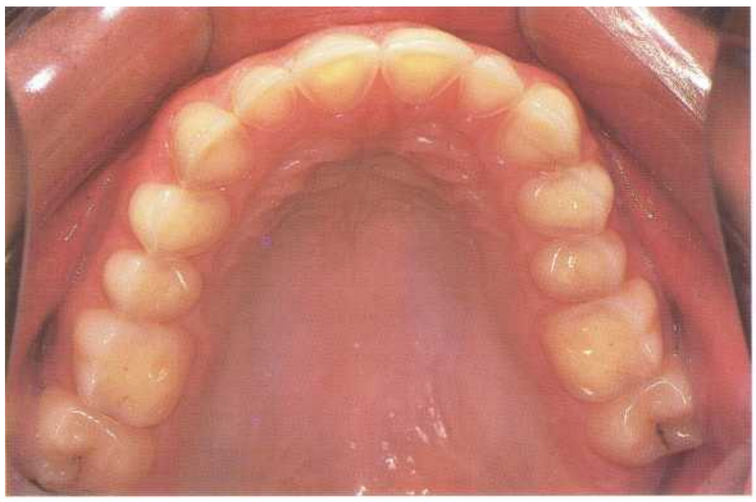
Diagnostics and Treatment Planning

With any adhesively bonded restorations, a carefully planned and enforced hygiene phase is especially important. Patients must be aware from the beginning that they must come regularly to the recall sessions. The weakness of all bonded restorations is the bond. The adhesive cements are only moderately filled composites that have higher plaque retention and cause a higher risk of secondary caries.

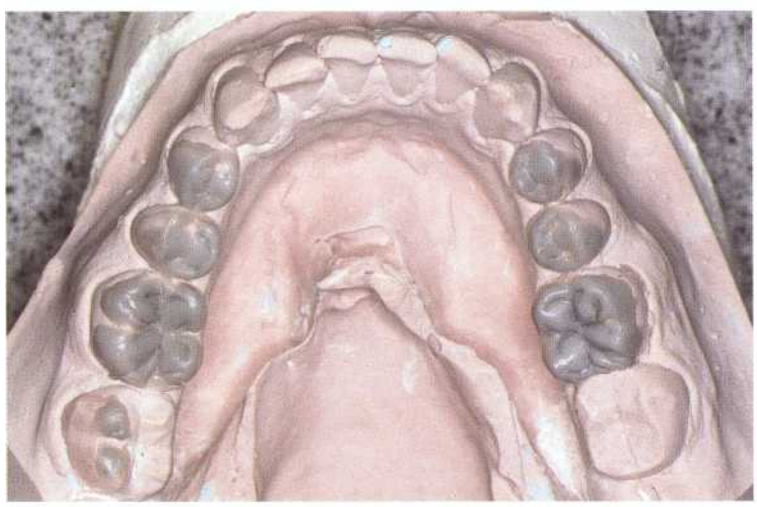
Initial Hygiene Session

1. Investigation of causes for changes to the front teeth. If particular nutritional factors were involved in the discolorations, this should be pointed out to the patient before treatment begins. Acid-containing foods can also change the surface of the ceramic. Also, parafunctions or habits that possibly lead to abrasion of the front teeth should be mentioned and recorded on the patient's dental chart.

418 Acid erosions
Rebuilding acid-eroded anterior and posterior teeth is best done with new adhesives. All lingual surfaces of the upper and lower teeth of this 17-year-old patient have been eroded through frequent consumption of acid-containing soft drinks (coke, soda).

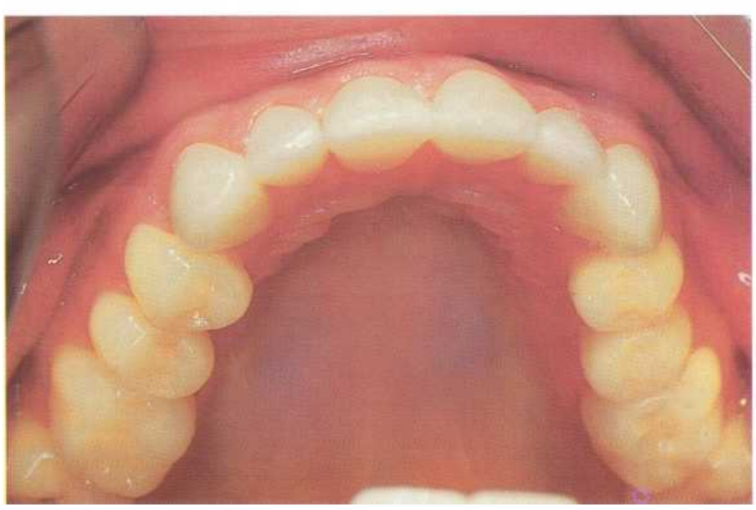


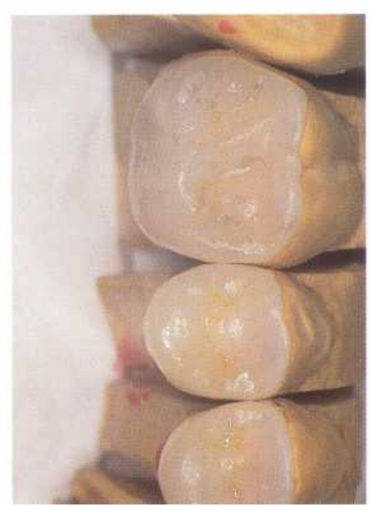
419 Lower jaw model of the same patient rebuilt with wax
Whenever a reconstruction of tooth length, tooth form, or occlusion is planned, a diagnostic wax up of the occlusion should be made.



420 Cemented veneers and partial crowns covering acid erosions
Left: Finished treatment with ceramic partial crowns and veneers.

Right: Occlusal overlays on the model.

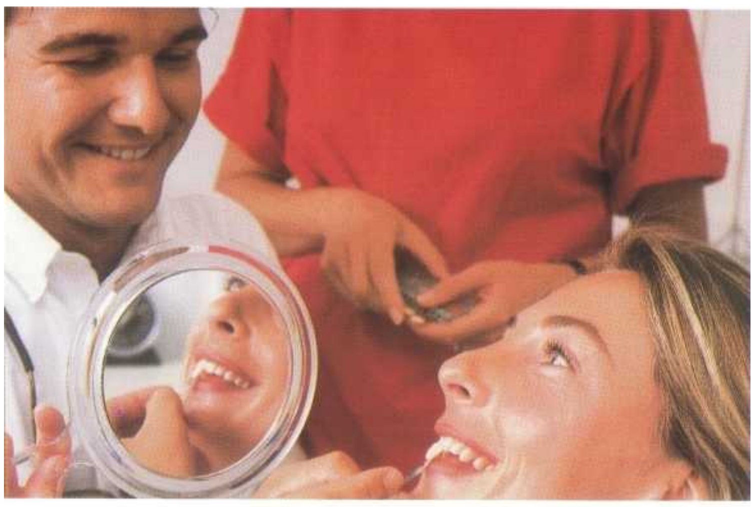




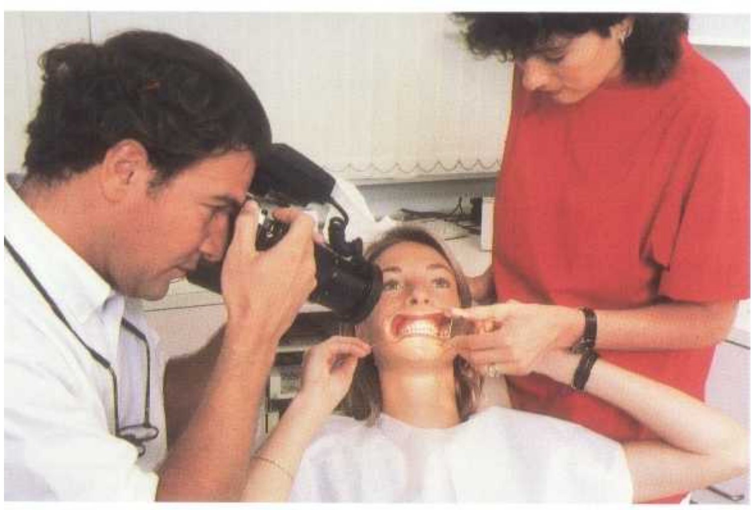
2. Oral hygiene must be adapted to the restorations. Toothpastes with low pH values or high abrasiveness change the ceramic surface over time. Therefore, an individual oral hygiene instruction program is presented and nutrition advice is given before treatment begins.

3. After a thorough professional tooth cleaning, the tooth color and the patient's desired color are carefully recorded on the chart. Taking intraoral photographs is always recommended. A complete set of radiographs and a panoramic radiograph are also required for the treatment planning.

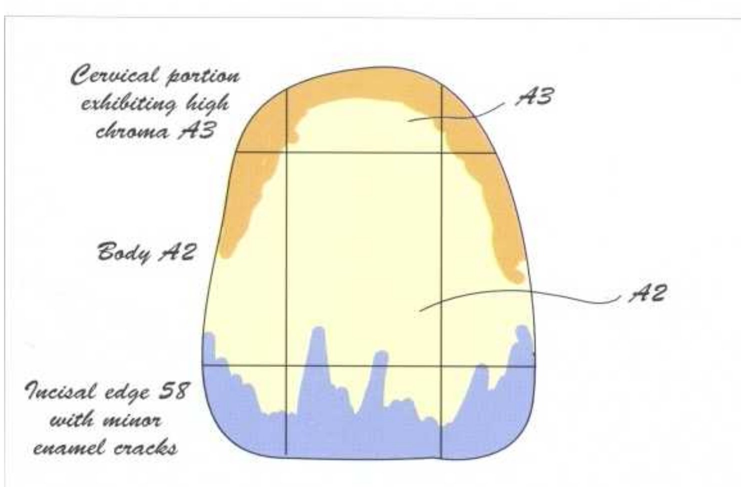
4. Finally, study models are prepared. If the plan is to change the tooth form/tooth length or to close a diastema, these changes should be planned in a diagnostic wax-up. This facilitates communication with both patient and laboratory.



421 Determining the treatment goal
The treatment goal should be decided at the beginning of the treatment: which tooth-color, form, and size?
Patients must participate in choosing the tooth color. Patients themselves must finally determine whether the existing tooth color should be retained or be modified according to their wishes.



422 Documentation of the initial situation by means of intraoral photograpy
In addition to radiographs, a photo-status is also part of treatment planning.



423 Color map of a central incisor
Before beginning preparation, not only existing, but also the desired tooth color should be determined and recorded. In addition, the layering of the remaining teeth should also be recorded. This is best done in the form of a color map that is prepared by the dental technician.

Preparation

In contrast to crown preparation, the preparation of veneers is a very simple dental procedure. If a study model and a diagnostic wax-up are available beforehand, the goal of treatment can be planned and visualized, which accordingly facilitates the preparation design. If the task only involves restoring existing enamel defects, then a simple standard preparation is sufficient. If there are larger composite restorations in the teeth concerned, the standard preparation must be widened. If minor malpositions and strong discolorations of single teeth are to be corrected, or a diastema is to be closed, then the standard preparation as shown must be modified accordingly.

Standard Preparation

About 0.5-0.7 mm of the entire labial surface is removed. The cervical and proximal margins should have a smooth chamfer which is approximately 0.5 mm deep. It is recommended that you approach the proximal contact point as much as possible. The incisal edge should be shortened by about 1.0-1.5 mm. The palatal margin should have a rounded bevel.

Goals of Preparation

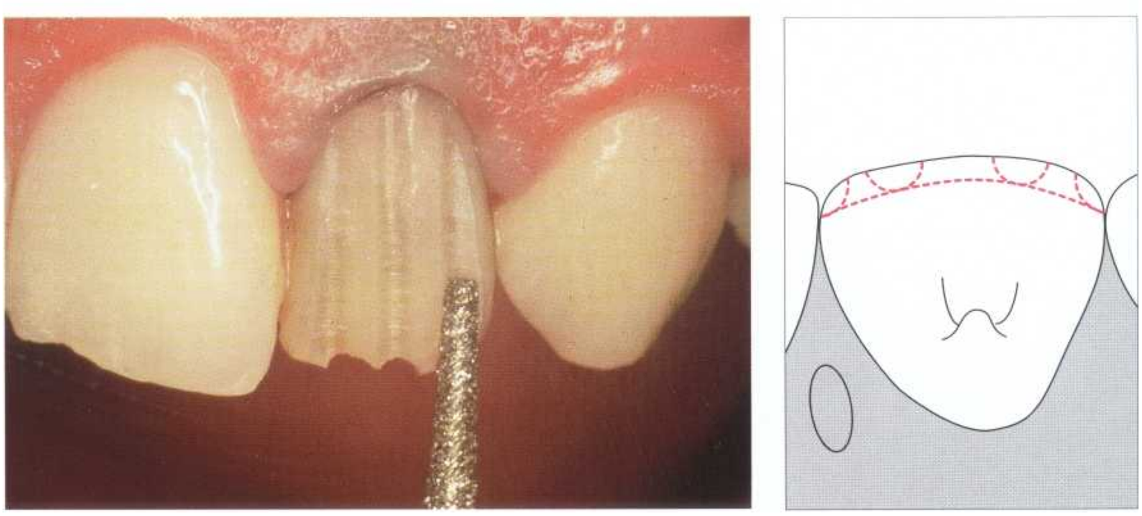
- To generate sufficient space for the porcelain
- To hide the preparation margins
- To generate a well-defined insertion direction without generating undercuts
- In case of strong discolorations, which must be covered with dentin mass and/or with opaquing cements, it is necessary to add additional space (approximately 0.2 mm)
- To facilitate insertion (e.g., with the chamfer)
- To save as much enamel as possible

Steps

1. Preparation: inject anesthetic and place retraction cords.
2. Labial reduction by about 0.5 mm.
3. Cut a chamfer along the proximal extension, which is located to the nonvisible proximal regions, without cutting through the contact point.
4. Place the cervical margin as a 0.5-mm-deep chamfer.
5. Shorten the incisal edge by approximately 1-1.5 mm and place the palatal chamfer.

424 **Arrangements before preparation**
Tooth 22 has been strongly discolored after endodontic treatment and will therefore be treated with a veneer.

Right. After injection, a retraction cord is placed that retracts the gingiva by approx. 1 mm.



425 **Preparation of depth cuts**
Depth cuts which are 0.5 mm deep are prepared with the help of a tapered bur (diameter at the center: approx. 1 mm).

Right: Graphic representation of the orientation grooves.

Preparation

The largest part of the preparation is in the enamel and therefore no pain is to be expected. Anesthesia is recommended before the preparation in order to be able to be relaxed while working. A retraction cord is placed after the injection and remains in place until after the impression has been made. With the cord in place a slightly subgingival preparation is possible.

Labial Reduction

Various companies produce special veneer preparation kits. However, these are not necessary. A regular, slightly tapered diamond bur that has a rounded tip is sufficient for the preparation. It should have a regular grain size. It is not necessary to smooth the surface with fine diamonds, as a rough surface increases the retention of the veneer.

Proximal Extension

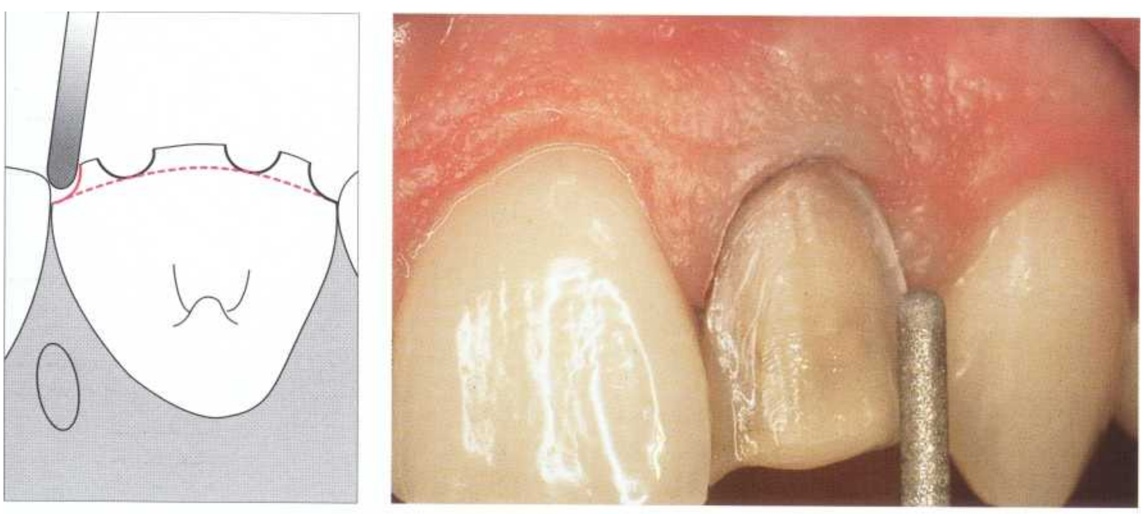
The proximal margin should be extended into the area of the contact point to make it invisible. The ceramic should not be too thin in this region, as this would impede the work in the laboratory unnecessarily and it would also increase the risk of fracture during cementation. Therefore a 0.5-mm-deep chamfer is prepared. If a particular laboratory technique would require the working dies to be separated individually, one can easily open the contact point with a fine diamond strip.

Cervical Chamfer

The entire veneer preparation is done with a single bur. The cervical chamfer is positioned with the rounded off diamond tip. The purpose of the chamfer is to facilitate the work and color build-up for the technician, and for the dentist when the veneer is cemented (reduction in risk of fracture).

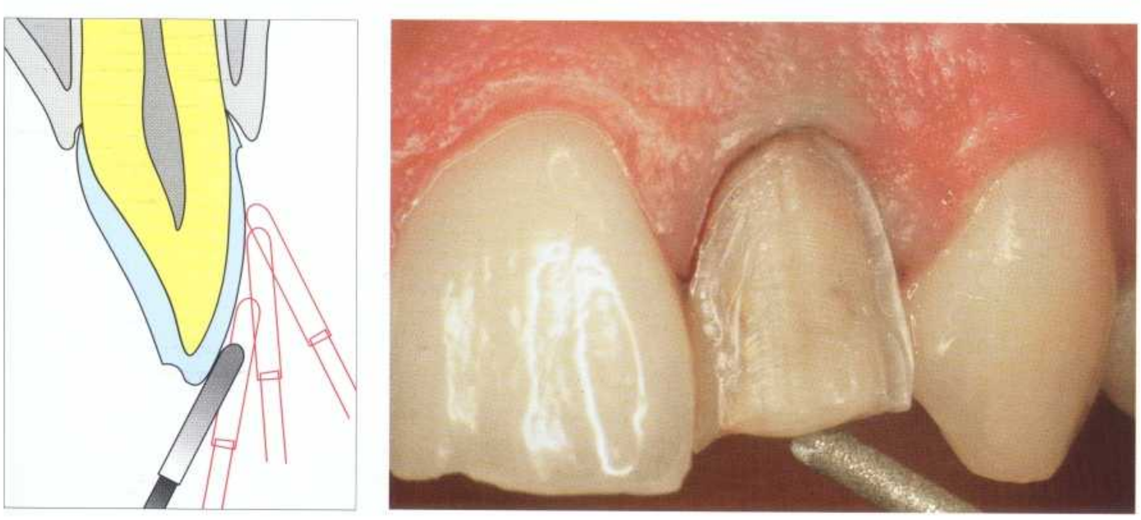
Incisal Reduction

Long-term studies have shown that the risk of incisal fractures of the ceramic is 13% if the veneer does not cover the incisal edge. It is absolutely necessary, therefore, to reduce the edge by about 1-1.5 mm. After the incisal edge has been reduced, a lingual chamfer is prepared with the same diamond bur or with a bullet-shaped carbide finishing bur. However, if lost front tooth length is to be restored, it is sufficient to level the incisal edge and place the lingual chamfer.



426 **Preparation of the facial surface**
The facial surface is reduced by approx. 0.5-0.7 mm along the depth cuts. A deep chamfer proceeds around the entire preparation. The incisal edge is reduced by approx. 1 mm.

Left: Placement of a proximal chamfer.



427 **Placing a lingual chamfer**
After some smoothening of the labial surface, the rounded chamfer has been placed and the incisal edge has been sufficiently shortened. A lingual, deep chamfer is also created. This chamfer facilitates cementation and increases the strength of the ceramic.

Left: Smoothing the labial surface.

Impression and Temporary Measures

Making a dental impression is usually no problem, since the preparation margins do not reach far subgingivally and are all visible. However, the temporary treatment can prove to be more difficult.

Making a Dental Impression

A retraction cord is placed even before preparation begins. Since the preparation extends only slightly subgingivally, a second retraction cord is usually not necessary. However, during the treatment it may be necessary to force the already placed cord into the sulcus again. A second, somewhat thicker, cord is suitable for this. The first cord remains in the sulcus whilst the impression is made.

Tear-resistant materials such as A-silicones or polyethers are recommended as impression materials. Hydrocolloids are not advantageous, since they do not have the necessary tear-resistance. It is particularly in the narrow interdental spaces that the hydrocolloid usually tears off.

If only one or two veneers are being produced, a Triple-Tray (Premier) impression that records the upper and lower rows of teeth simultaneously is usually enough. If the study models are already available, the impressions of a whole jaw are made with an elastomeric material.

Temporary Measures

Many authors are of the opinion that a provisional restoration is not necessary because in most cases dentin is not exposed and it is therefore not necessary to have a temporary restoration that protects the tooth and the pulp. Some also add the comment: "Ugly in, ugly out." As I see it, all prepared teeth should be temporarily restored. Two different methods are available for this.

1. Direct Composite Veneers

A spot is etched in the enamel at the center of the prepared tooth. Some bonding material (unfilled plastic) is placed on this etched site. Without polymerizing the bonding agent, a pea-sized amount of composite is placed and modeled (with some bonding agent on the spatula), so that the tooth form is reproduced. Since the composite is light-cured, there is sufficient time to shape the veneer. At the end, the composite is light-cured. It can be corrected further by adding more or removing some material. If the shaping procedure is executed carefully, it will be unnecessary to cut and trim the composite significantly. Finally, it may be necessary to polish again briefly with a composite polishing paste and check occlusion and function. The provisional arrangements should experience no functional pressure.

428 Making a dental impression
The impression for one veneer can be made with a Triple-Tray. Lower and upper jaws are recorded simultaneously.

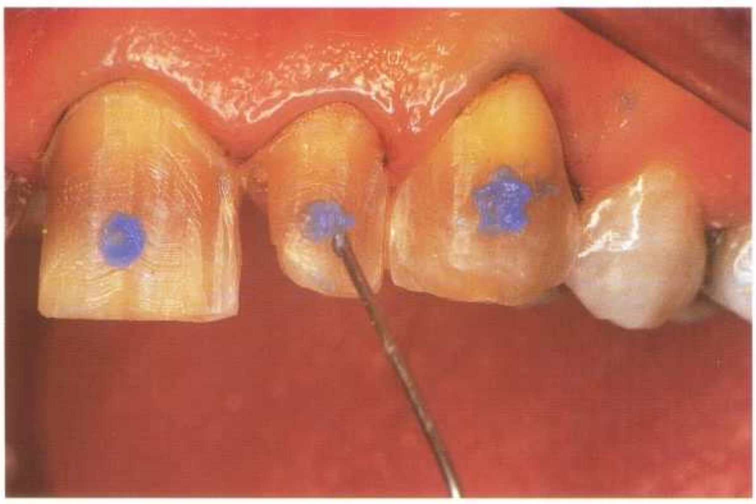
429 Material
An elastomeric material (polyetherorA-silicone) is most suitable.

2. Ready-made Crown

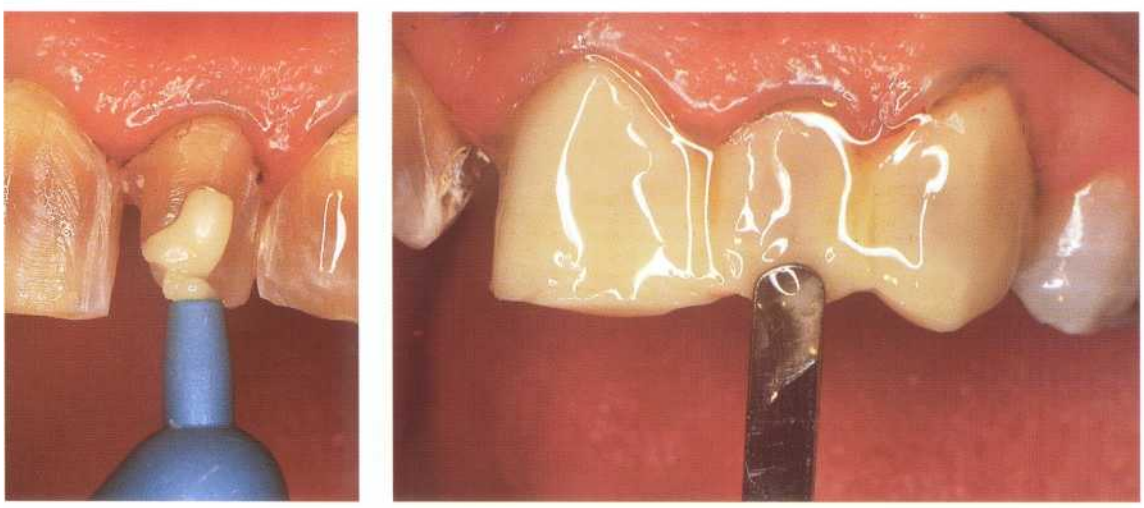
Crystal-clear celluloid crowns are suitable as ready-made crowns or transparent trays made on a situation model. After the ready-made crown or the transparent tray has been tried in, it is filled with composite of the desired color. The excess is removed carefully. Then the composite is light-cured. Afterwards, the temporary veneer is removed, contoured, and checked for form and function, and then bonded. A round spot is etched into the cut enamel surface and the temporary veneer is then bonded with a small amount of light-curing bonding agent.

The same procedure can also be done on a model. For this, an alginate impression of the preparation is prepared and filled with Snap-Stone (WhipMix). The plaster sets after five minutes. The provisional arrangement is then produced on the plaster model and afterwards placed.

N. B.: Remember to remove the retraction cord.



430 **Conditioning of the surface**
Spots are etched into the labial surface.



431 **Direct placement of composite**
The light-curable composite is modeled with a spatula and some bonding resin.

Left: After the enamel has been etched, a light-curable composite is placed directly on the tooth.

432 **Temporary veneers**
The finished, temporary ceramic veneer restoration that has been directly made and lightly layered incisally.

Left: The directly produced, provisional composite veneers after two weeks, just before the final ceramic veneers are to be cemented.

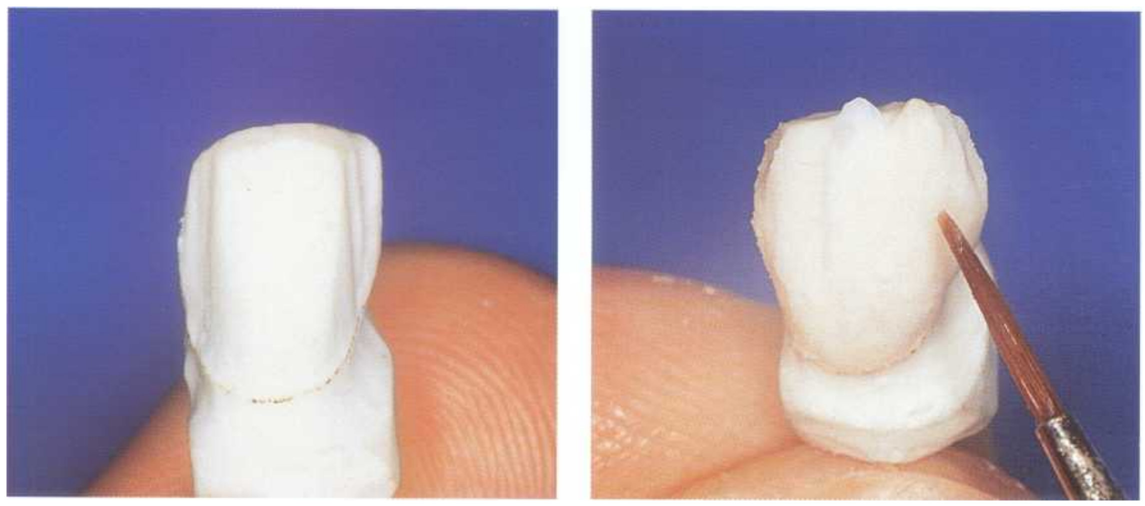
Laboratory Technique

Sinter Technique

Sintering ceramic is the perfect technique for manufacturing ceramic veneers. However, it requires a highly skilled dental technician. The technician forms the individual layers of the ceramic restoration on a refractory die.

Celay, IPS Empress, and OPC are less suitable than sintered ceramic for making veneers. Monochrome shells that are characterized individually by superficial painting are produced using these technologies. For individual characterization one can add additional layers onto the pressed framework. However, since the layers are less than 1 mm thick, this is extraordinarily difficult.

The disadvantage of sintered ceramic is its high price. Surprisingly, the few physical properties of the sintered ceramics are not a clinically significant problem when the correct adhesive technique is employed.

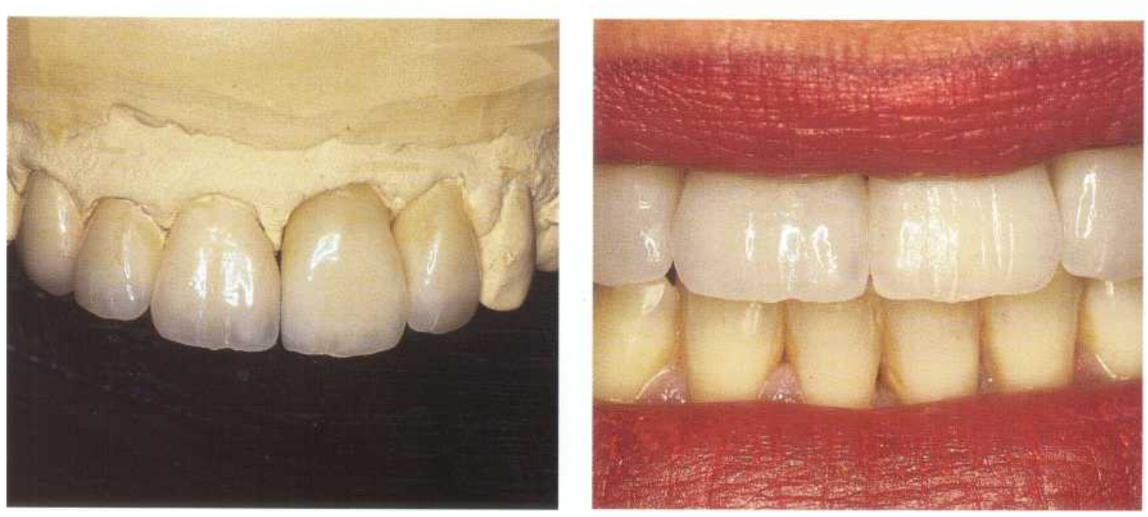


433 **Preparation of a veneer**
Left: A refractory die is made.

Right: Dentin mass is first placed on the die.

434 **Layering the ceramic**
Left: The dentin mass is covered with appropriate enamel masses.

Right: The dental technician's ceramic palette.



435 **Sintered veneers**
Sintered and laminated veneers create the best possible aesthetic results. Unfortunately, they necessitate a highly trained technician and are rather expensive.

Left. All-ceramic sintered veneers were placed on teeth 13, 12, 11, and 22, while an all-ceramic crown was placed on tooth 21.

Right. Veneers in situ.

Dental technician: *R. Schubert*

Cerapress Technique

The Cerapress system is suitable for anterior crowns, veneers, inlays, and onlays. Posterior Cerapress crowns should only be produced in regions exposed to low chewing forces.

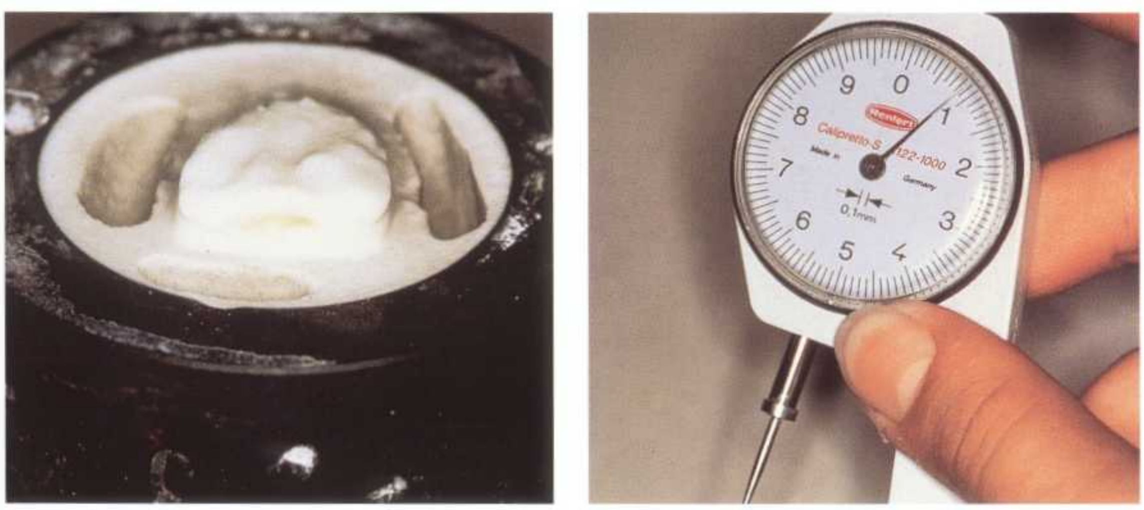
All Cerapress restorations should be etched, silanized, and adhesively bonded. If one uses a leucite-reinforced ceramic mass, the physical properties are identical to those of other ceramic press procedures.

An advantage of the Cerapress technique is its relatively simple application procedure:

- Duplicate working die in a refractory material.
- Shape the restoration in wax on the die.
- Transfer the wax model to the refractory die.
- Embed the refractory die with the wax pattern into a special flask.
- After wax burnout, place the ceramic in layers into the form and fire.
- Compress the two flask halves with special tongs.
- Adjust the restoration after it has been removed from the investment.

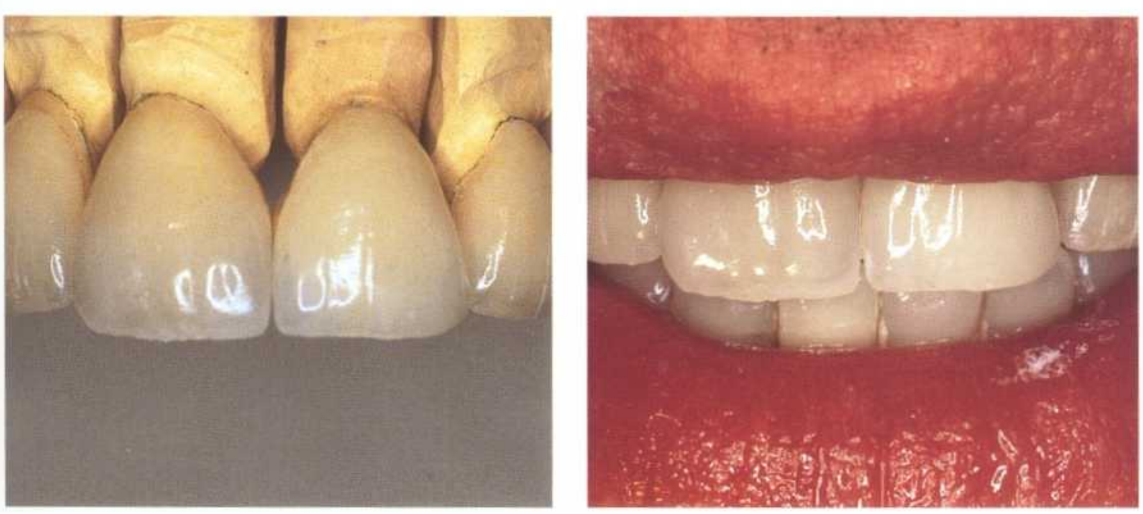
436 **Pressing all-ceramic veneers**
Left: The veneer is waxed and the wax pattern is transferred to a refractory die, whereupon it is embedded.

Right: The Cerapress technique allows the ceramic masses to be individually composed and layered before pressing.



437 **Build up of the ceramic**
Left: The veneer is covered with a clear porcelain mass.

Right: The pressed veneer is 0.8-0.9 mm thick.



438 **Finished Cerapress veneers**
Left: Veneers shown on the model.

Right: Veneers in the patient's mouth.

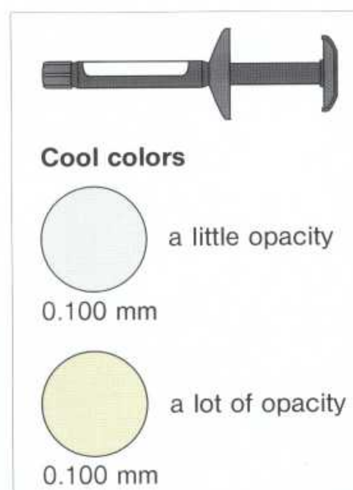
Dental technician: *A. Schmidseder*

Try-in and Color Correction

The try-in process is very important. Smaller color corrections can now be made. Sometimes it is necessary to carry out correction of the form in the laboratory or to remake the restoration. It is not possible to have a try-in and adjustment procedure, as is the case with crowns, nor is it possible to make correction after the veneer has been adhesively bonded. The decision to finally cement the veneers or not must therefore be made immediately.

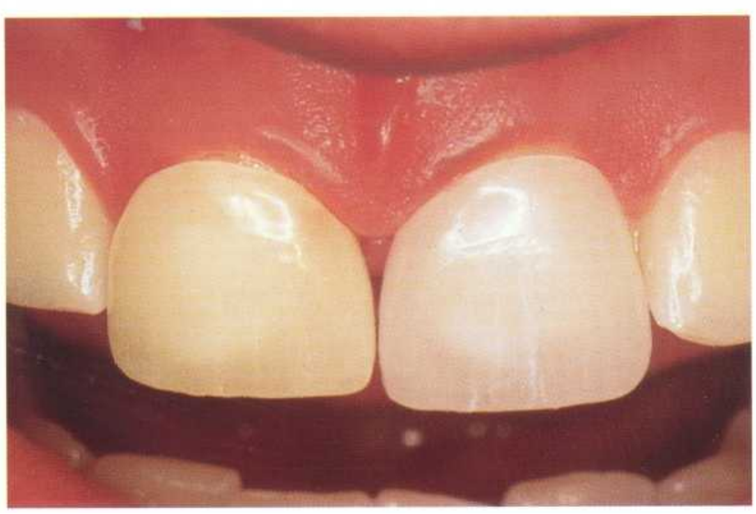
Preparation for bonding: First locally anesthetize. Dentin is frequently exposed here and there and this is later etched with phosphoric acid. Cementation is the most complicated part of the treatment, during which the patient must not have any uncontrolled pain reactions. Removing the temporary restorations is trouble-free. Some postpreparation at the site which was etched and bonded is necessary, as otherwise the resin layers cannot be removed. The entire tooth surface is cleaned with a rubber cup and fine pumice; the proximal spaces with a diamond strip. Finally, a retraction cord is again placed.

439 **Selecting the cement**
The opalecent bonding cement by 3M offers the possibility of a color try-in using the catalyst in tube B. The bonding of the veneers can be done with the light-curable material in tube A. If one is satisfied with the color match, the veneer is bonded with the light-curing "Clear" component alone.



440 **Color changes with cool colors**
Cool colors (low, medium, or high opacity) can be made more white.

Right: Color range of the opalecent bonding cement by 3M.

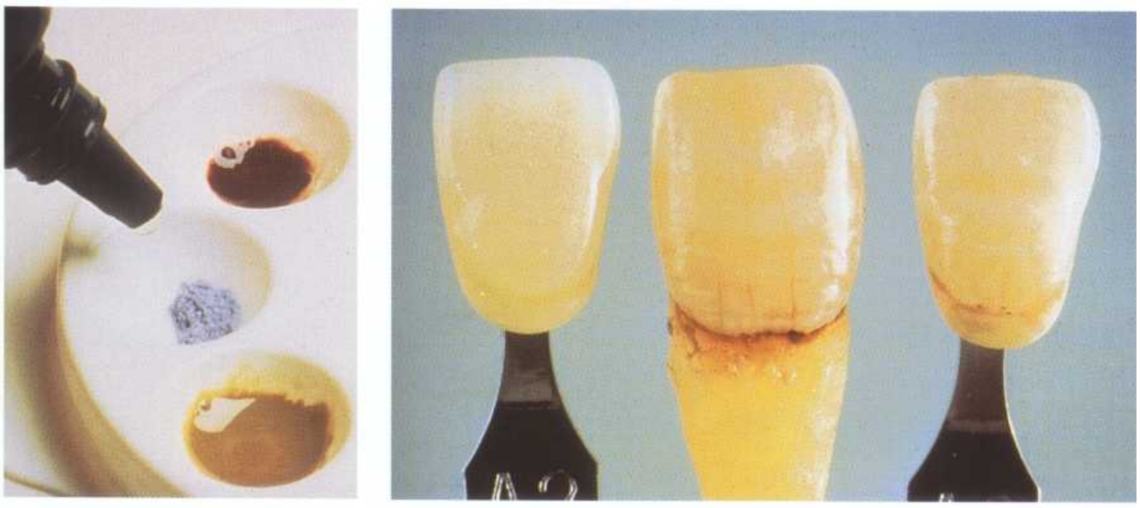


441 **Color changes with warm colors**
Warm colors (low, medium, or high opacity) can be made more yellowish.

Try-in: The tooth and the inside of the veneers are lightly moistened. The veneer is placed on the tooth. If color and form are satisfactory, the veneer can be bonded with clear cement. If the form needs to be changed only slightly, this is often best done after cementation. In case of larger modifications, the veneer is returned to the laboratory.

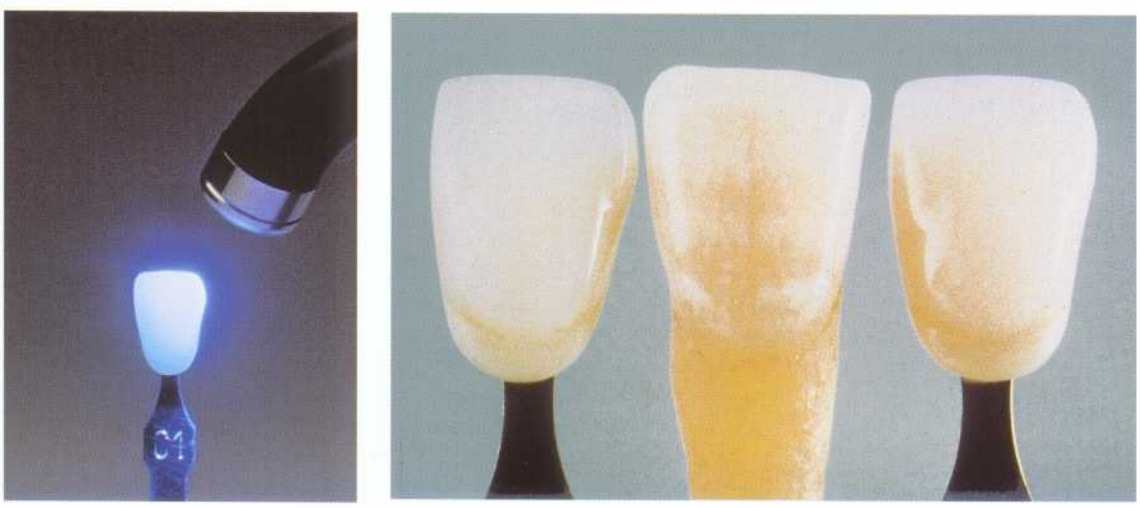
Minor *color corrections* are achieved with the cement. A try-in paste that does not change color after polymerization and cementation is recommended. This facilitates changing the shade of the color, either to make it more white (cool colors) or more yellow (warm colors). Instead of the pastes, different opaquers can also be used.

It is also possible additionally to paint the tooth with light-curable ceramic colors that are applied and then fired. It is important for color stability that painting and glazing are done in separated firing steps, since this increases the durability of the color by more than 50%.



442 Individual characterization
Ceramic restorations can be individually characterized using the light-curable ceramic colors Orbit LC.

Left. The light-curable ceramic stains are stirred and painted onto the ceramic surface.



443 Light-curing the colors
Individually characterized ceramic surface.

Left. The color is stirred, applied, and cured with the polymerization light. Now the colors can be matched in the mouth, without blurring the color during the try-in. Then the color must be refired in the laboratory.

444 Individually characterized veneers
The slightly individually characterized veneers (also see Fig. 440) were cemented with the "warm color" cement of medium opacity.

Adhesive Bonding

Preparation of Tooth and Veneer

The *veneer is* cleaned thoroughly again. The ceramic surface is cleaned in the laboratory by etching the inner surface with 32% phosphoric acid. In addition, this treatment conditions the ceramic surface for the silane treatment. The inside surface of the veneers should now have a frosty surface similar to that of etched enamel. If this is not the case, it may be necessary to reetch it with hydrofluoric acid (10% hydrofluoric acid gel).

The inside of the veneers, which has been pretreated with acid, is coated with a thin layer of silane. There are two silane products on the market, one- and two-component silanes. One-component silane is simpler to handle, but it requires that the ceramic surface be treated with acid immediately before being placed. Two to three layers of silane are added. Only then can the veneer surface be prepared for bonding.

The *tooth surface* must also be pretreated, like the ceramic surface. Ever since the total etch technique became generally accepted worldwide, it has no longer been necessary to differentiate between enamel and dentin surfaces. Since the entire tooth surface is treated with 32% phosphoric acid, the existing dentin surface should not be etched for longer than 15 seconds. The acid is first applied to the periphery dominated by the enamel and then to the center of the tooth, where dentin is possibly exposed. The acid etch is very good method for both cleaning and disinfecting the tooth surface.

Placing the Adhesive

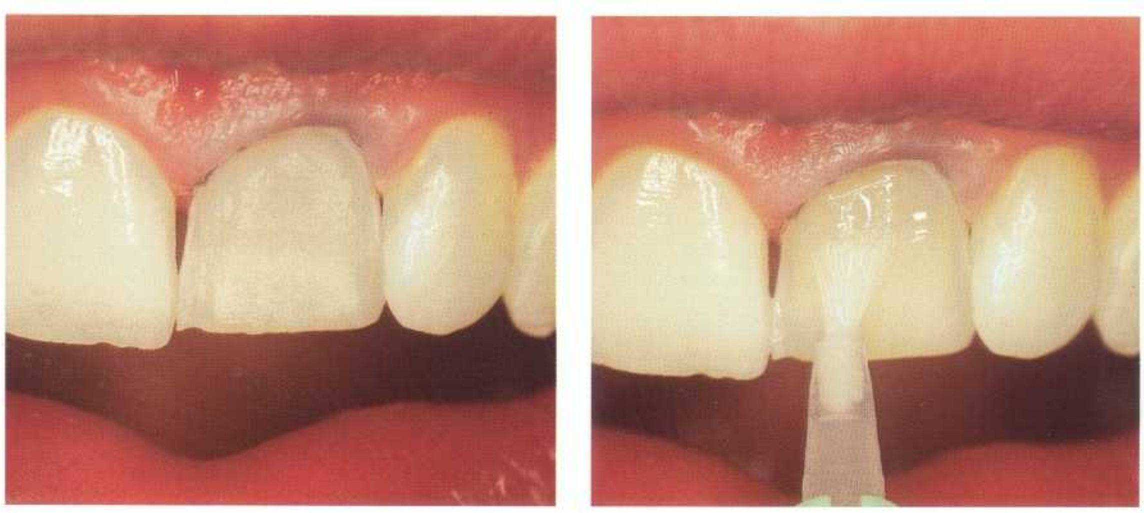
After rinsing and brief air-drying, the entire tooth surface is treated with a *dentin adhesive.* The dentin adhesive (primer and adhesive) should not be polymerized before the next step. The three-component systems, such as Scotchbond MP, are preferred to fifth-generation adhesives.

Some adhesive is placed on the silane-treated ceramic surface and lightly air-thinned (make sure the layer does not become too thin).

Even if the veneers are only applied using light-curing cements, some dentin adhesives (e.g., Clearfil New Bond) can start and accelerate the polymerization process. This does not mean that one need be in a big hurry, but subsequent steps should be carried out as quickly as possible.

445 **Arrangements for adhesive cementation**
Left. The tooth is pretreated in the same way before cementation as it was before and during preparation (injection and placement of a retraction cord).

Right: When the veneer has been sufficiently conditioned and prepared (color-matched, etched with hydrofluoric acid, and silanized), bonding can start. The first step is to etch the enamel surface with phosphoric acid.



446 **Conditioning, priming, and bonding**
Left: Etched and slightly dried tooth.

Right: Applying primer and bonding agent.

The cement that is used should be light-curable only and should be placed into the veneer with a Centrix tip. Since the veneers should fit just as well as inlays and a die spacer approximately 60 pm thick was applied on the die, only a thin layer of cement layer is necessary.

Placing the Veneer

Now the veneer can be applied on the tooth. I prefer not to use matrix bands. Therefore, it is important that most of the excess cement be removed immediately and that the contact points are rid of cement with dental floss. The proper location of the veneer is checked again with a mirror and an explorer.

Then, the veneer is bonded to the tooth by means of a *brief light curing* (10 seconds from the buccal and from the lingual). Excess can now easily be removed because the cement is not completely hardened. After this has been done, the veneer is repolymerized at three locations (buccocervical, buccoincisal, linguoincisal) for one minute at each location. However, the long *curing* step can also take place at the end if several veneers have been placed during the same session.

Several Veneers Placed in One Session

If one wants to apply several veneers simultaneously, the two central incisors are placed together or, if one is still somewhat inexperienced, bonded one after the other. Then, the lateral incisors and finally the cuspids and possibly the premolars are seated. If one proceeds from the right to the left, a small mistake during cementation can, similar to the domino effect, cause a more pronounced displacement as the cementation proceeds.

It is very important that all veneers are intensively light cured (three minutes per veneer) with the curing light. The light is used at its greatest intensity.

447 **Preparing for cementation of veneers**
Left. The prepared veneer is etched and silane-treated.

Right: The purely light-curable cement is ready.

448 Curing
Left: The attached veneer from which excess has been removed is briefly light cured.

Right: Small cement remains are removed from the margins and each veneer is cured for three minutes (one minute each from cervical, incisal, and palatal locations).

Adjustments and Finishing

The wonderful thing about veneers is their invisibility, although it is exactly this property which makes any adjustment or finishing difficult. First, one removes cement remains from the veneer surface with a curet. An explorer is used to localize any excess cement and this is removed with a carbide finishing bur. These burs have the advantage that they are not sharp at the tip and can not injure the root surface, in contrast to finely grained diamond finishing burs.

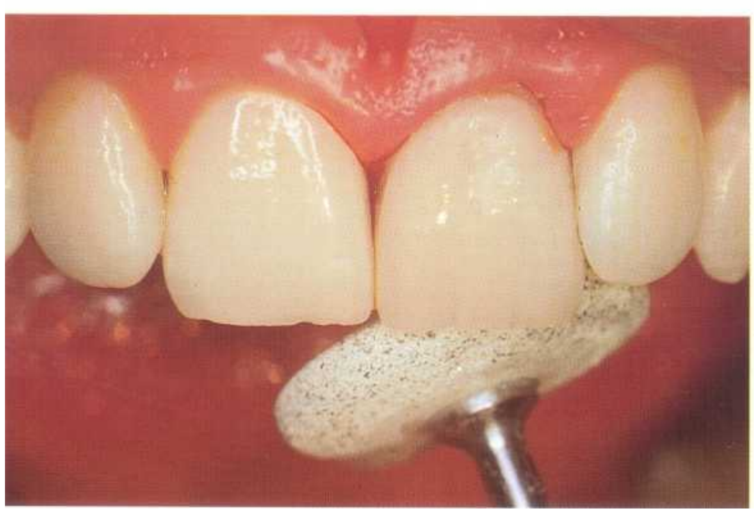
Finishing begins with hard metal finishing burs. Then, the proximal spaces are smoothed with finishing strips. Lingual excess is removed with a bullet-shaped carbide finishing bur. Dental floss is used to check whether there is any excess in the proximal spaces and cervical transition.

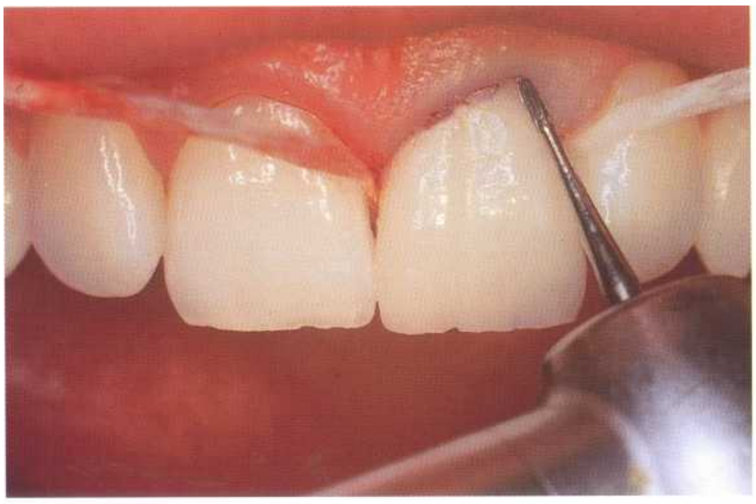
Before treatment is completed, occlusion and function still need to be checked and possibly corrected. The patient is recalled after one to two weeks in order to check for any remaining excess. It is often not possible to detect all the excess during the first session.

449 **Removal of excess**
Cervical and proximal excess is best removed with a scalpel or a gold knife.

450 **Cervical and proximal finishing**
A piece of dental floss can be used to check whether there is any excess cervically or in the proximal regions.

451 **Palatinal adjustments**
The palatinal transition between the veneer and the tooth is best finished with a white ceramic rubber polisher.

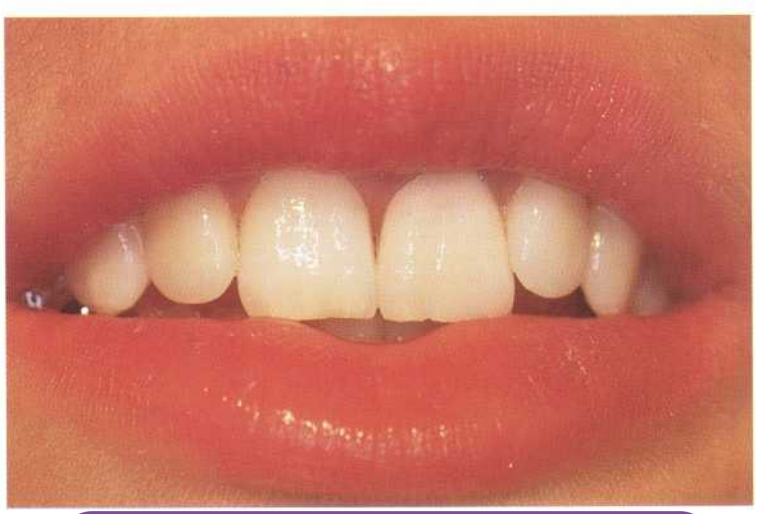




452 **Trimming with a hard metal finishing bur**
If necessary, a flame-shaped hard metal finishing bur can be used to trim the cervical margins. Hard metal finishing burs are preferred to diamonds, since hard metal burs only cut on each side and do not injure the root surface with their tips

453 **Finished veneer**

454 Initial situation
Nonvital tooth, blue-gray discoloration seen after endodontic treatment.



455 Finished veneer in situ

Checklist—Veneers

For the Dentist

Treatment Planning

- Professional tooth cleaning
- Radiographs
- Situation models
- Diagnostic wax-up
- Deciding the treatment goal:
  —Tooth color: stratification, transparency, incisal, core, and dental neck
  —Tooth shape (diastema, height, contour)
  —Tooth position
  —Tooth surface
- Simulating the treatment goal with image processing (imaging system or digital camera)

Preparation

- Anesthesia
- Place retraction cord
- Prepare depth cuts
- Remove a maximum of 0.7 mm of enamel
- Prepare a surrounding chamfer
- Make dental impression
- Temporary restoration
- Remove retraction cord

Technique

- Primary tooth color after preparation
- Final color (desired color)
- Opacity (low, medium, high)
- Incisal length
- Diastema closure: yes/no
- Interproximal spacing: open, slightly open, closed
- Surface: light, medium, strong texture
- Glaze: light, medium, intense
- Ceramic etched: yes/no
- Desired technique: sintered ceramic, pressed ceramic

Cementing

- Anesthesia
- Place retraction cord
- Remove temporary restoration
- Clean the surface with pumice
- Clean the proximal surfaces with strips
- Color try-in and select suitable cement
- Etch and treat ceramic with silane
- Etch the tooth, rinse, dry, and prime
- Apply bonding agent to veneer and tooth
- Apply cement to the veneer
- Place the veneer
- Remove resin excess
- Selective short curing
- Remove additional excess
- Curing (3 min per tooth)
- Trim margins, finish
- Recall patient after 2 weeks to remove resin remains

For the Dental Hygienist

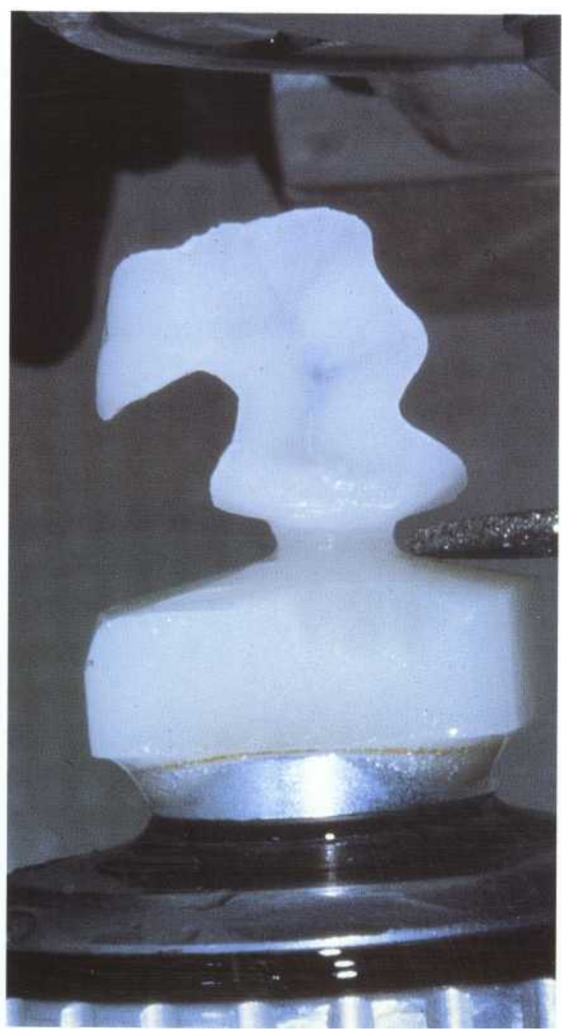
- Record presence and extent of veneers (veneers are invisible and may be difficult to detect)
- Do not use ultrasonic or air-abrasives
- Modified professional tooth cleaning (see p. 16)
- Do not use chlorohexidine
- Recall every 3 months

For the Patient

- Recall every 3 months to allow less aggressive tooth-cleaning methods to be used
- Use low-abrasive toothpastes which contain sodium fluoride if possible
- Use soft toothbrush

The Celay System

The Celay (Ceramic Inlay) System was developed in 1988 at the Clinic for Fixed and Removable Prosthodontics at the University of Zurich, Switzerland in cooperation with Microna Technologie (Spreitenbach, Switzerland) (Eidenbenz 1992). The goal was to produce strong and highly aesthetic inlays as efficiently as possible. The basic idea was to produce an individual, well-fitting ceramic component from an industrially prefabricated ceramic block. The use of a more homogeneous ceramic material with optimized physical properties represents a substantial advantage compared to ceramics constructed in the dental technician's laboratory. Today, the Celay system is mainly used to manufacture ceramic inlays and onlays in the laboratory. It is also combined with the In-Ceram technique (Celay In-Ceram) to manufacture aluminum oxide (Al_2O_3) as well as spinel ($MgAl_2O_4$) frameworks for single crowns and small anterior bridges.



456 Copy-milling procedure
Left: Mechanical sensoring of the reconstructed inlay.

Right: Synchronous milling of the ceramic inlay from an attached ceramic block (Celay Blank).

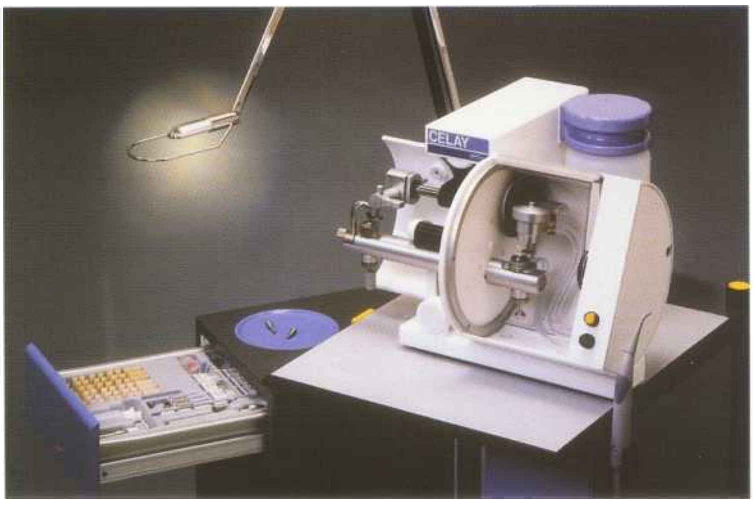
Copy-Milling Procedure

In contrast to the Cerec system, the Celay system does not use an "optical impression" to create a model, from which information is taken and used by a computer and transferred to a mill. Instead, the model (pro-inlay or pro-crown) is preformed using a light-cured resin on the master model (Celay Tech).

The piece is fixed in a special attachment unit and a three-dimensional construction is copied by means of mechanical sensoring and synchronous milling. The degree of freedom and the interpretation of the Celay system's reader allows it to shape any forms from industrially presintered ceramic blocks (Vita Celay Blank or Vita Celay Alumina Blank). The copy-milling unit is driven by an air turbine (4.2 bar, 80 m/sec).

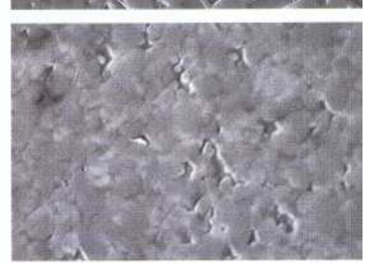
Technical Procedure

Based on the size of the piece to be copied, the ideal ceramic block is first selected from a number of different sizes of prefabricated blocks and fixed in the milling unit. Ceramic blocks are available to the technician in the Vita Colors A4, A3, and A3.5.



457 Celay machine
The sensoring device is on the left, the milling unit on the right.

458 Scanning devices (disk, cylinder, ball) have exactly the same shape as the corresponding milling instruments



459 Ceramic blocks
Prefabricated ceramic blocks for inlays (Vita Celay Blank; A2/A3) or crowns as well as bridges (Vita Celay Alumina Blank; white).

Right above: **Vita Celay inlay ceramic (feldspar ceramic; flexure strength 123 ± 15 MPa; magnification x 1000).**

Right below: **Vita Celay alumina ceramic (infiltration ceramic; flexural strength 547 ± 13 MPa; magnification x 3000).**
SEM micrographs: H. *Luthy*

The mechanical scanning of the pro-inlay or pro-crown attached to the scanning unit is carried out with different scanning tools. These tools correspond in form to diamond-coated milling tools. The shape of the piece is copied and roughly cut with the cutting tool (124 pm) under continuous water cooling with three nozzles aimed at the ceramic platform.

In a second step, the different milling diamonds are replaced by correspondingly finer finishing disks and cylinders (64 um) and the final shape of the ceramic piece is milled with the help of touch control.

A very thin layer of white powder is sprayed onto the prefabricated plastic body as touch control and serves to provide an overview of the scanning process. It is not until after finishing is completed that the fit of the inlay or the crown cap can be optimized by carefully trying it on the master model.

Preparation and Fit

Inlays and Onlays

A mechanically shaped inlay or onlay (e.g., Celay OF Cerec) is dependent on the availability of a careful, smooth preparation with perpendicular outer preparation margins, since irregular sections can only be reproduced to a limited degree due to the size of the milling tool. The cavity surface should have no sharp-edged transitions, because these concentrate stress (possible fracture locations) that will lead to fracture of the tooth and/or the inlay.

In vitro evaluations of composite and ceramic inlays show that composite inlays and pressed ceramic inlays have the best average fit (10-50 pm). The optimal fit of a shaped Celay inlay, measured over the entire marginal length, is between 50 and 80 pm and is comparable with the Cerec 2 generation. It is also comparable with perfect, laminated inlays. The fit of ceramic inlays can, from a technological point of view, be efficiently optimized with a mixture of wax and ceramic (Celay Optimizer).

The advantage of the Celay system as compared to the new Cerec 2 generation is that the occlusal and interproximal anatomy of inlays and the form of the framework of the crown can be individually shaped.

460 Initial situation
Old, defective amalgam restorations located in the first quadrant.

461 Clinical end result
Adhesively cemented ceramic Celay inlays (tooth 17, MOD; tooth 16, onlay; tooth 15, DO).

462 Initial situation
Old, defective amalgam restorations located in the fourth quadrant.

463 Pretreatment of the cavity before cementation
Cementation of the inlays is done with a rubber dam in place and with the use of a dentin bonding agent (All-Bond II) and a dual-cured composite cement (Porcelite).

Right: Master model of the inlay preparation (tooth 46); well-defined, sharply extended preparation.

464 Finished characterized inlay
Right: Molded pro-inlay made from light-cured resin (Celay Tech).

465 Clinical end result
Adhesively cemented ceramic Celay-inlays (tooth 47, MODB; tooth 46, DOB; tooth 45, O).

Right: Fit of the milled inlay. Small sub-marginations can be corrected with a low-fusing ceramic mass (Celay Optimizer).

Crowns and Bridges

For high-quality aesthetic crown or bridge reconstructions, a clearly defined, rounded shoulder (at a 90° angle to the surface of the die walls) with a preparation width of approximately 1 mm is used.

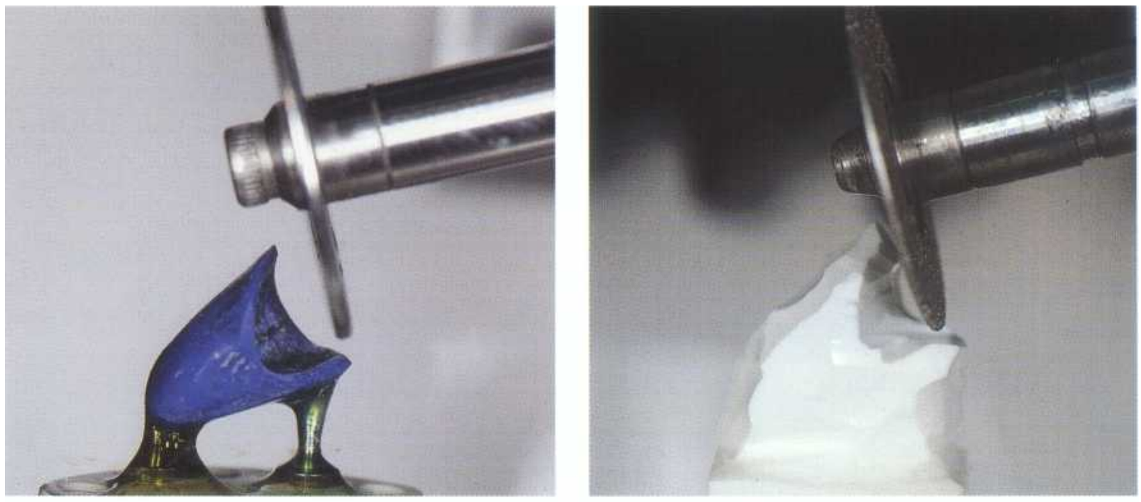
Such a shoulder not only gives the technician sufficient space for an aesthetic and well-fitting layering of the ceramic masses in the marginal region, but also secures mechanical strength after final cementation. Lehner et al. (1995) were the first to show in vitro that the fracture resistance of ceramic margins with reduced metal frameworks under axial pressure was eight times higher with a 90° chamfer preparation than with a 45° chamfer preparation (rounded shoulder).

When manufacturing In-Ceram restorations it is possible to create well-fitting crowns and bridges on a shoulder preparation both with the conventional In-Ceram slip-casting technique as well as with the Celay In-Ceram method. Anterior crowns show significantly smaller gaps (median: 38 um) than bridges (median: 52 um).

466 Tooth 11 with composite reconstruction of the incisal edge region, which is too light

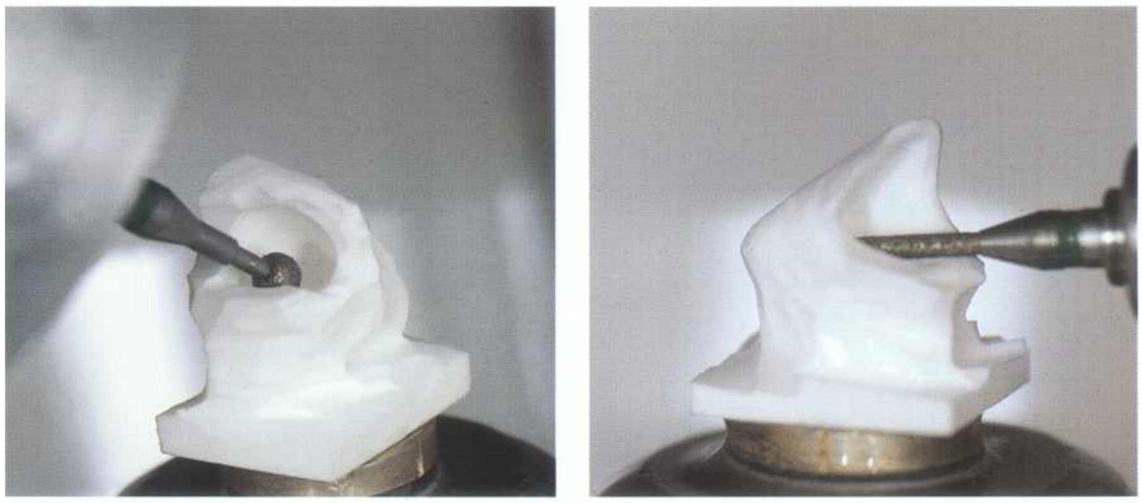
467 Slightly subgingivally prepared full crown of a vital tooth

468 Successfully bonded Celay In-Ceram Spinell crown



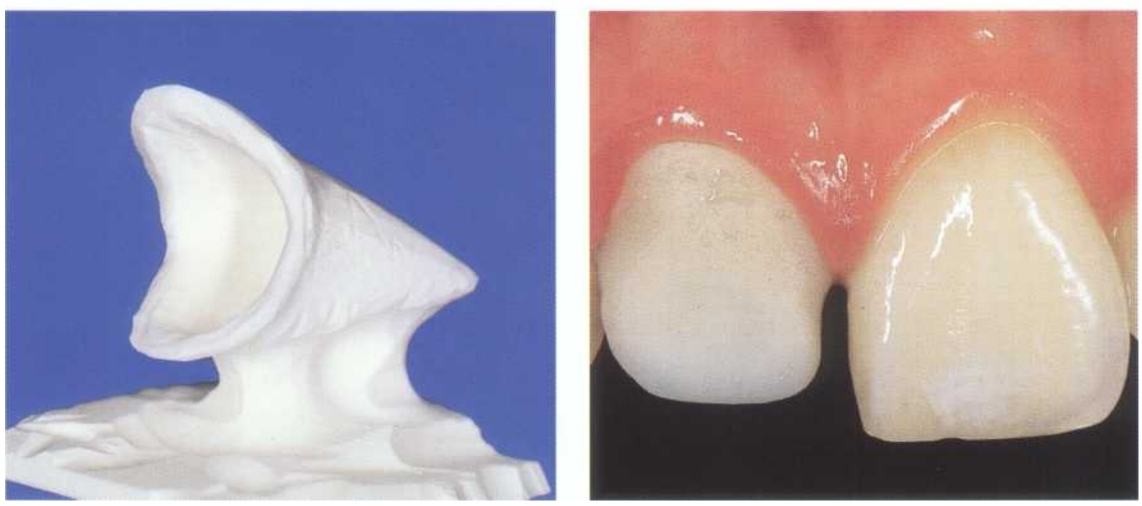
469 Copy-milling procedure
Left: Mechanical scanning of the attached pro-crown.

Right: Synchronous milling of the crown framework in an attached alumina block.



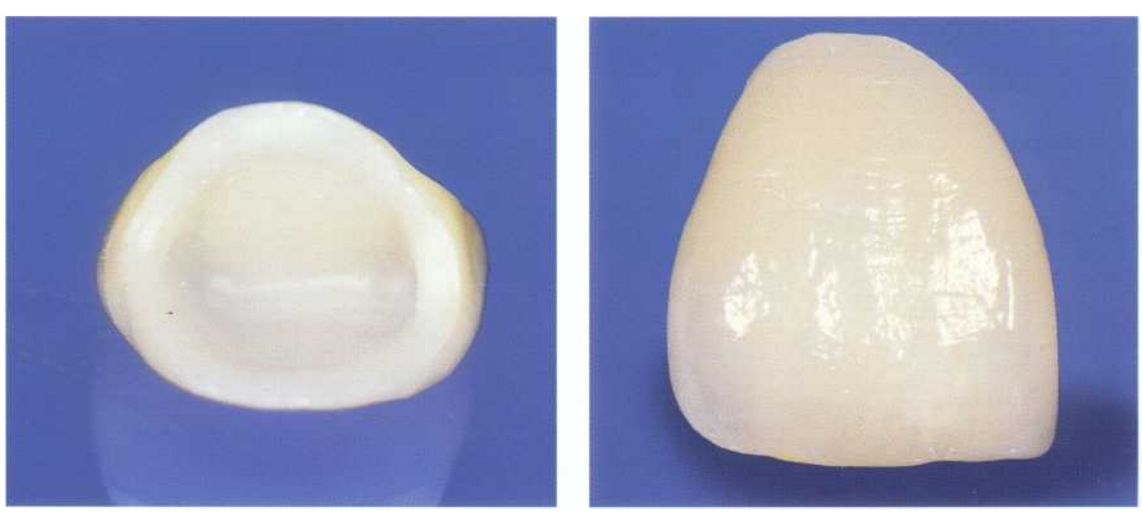
470 Processing the inside
Left: Coarse shaping with a spherical milling tool.

Right. Detailed milling with a cylindrical milling tool.



471 Spinell framework
Left: Shaped In-Ceram Spinell framework.

Right: The glass infiltrated Spinell thimble take on the color of the underlying vital cone thanks to its natural light-transmitting ability.



472 Finished Spinell crown
Left: The Spinell framework appears much less opaque than conventional alumina ceramic frameworks (see also Fig. 481).

Right. Even when it has not yet been cemented, the finished Spinell crown shows a very natural transparency.

Ceramic Materials

Inlays, Onlays (Vita Celay Blank)

The prefabricated ceramic used for milling inlays as well as onlays is a very homogeneous feldspar ceramic (Fig. 459, top right), which is very similar to the material Vita Mark 11 (Cerec) in terms of structure and strength (123 ± 15 MPa). These blanks are available to the technician in three colors (A2, A3, A3.5) and in various sizes.

Crowns, Bridges (Vita Celay Alumina Blank)

Being able to shape all-ceramic frameworks from a ceramic block is considered a further development of the Celay system (available since 1993) within the scope of the In-Ceram technique (slip-casting method).

For individual crowns exposed to high pressure or for small three-unit bridges, the stable, pure A1203 *framework material is* exclusively used (flexural strength 547 ± 13 MPa, Fig. 481). Anterior crowns on vital teeth with high aesthetic demands can be made from a translucent, but less strong framework material, so-called *spinel* (MgA1204, flexural strength 377 ± 64 MPa).

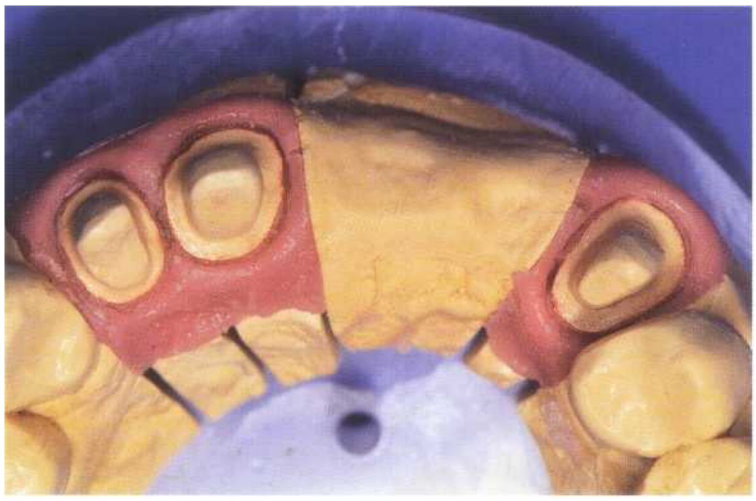
The high flexural strength of the In-Ceram material is not attained until after the glass infiltration. The strength is due to the homogeneous distribution of the Al 203 particles in the glass and their reciprocal contacts. Microcracks that propagate through the glass are stopped at the crystal interfaces and are diverted, so that tensile stresses are reduced. The industrially produced sintered blocks are especially characterized by an improvement in the quality of the ceramic structure and have a flexural strength which is approximately 10% greater.

Long-term clinical studies of In-Ceram single crowns on anterior teeth as well as posterior teeth have shown that this type of single tooth restoration has a good long-term prognosis.

However, there are as yet not enought scientific data on the clinical long-term prognosis of small anterior or posterior bridges to justify recommending these bridges be routinely used in the practice. The possibility of constructing a sufficiently large framework, particularly in the proximal connecting regions, represents a crucial factor for the long-term success of an all-ceramic bridge.

473 **Finished, slightly subgingivally prepared teeth 12, 11, and** 23
The prepared teeth are ready to receive a four-unit bridge and a single crown for tooth 12 respectively.

474 **Celay In-Ceram anterior reconstructions**
The single crown 12 and the bridge 11-23 are bonded adhesively with a chemically cured cement.



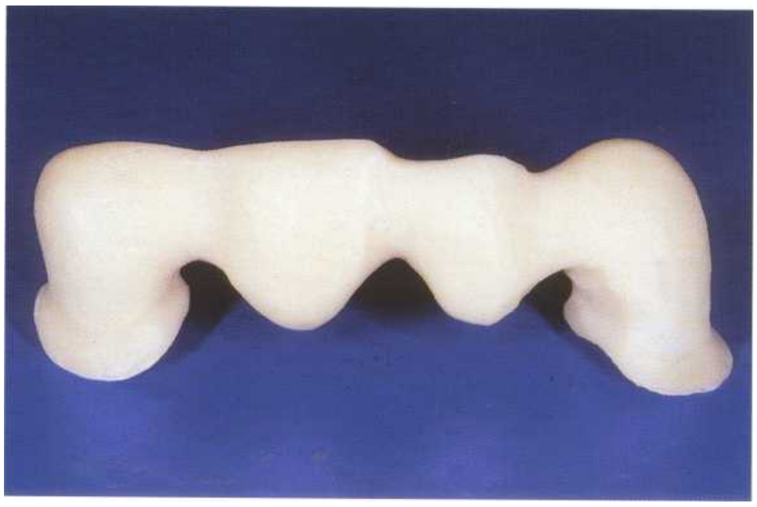
475 **Preparation**
The clearly defined rounded shoulder preparation is visible on the model (1-1.2 mm)

476 **Wax-up try-in**
Evaluation of a front tooth reconstruction that should look as natural as possible.

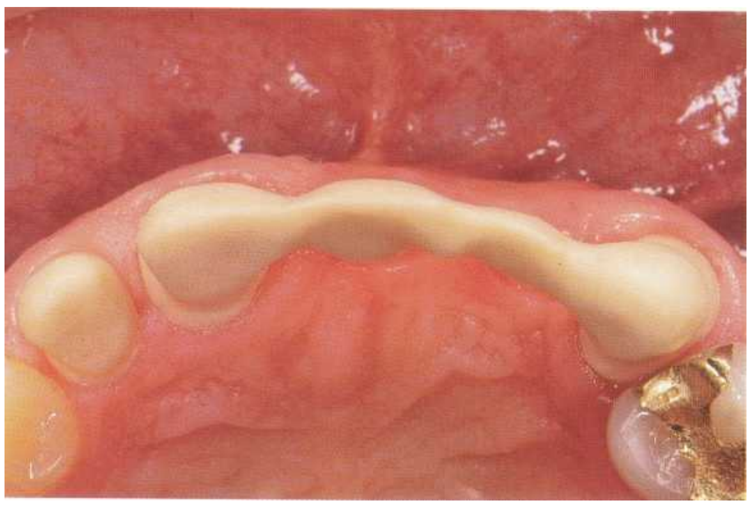
477 **Copy crowns**
The plastic framework is modeled in accordance with the wax-up on the master model.

478 **Copy-milling procedure**
The first coarse contours of the synchronously milled alumina framework are visible.

Right. Mechanical scanning of the fixed framework.



479 Glass infiltrated and adjusted Celay In-Ceram framework.
The clearly shaped connections are clearly visible



480 Clinical try-in of the framework
The fit is checked.

481 Optimum marginal rigidity
The alumina framework extends to the preparation margins, which are clearly visible here.

482 Strong, naturally appearing end result

Celay In-Ceram Spinell

The substitute of a single anterior crown with natural properties makes the highest demands on the all-ceramic system (Figs. 466-472).

Conventional In-Ceram crowns with their white-opaque alumina framework tend, particularly in the marginal area, to block light. Therefore, on vital teeth with high aesthetic requirements, the anterior crowns should be produced using the translucent Spinell framework material. The compound spinel is a magnesium-aluminum mixed oxide ($MgAl_2O_4$) with a higher translucency than In-Ceram alumina. The shade of the originally white spinel powder becomes saturated, like alumina, through infiltration with specially colored glass. The price for the improved aesthetic properties is a decrease in flexural strength (377 ± 64 MPa) in comparison with the alumina material (547 ± 13 MPa). Therefore, the indication for Spinell crowns is restricted to anterior crowns.

Spinell crowns are processed with a particular layer technique. Newly developed masses are helpful for imitating optical effects.

Cementation

All-ceramic restorations should always be adhesively bonded, i.e., cemented with a dentin bonding agent and composite cement. By doing so, not only are the outstanding aesthetic qualities of the transparent ceramic material achieved, but also the risk of fracture of the all-ceramic restoration is significantly reduced.

However, in contrast to conventional feldspar or glass ceramic, the bond between alumina or a magnesium-alumina ceramic and composite cement is more problematic, because the latter two cannot be etched with hydrofluoric acid and then silane-treated. In vitro studies have shown, however, that with sandblasting (110 um, Al_2O_3) and Panavia 21, or through silicate treatment (Rocatec) and cementing with a BisGMA-based composite, it is possible to achieve a lasting composite-ceramic bond with the latter two alumina-based ceramics.

Advantages of the Celay System

- Purely mechanical system, independent of electronics (computers, "black box").
- No additional equipment needed in the laboratory.
- Handling is easy to learn.
- Commonly used dental materials (plaster, composites, ceramics).
- Independent of cutting tools (all tools fit the milling component of the turbine; "open system").
- Use of industrially manufactured ceramics.
- Individual cavity shape possible because of sufficient degrees of freedom of the machine.
- Good fit with adequate preparation.
- Functionally correct occlusal surfaces can be milled using the machine.

Summary

The basic idea behind the Celay system is to produce an individual, well-fitting ceramic body that is made from an industrially optimized prefabricated ceramic block.

Three colors (Vita A2, A3, A3.5) of a homogeneous feldspar ceramic are available to the technician for manufacturing ceramic inlays and onlays. Depending on the indication, frameworks for single crowns can be made in presintered In-Ceram alumina or in magnesium-aluminium oxide blocks. The question of whether smaller all-ceramic bridges will resist clinically occurring forces over time cannot be answered at the present time.

The Celay system is a purely mechanical technique, which the dental technician can easily learn. With correct preparation by the dentist, it leads to a good fit of the ceramic restoration.

CAD/CAM in Restorative Dentistry

The aim of developing computer-controlled production technologies for use in restorative dentistry is to improve the quality of the construction units and at the same time to lower manufacturing costs by simplifying the method and reducing the production time. More than ten different computer systems have already been described in the literature for dental applications and have also to some extent been used clinically (Rekow 1993). The use of computer technology is justifiable only if *computer-assisted design* (CAD) and *computer-assisted manufacturing* (CAM) produce dental reconstructions that fulfill or improve existing material characteristics and/or clinical quality (Besimo et al. 1995).

The computer-assisted systems known today differ mainly with regard to the type of three-dimensional data recording system used to image the prepared tooth. In contrast, the automatic manufacturing (CAM) of the pieces is quite similar and consists mainly of a numerically controlled (NC) machine with a material-specific milling unit that can be moved in three axes in relationship to the piece being worked on (Becker and Heidemann 1993). The precision of the optical recording unit is achieved with a charged coupled device (CCD) image recorder (e.g., Cerec) and is dependent on the number of pixels (Schlegel et al. 1991). This also determines the resolution of the combined CCD camera and three-dimensional scanning through laser triangulation (e.g., Sopha and Cicero).

The Cerec system has for some time now made intraoral data recording possible. Thanks to the short exposure time, it is no longer necessary to temporarily attach the camera to the jaw. However, the precision of the method is not only restricted by the resolution of the image recorder, but also by the coating that needs to cover the tooth surface to enhance the contrast between the projected lines and the tooth surface (Becker and Heidemann 1993).

Modern *mechanical sensing methods (e.g.,* DentiCAD and Digitizing Computers System [DCS]) in principle allow higher resolutions (Schlegel et al. 1991) than optical systems. In addition, they are capable of reading details intraorally, thus permitting the location of subgingival parts of the crown preparation. In general the miniaturization of purely mechanical digitizing units has not yet progressed to a point when they are useful directly in the oral cavity. Moreover, the sensing device must be attached to the jaw during the digitizing procedure. Another problem is the physiological mobility of the supporting teeth. This can cause reading errors that can be avoided during intraoral recording with the touch-free optical data recording systems. Therefore, today's computer systems equipped with mechanical readers are only and exclusively used on the model (Becker and Heidemann 1993).

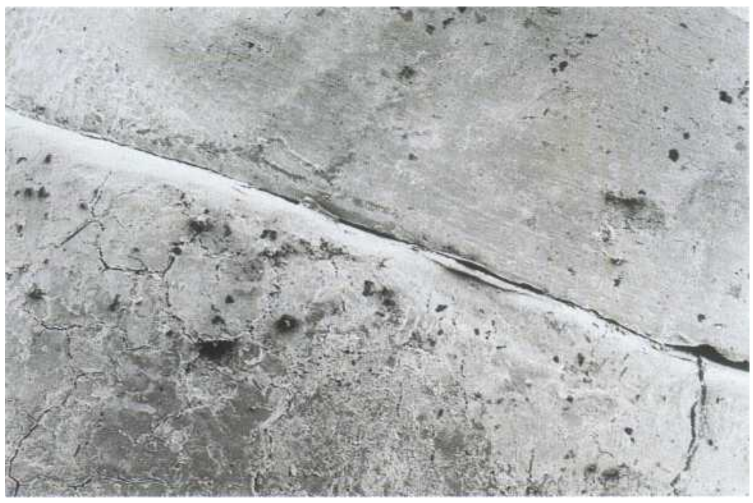
A possible parameter for judging the performance of a production method is the *marginal fit* of the pieces. Reactions in the literature to the marginal adaptation of complete casts or metal-ceramic crowns made with the traditional casting technique have been mixed. As different studies have shown, the average gap size of 20 um can be achieved under optimal laboratory or clinical-experimental conditions (Belser et al. 1985; Bottger et al. 1988). These results are in conflict with clinical observations. In a retrospective cross-sectional study, Diedrich and Erpenstein (1985) found that of fifteen partial and full crowns produced under uniform practice and laboratory conditions, the average gap width was 91.5 ± 89.1 pm.

Possibilities and Limitations of Computer-Controlled Production Technologies

Using the Cerec system, the average gap size under experimental conditions of uncemented ceramic inlays is 100-150 pm (Hahn 1990; Peters and Dieniek 1991; Rose et al. 1990).

The DentiCAD System enables an average gap size of 23 ± 23 pm for single crowns. The measurements ranged from 1 to 49 pm (Rekow et al. 1991).

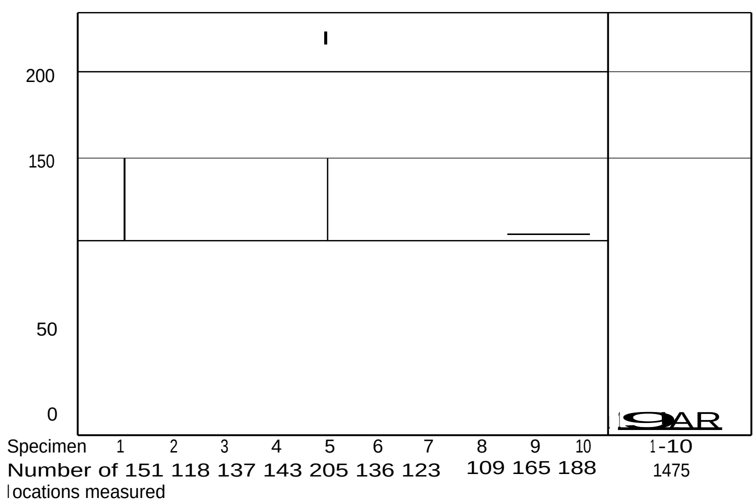
The DCS described below achieves an average marginal fit of 47.0 ± 31.5 pm in the newest in vitro studies on crown frameworks made from titanium. The data ranged between 0 and 220 um. Of the measurements, 6.8% exceeded 100 um, usually caused by titanium chipping in the marginal area of the crown margins (Besimo et al. 1995).



483 Margin area of a crown framework milled in titanium using the DCS System

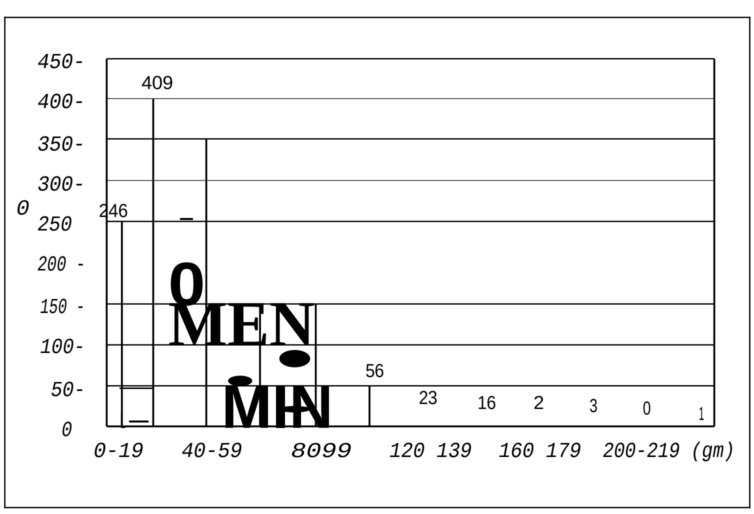
C Crown
T Tooth

SEM micrograph, magnification x50

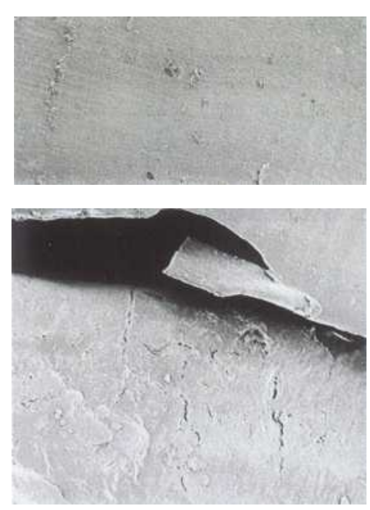


484 Variations in margin gap size of ten DCS frameworks milled in titanium
The boxes include the 25th to 75th percentile of the observations. The small stars mark extreme values; the red dots represent mean values. The line within the box indicates the median. The number of measurements for each crown examined by SEM is shown below the diagram.

(Adapted from Besimo et al. 1995.)



485 Frequency distribution of the measurements for all test specimens
As the grouping of the measurements in 20 pm intervals shows, 68.3% of the gaps are smaller than 60 pm and only 6.8% exceed the 100 pm gap width (adapted from Besimo et al., 1995).

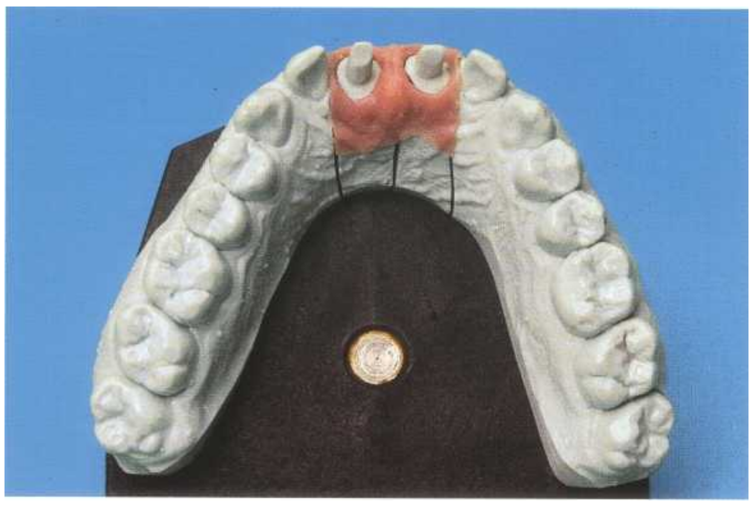


Right: Titanium flaking was the most common cause for a deficient marginal fit.

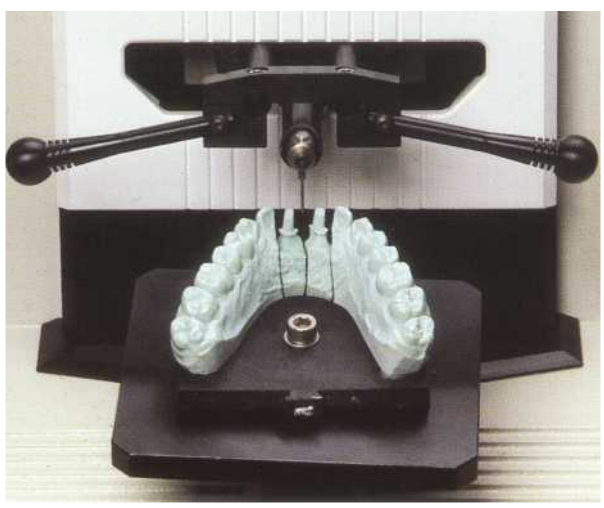
SEM micrograph, magnification x 50

Digitizing Computer System

Today, the Digitizing Computer System (DCS Production AG, Allschwil, Switzerland) enables computer-controlled production of frameworks for crowns and/or smaller bridges. The three-dimensional form of the prepared crown is recorded on the model by mechanical surface scanning with the digitizer. The model is installed on a pedestal which can be moved in three dimensions and is oriented so that the same setting can be used to sense the prepared surfaces of all abutment teeth of the bridge construction with the tungsten probe. Profiles of the prepared margins are recorded in one single step. This is shown on the screen and its completeness checked.

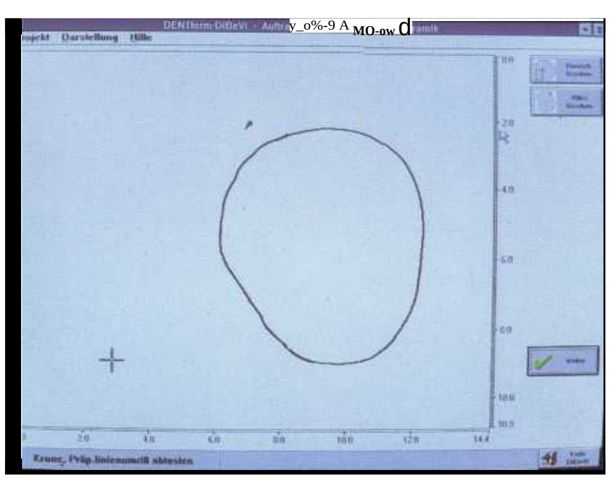


486 Working models
Epoxy resin has, despite its problematic volumetric qualities, proved to be a better material for the mechanical surface scanning model than special die plaster.



487 Digitizer of the DCS system with the pedestal for attaching the model
The guidance of the tungsten probe is done bimanually.

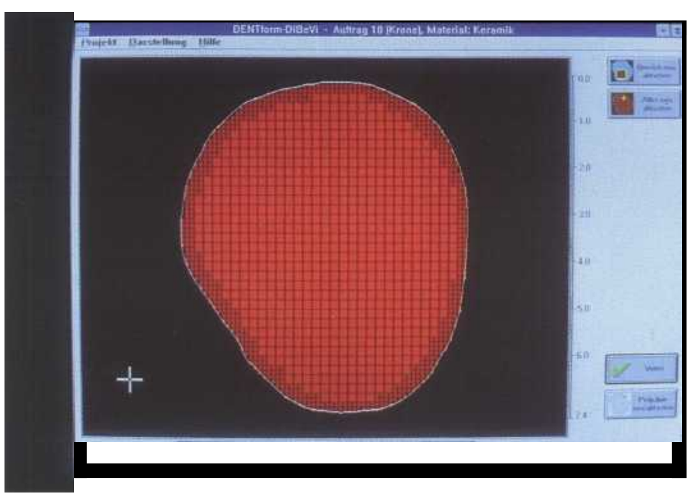
Left: Mechanical sensing of the preparation margin on the master model.

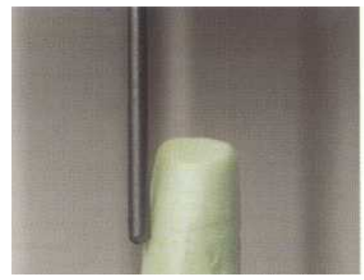


488 Representation of the preparation margin on the monitor

Digital Data Recording and Computer-Aided Design

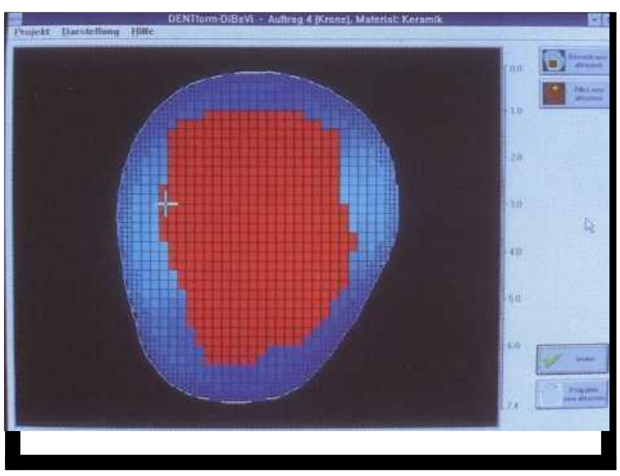
Thereafter, the form of the post is recorded three-dimensionally. To control the quantity of digitized data, a grid appears on the screen within the preparation margin. Each square consists of a number of points that is used by the CAD/CAM program as a base for preparing a three-dimensional model. Each sufficiently registered square is marked on the screen in a particular color by the computer. Scanned surfaces outside the preparation margin are not recorded. The prepared surface is sensed systematically along its height, until there are sufficient data, i.e., that all the squares are marked. Visualization is done three-dimensionally on the screen showing form and relationships between the abutments. This allows single crowns or bridges to be computer-generated. The CAD/CAM program controls the milling machine.

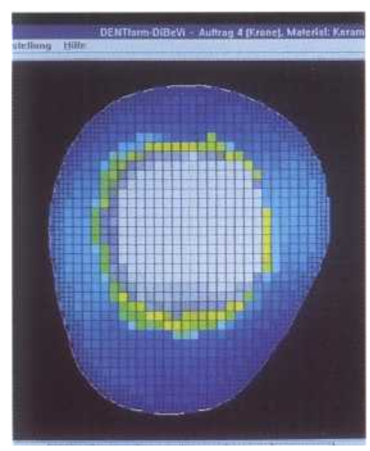




489 Surface scanning
A network-like pattern within the preparation margin is used on screen to record data.

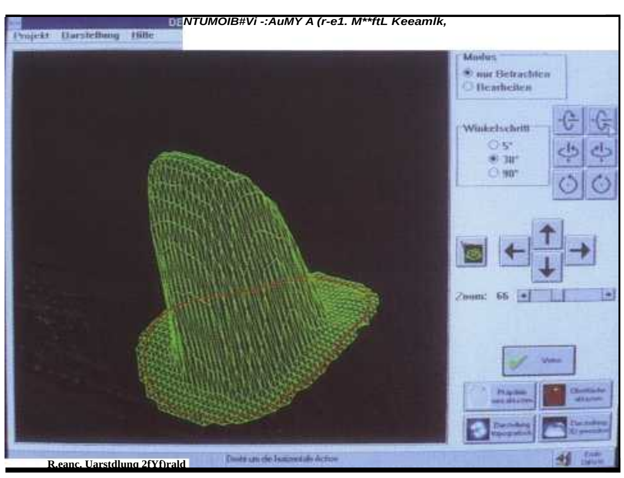
Right: Scanning the abutment surface.

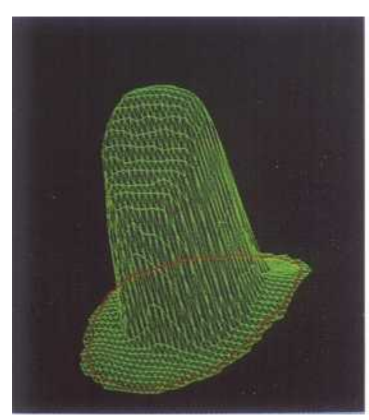




490 Inspection of the data recording on screen
Squares with sufficient data content are marked with colors other than red.

Right: The different colors mark the vertical position of each individual field on the prepared tooth. This facilitates orientation during scanning.

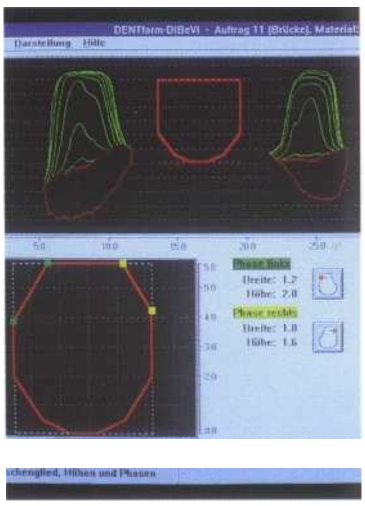


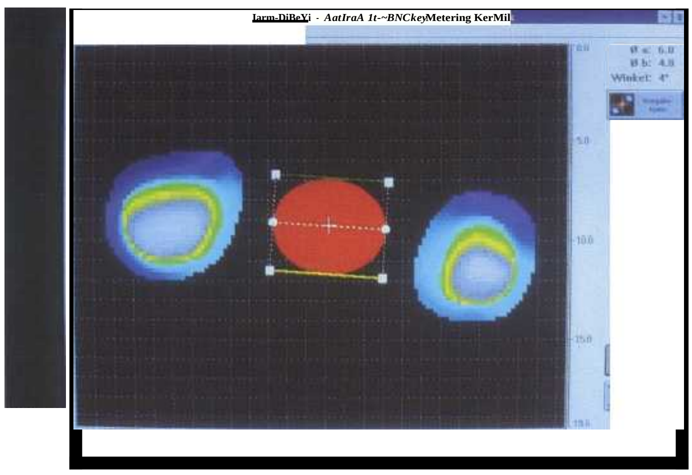


491 Three-dimensional visualization of the digitized preparation, here shown as a network graph
The red line corresponds to the preparation margin.

Right: The network graph can be rotated on screen, thus facilitating planning of the framework.

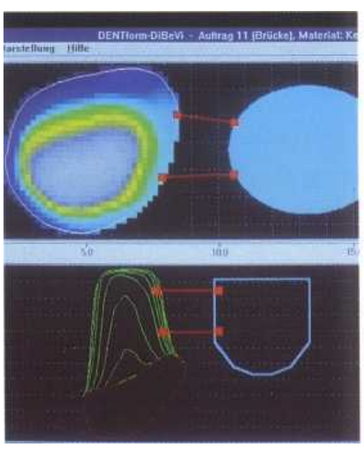
492 Designing the crown framework
The CAD program helps to define the thickness of the wall and the cement of the crown framework. Moreover, the crown wall can be reinforced at any positions, for example, in the region of a metal margin or at the joint between a crown and a pontic.

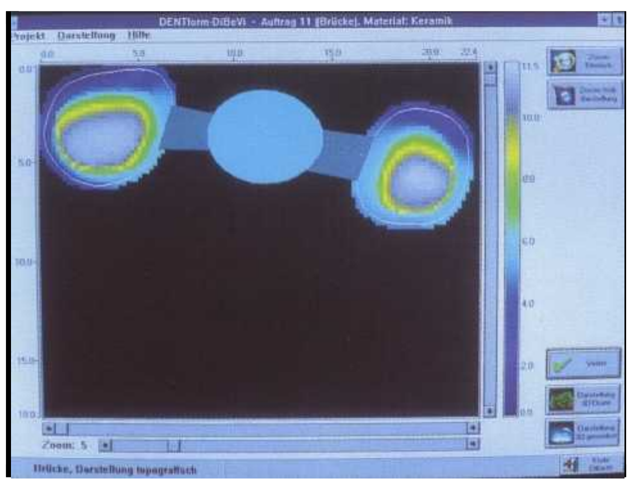




493 Definition of form and location of one or more pontics on screen
Local horizontal relationships. In future, the digitizing procedure will also record the gingival margin and the alveolar ridge.

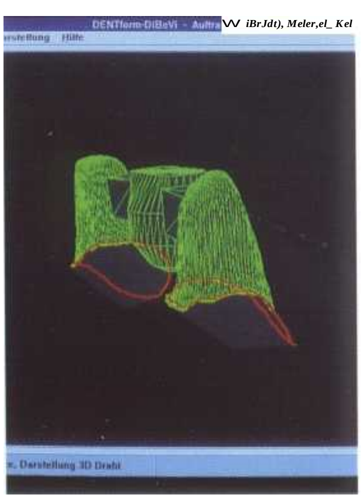
Left: Local vertical relationships.

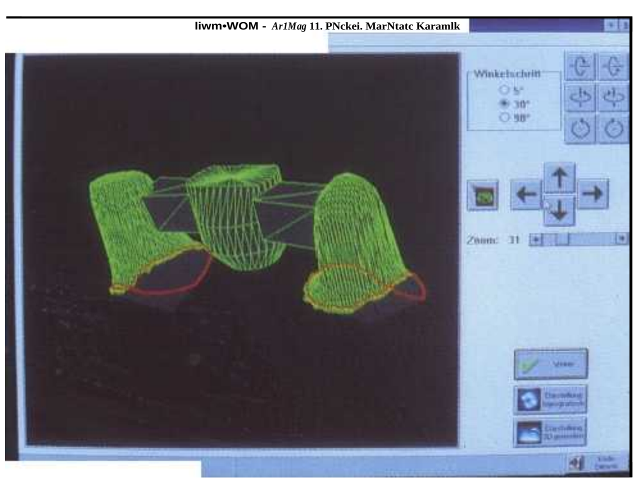




494 Attaching the connector
Presentation of the finished bridge construction in a horizontal plane.

Left: Installing the connector between an abutment and a pontic.





495 Three-dimensional network graph of the bridge framework
The red lines mark the preparation margins of the abutments.

Left: The network graph can be viewed from any angle. This allows the planned construction to be precisely checked.

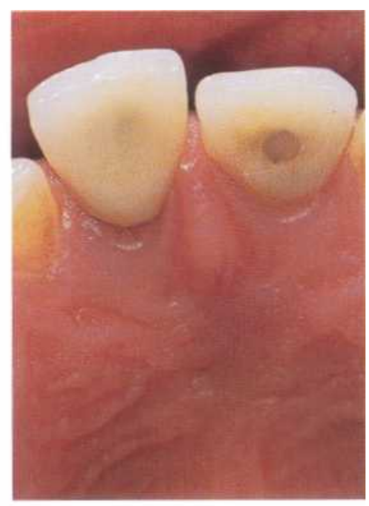
Mechanical Processing of Ceramic Materials

Computer-aided methods make it possible to use industrially manufacturered materials with optimized biological and physical properties (Graber and Besimo 1994). Using the DCS method, it has been possible for some time to process titanium frameworks for single metal-ceramic crowns and bridges. The processing of alumina (In-Ceram) and zirconium oxide high-strength ceramic is also possible. However, for the clinical application these DCS ready-made ceramics are at present only available for making single crowns.

The mechanical processing of industrially sintered alumina ceramic blocks, which is possible with the mechanical Celay and the electronic DCS system, makes it possible to achieve *improved strength* when compared to the conventional In-Ceram technique. Moreover, significant *time-saving is* achieved, in that the slip-sinter firing in the special oven (which takes 10 hours) and the glass infiltration firing (taking four hours) can be reduced to only 40 minutes.

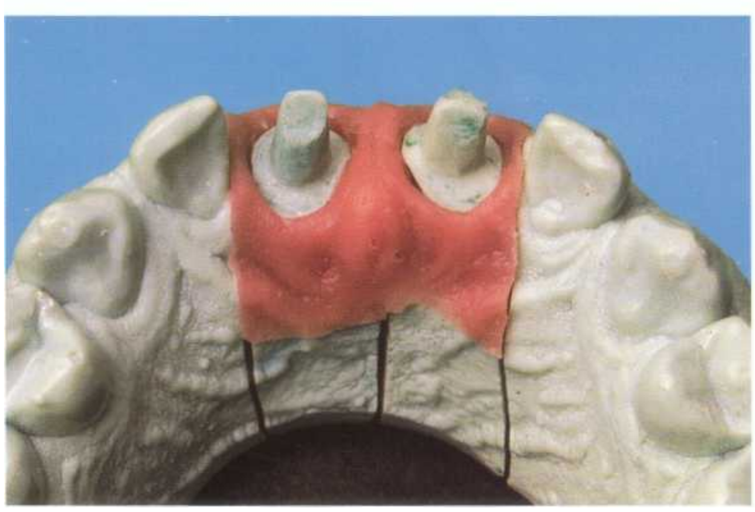
496 Physical properties of zirconium oxide, high-performance ceramic compared with other materials
The zirconium oxide ceramic (TZP = tetragonal zirconia polycrystal) shows physical properties that far outperform the alumina ceramics. These ceramics have properties comparable with tried and tested cobalt-based alloys.

Material	Flexural Strength (MPa)	Modulus of Elasticity (GPa)	Fracture Toughness (Mpa/m z)	Density (g/cm^3)
Bones:				
-long axis	100	15	6	–
-diametrical	60	5	3	–
Al_2O_3 (ISO 6474)	400	380	4	3.90
ZrO_2 + TZP	900	210	9	6.08
Hydroxyapatite	100	100	1	3.16
Co-based Alloy	1000	200	–	8.30
Ti_6Al_4V	860	110	–	4.43

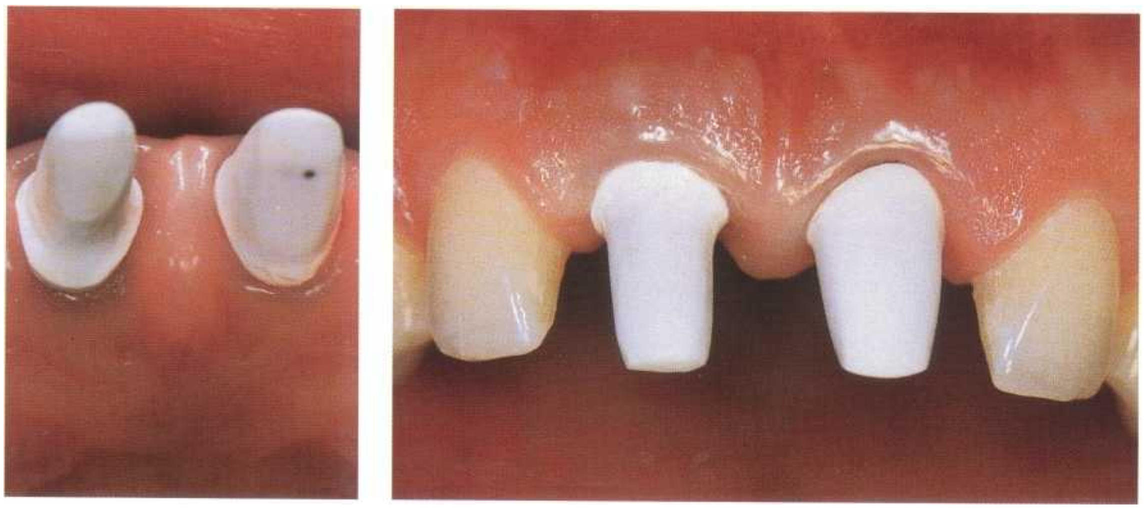
497 Initial clinical situation
A 26-year-old patient with unsatisfactory crown restoration of endodontically treated central incisors in the upperjaw.

Right: The palatal view shows the unfavorable position of the crown on tooth 11.




498 Working models made from epoxy resin
For electronic data recording, the circular step preparations with interiorly rounded transitions are prefered to a model with accentuated rounded shoulders. (Schlegel et al. 1991).

Right: A single- or two-step impression is made with a polyvinyl siloxane or a polyether impression material for model processing.



499 **CAD/CAM-processed crown framework made from industrially sintered alumina ceramic (In-Ceram)**

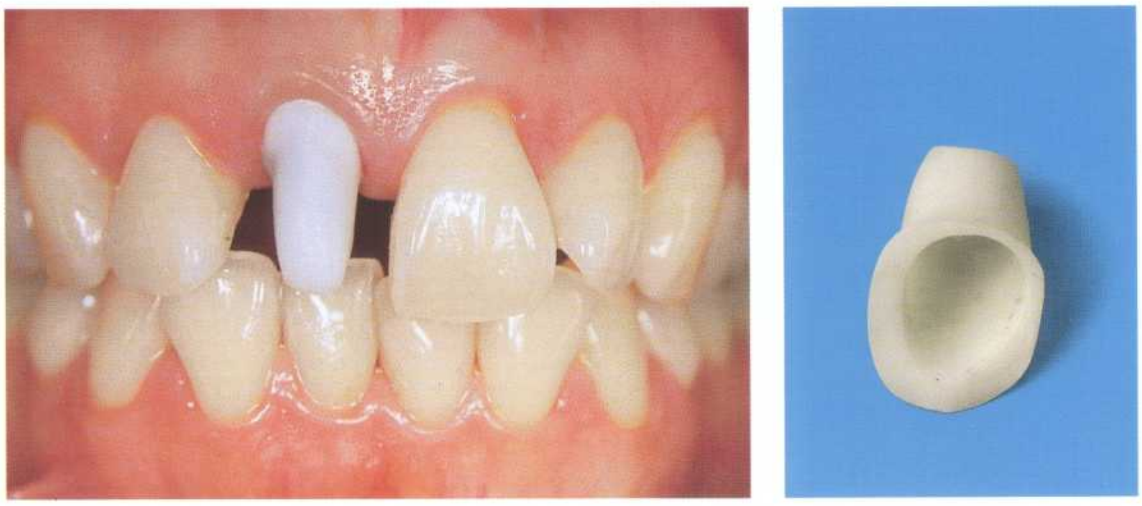
500 **Try-in of the biscuit-baked crown**
The glass infiltrated crown framework has, in accordance with the conventional In-Ceram technique, been covered with a Vita ceramic mass.

501 **Final try-in**
The all-ceramic crown can be cemented with conventional zinc phosphate cement or be bonded with a resin cement after sandblasting and silane treatment of the inside surface the crown.

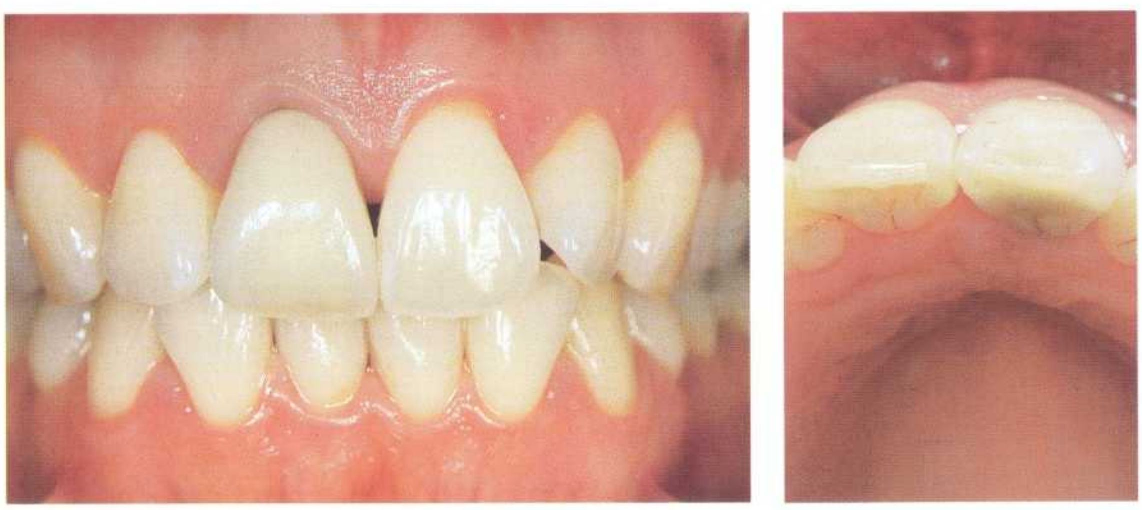
502 **Final clinical** result

503 **Initial clinical situation**
Unsatisfactory crown on the endodontically treated central incisor 11 of a 32-year-old patient.

Right: Incisal view.



504 **CAD/CAM-processed crown framework made from zirconium oxide ceramic**
Individual masking requires a special Vita ceramic mass matched to fit the physical properties of the high-performance ceramic.



505 **Final try-in**
Cementation of the zirconium oxide reinforced crown is done with zinc phosphate cement.

Right: Incisal view.

506 **Final clinical situation**

Aesthetics in Implantology

Over the past 15 years, it has become generally accepted in the daily practice of dentistry to use implants to replace missing teeth. It has also become an integral component of modern restorative dentistry. This development is based on fundamental discoveries made by P.I. Branemark's team (Goteborg, Sweden) and A. Schroeder's team (Bern, Switzerland). More than 20 years ago hese two groups independently showed that titanium implants can be integrated into and form a reliable attachment with the jaw bone (Branemark et al. 1969; Schroeder et al. 1976). This phenomenon is called osseointegration. Titanium has become a generally accepted implant material because of its excellent biological and mechanical properties, which are crucial for long-term clinical success.

507 Implant region 11
Labial view approx. six months after placing an endosseous implant in the area of tooth 11, which was lost due to trauma. To minimize the risk of the future implant-supported denture being recognized as such, the implant must be incorporated in a way that conserves a stable and aesthetic soft tissue contour. The affixed mesostructure serves as the support for the metal-ceramic restoration.

508 Final clinical result
To optimize aesthetics, it is particularly important to consider the symmetry and similarity of crown shape, crown volume, and gingival margin when the implant and the natural "control" tooth (21) are compared. The ceramic materials and the techniques that are available today make it possible to reproduce the appearance of natural hard tooth tissues.

Osseointegration

Nowadays, titanium implants with an axial symmetrical design are mostly on offer. A great variety of screw-shaped implants predominate. Extension implants, like blade implants or subperiostal framework implants, have lost in importance because they can cause considerable bone defects in the jaw in case of failure. A recently conducted long-term, multicenter clinical study with more than 2300 ITI implants (Buser et al. 1997) showed that after eight years the cumulative survival rate was 96.7%, while the respective success rate was 93.2%.

For an osseointegrated implant to succeed in a healthy patient, the implant bed needs to be carefully prepared and the implant inserted and stabilized, whereupon a healing phase, without pressure, of at least three months is required. If these prerequisites are fulfilled, osseointegration with tissue coverage (two-phase surgery) or with open transmucosal (one-phase surgery) healing can be achieved. Various experimental and clinical studies show the equivalence of the two methods (Gotfredsen et al. 1991; Ericsson et al. 1995; Weber et al. 1996).

Treatment Planning

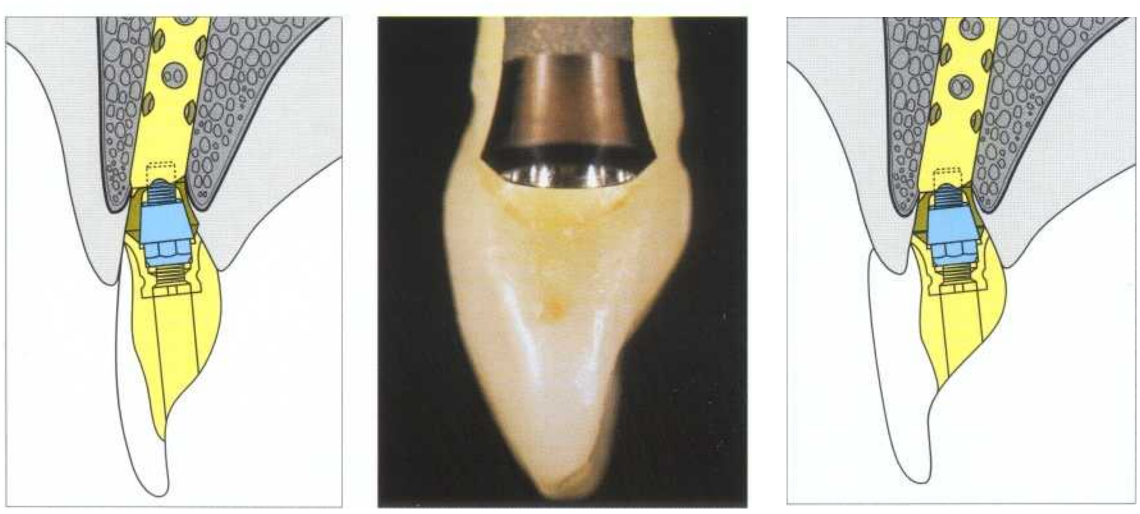
Today one does not consider that placing endosseous implants in partially edentulous patients is a special, independent therapeutic modality, but rather as one of many options to be considered within an extensive restorative treatment plan. The following questions are of importance, primarily from a prosthetic point of view:

- Can the implant substantially decrease the invasiveness (abutment preparation) of a conventional prosthetic procedure, i.e., can intact tooth tissue be saved through such a treatment?

- Can implants significantly reduce the risk associated with an extreme, conventional crown-and-bridge reconstruction (unfavorable qualities and distribution of abutments, wide gaps, etc), or is it likely that later reintervention will be locally restricted and/or simplified because of the implant-related segmentation of the restoration?

- Do implants offer a meaningful, fixed prosthetic solution as opposed to a removable prosthetic solution?

509 Single tooth gap, region 22
The single tooth gap surrounded by otherwise intact teeth represents a frequent indication for implants in young patients on the basis of the minimal invasive approach that is associated with implant treatment. Beside the analysis of the local bone volume, the preoperative treatment includes diagnosing and evaluating the surrounding soft tissue structures, the dimension of the edentulous jaw section, and most importantly the localization and the course of the neighboring roots.



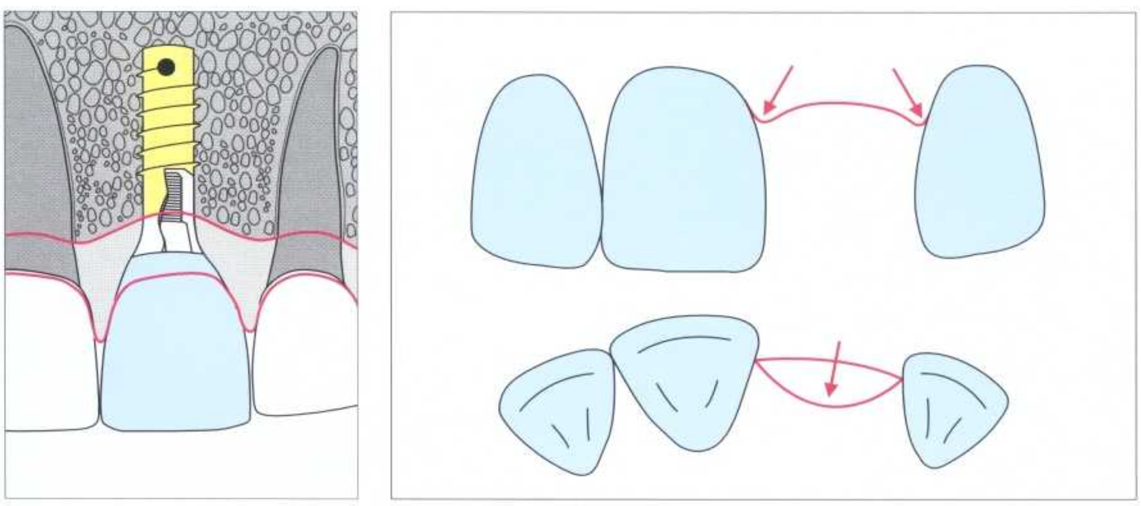
510 Implant supported front tooth suprastructures
Left: Implants with integrated angle adjustment make it possible to compensate for a divergence between the axes of the implant and the prosthetic reconstruction.
Middle: Average-sized implants of all systems show smaller orofacial diameters than, e.g., upper central incisors.
Right: An implant that is located too far lingually can result in a suprastructure overlapping the ridge.

Implantology and Aesthetics

Implants should be considered only after the completion of the initial treatment phase and after the elimination of all existing pathological processes. Restoring the chewing function was the main goal of treatment during the 1980s. During the 1990s, the treatment goal changed decisively, in that the aesthetics today also plays a relatively important role alongside the chewing function. This has led to a clear increase in overall demands made on the dentist. The goal of the treatment plan is to secure long-term success for the patient with specific consideration of chewing function and aesthetic needs. At the same time, this goal should be achieved within the shortest possible time and at a reasonable cost.

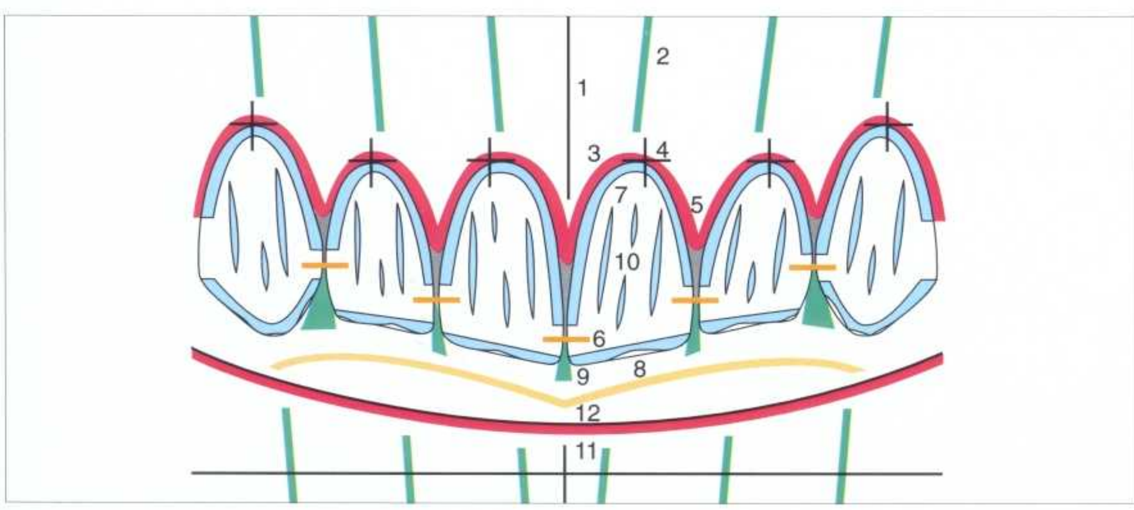
The dentist must be aware of the differences between implant indication in the posterior, nonaesthetic regions and the anterior, aesthetic regions, because they are characterized by quite specific demands based on the location.

More recently, dental restorations have been increasingly influenced by aesthetic considerations. Two main reasons were and still are responsible for this development: the wish of the patients to have as natural an aesthetics as possible and the continuing search within dentistry for less invasive restorative treatment procedures (Magne et al. 1993a, 1993b, 1994). Missing front teeth can either be replaced through conventional, fixed bridges or through bonded bridges with excellent aesthetic and functional long-term results. They represent the gold standard for each innovative therapeutic alternative. Implant-supported restorations are an alternative to such treatments. Implants performed without optimal preoperative planning and treatment can result in faulty implant positioning and/or insufficient management of the surrounding soft tissues which will result in an aesthetic failure (Garber and Belser 1995). Consequently, diagnosis and treatment planning have an important role in the preoperative treatment. As already stated, in most cases one can achieve good functional and aesthetic results by treating upper maxillary front teeth with conventional, fixed dentures.



511 Alveolar ridge after tooth loss
Tooth loss in the maxillary front tooth area usually leads to flattening of the vestibular bone lamellas.

Left: The axial profile should be continuously widened in a coronal direction from the submucosally located implant shoulder to the mucosa opening, so that the visible area of the suprastructure of the implant corresponds to the clinical crown of the neighboring tooth.



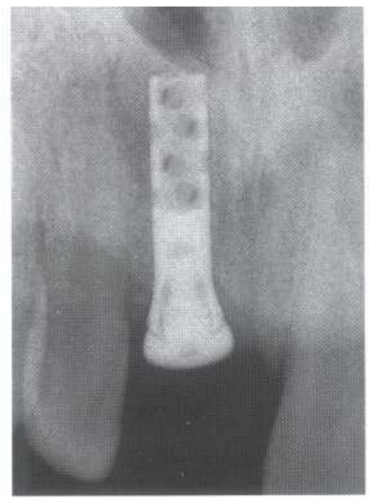
512 Aesthetic parameters
A series of objective aesthetic parameters, here summarized as a schematically depicted twelve-point checklist for clinical application (Belser 1980), particularly emphasize the importance of certain symmetries in the maxillary anterior area. It is of the greatest importance to produce a harmoniously arcade-shaped course of the gingiva with clearly marked interdental papillae and without abrupt differences in level between neighboring teeth.

Implant-Supported Front Tooth Replacement

Patients' expectations are always high and room for compromises with implant-supported dentures is, therefore, particularly in the presence of a high smile-line, correspondingly small.

Consequently, an optimal aesthetic implant treatment depends not only on the prosthetic and technical procedures, but also to a great extent on the following anatomical and surgical parameters:

- Submucosal localization of the implant shoulder.
- Proper three-dimensional implant position that is determined by the planned prosthetic suprastructure and not by the local anatomical realities. This is called "restoration-driven implant placement" (Garber and Belser 1995).
- Long-term stability of aesthetic soft tissue contours.
- Symmetry of the clinical crown volume when the implant is compared with the contralateral natural control tooth.

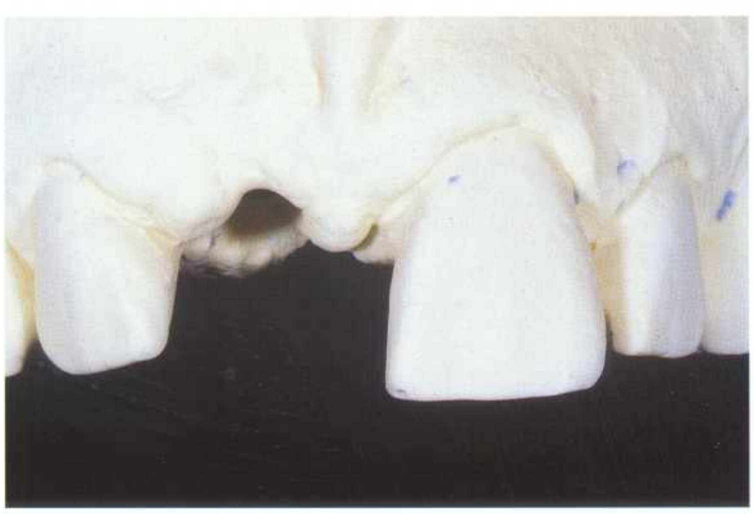


513 Single tooth implant, region 11
Labial view of a 25-year-old patient, three months after receiving a transmucosally placed implant in the region of the lost tooth 11. The neighboring interdental papillae have collapsed towards the center of the tooth gap.

Right: Three months after placement, the radiograph shows the 12-mm-long hollow cylinder implant angled at 15° and sufficient bone.

514 Shaping the soft tissue
The short titanium healing cap which has been in place during the three-month healing period is replaced with a longer healing cap as the first step in the prosthetic reconstruction. This will induce the formation of the funnel-shaped soft tissue collar around the implant.

Right: The corresponding radiograph confirms the perfect cervical fit of the long titanium healing cap.



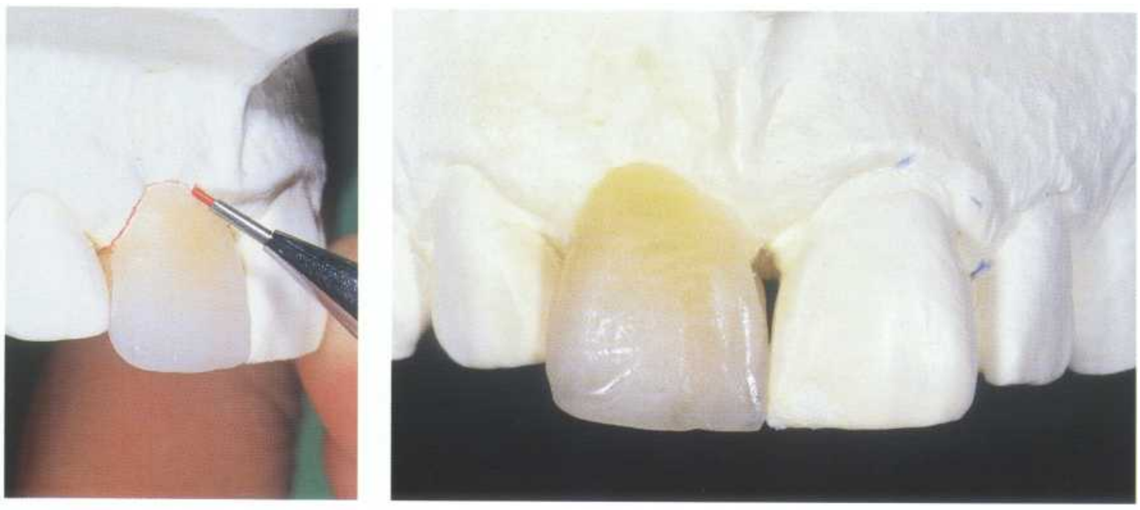
515 Master cast
The labial view of the cast clearly shows the discrepancy between the diameter of the present peri-implant soft tissue and that of the neighboring dental neck region of the natural incisor serving as a reference.

Right. The corresponding lingual view shows the spatial relationship between vestibular mucosa margin and the prosthetic connection to the implant, which was located much more apically at the time when the picture was taken.

Implant Positioning

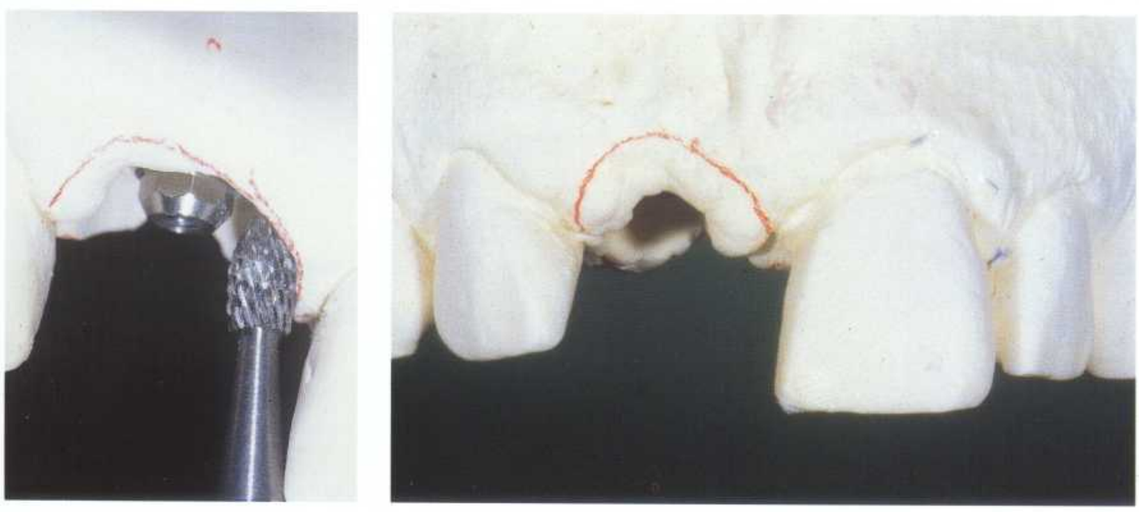
During surgery, the implant should be placed into a favorable three-dimensional position. The implant thus becomes the apical extension of the future implant crown. Regarding the vertical position of the implant shoulder, the implant is placed approximately 2 mm deeper into the bone as compared to other locations. That means that with an ITI implant, the smooth neck part of the implant will lie in the enossal region. To limit bone resorption, special implants should be used, on which the TPS coating is extended about 1 mm further coronally.

The buccal position of the implant shoulder should be the same as the buccal contours of the adjacent teeth, so that an implant crown can be produced with a favorable cervical contour. This position is often limited due to vestibular bone flattening and one must ensure that during the implant placement the buccal bone lamella is sufficiently thick (> 1 mm). This bone wall is important for supporting the facial soft tissues and to maintain long-term stability. Therefore, there is no room for compromises.



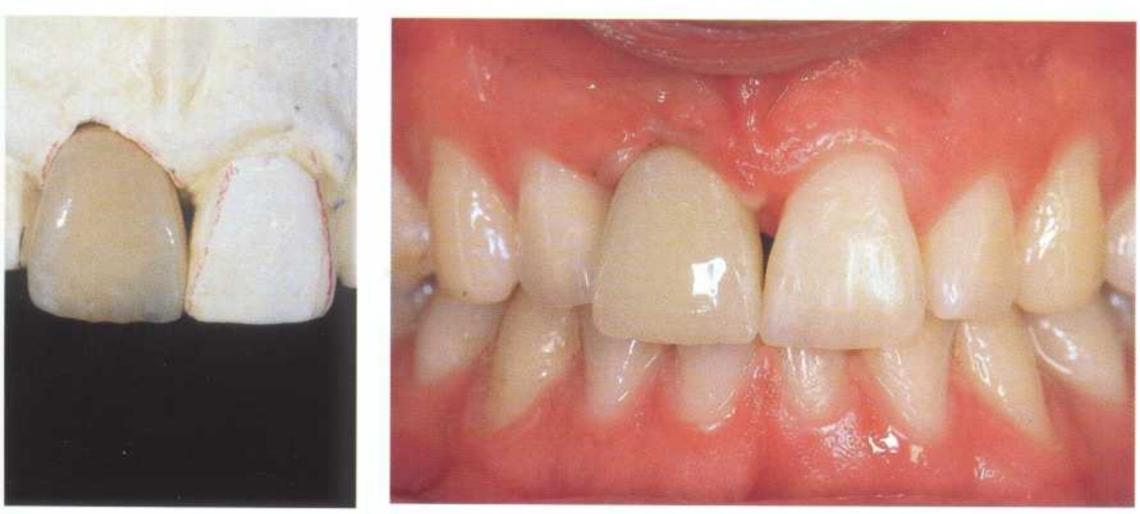
516 Wax reconstruction
The goal of the wax reconstruction is to visualize the future implant suprastructure. This step is taken without taking the position of the underlying implant into consideration.

Left: After completed wax reconstruction of the clinical crown, the cervical margin, which corresponds to the future mucosal penetration site of the planned prosthetic suprastructure, is marked using a red pencil.



517 Correcting the soft tissue
After the wax pattern has been removed from the master cast, the red line, representing the mucosal penetration site for the future implant suprastructure, is clearly visible.

Left: After removing the waxed crown, the dental technician uses a suitable bur to create the space that is needed to allow an optimal cervical axial contour of the suprastructure.



518 Temporary implant crown
The picture was taken after attaching the temporary resin crown. It shows a mild, pressure-induced anemia of the soft tissue surrounding the crown. The cervical contour of the temporary crown should together with an adequate massage technique lead to a harmonious course of the gingival margin.

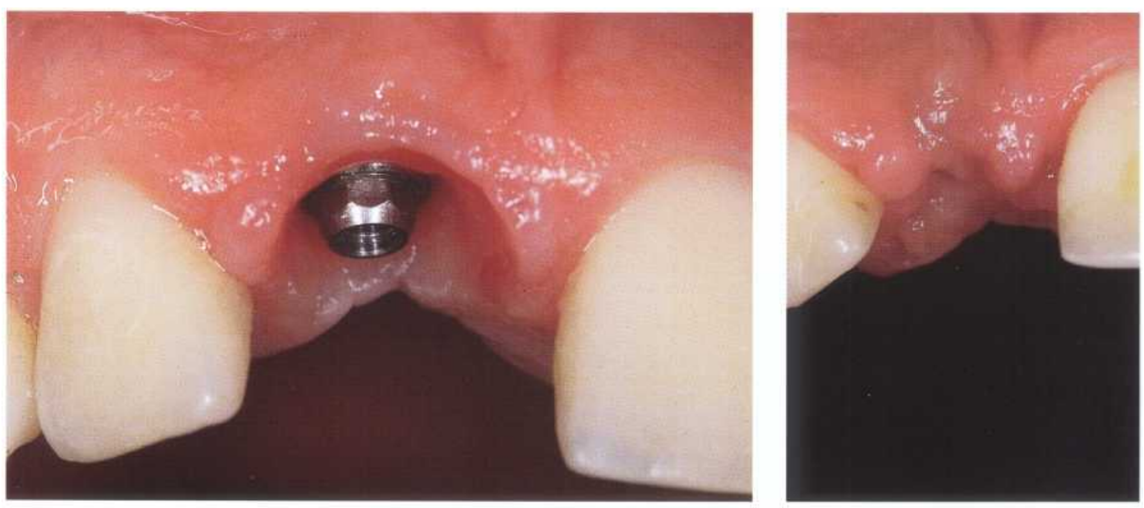
Left: After excessive soft tissue has been removed, a temporary crown is made on a prefabricated titanium cap.

Surgical Procedure

Important points in the surgical technique include:
- a slightly lingually placed ridge incision
- a correct three-dimensional implant orientation
- if necessary, use a connective-tissue transplant gained from the palate to enhance facial soft tissues
- the use of special, buccally flattened healing caps as well as
- partial or complete coverage during healing

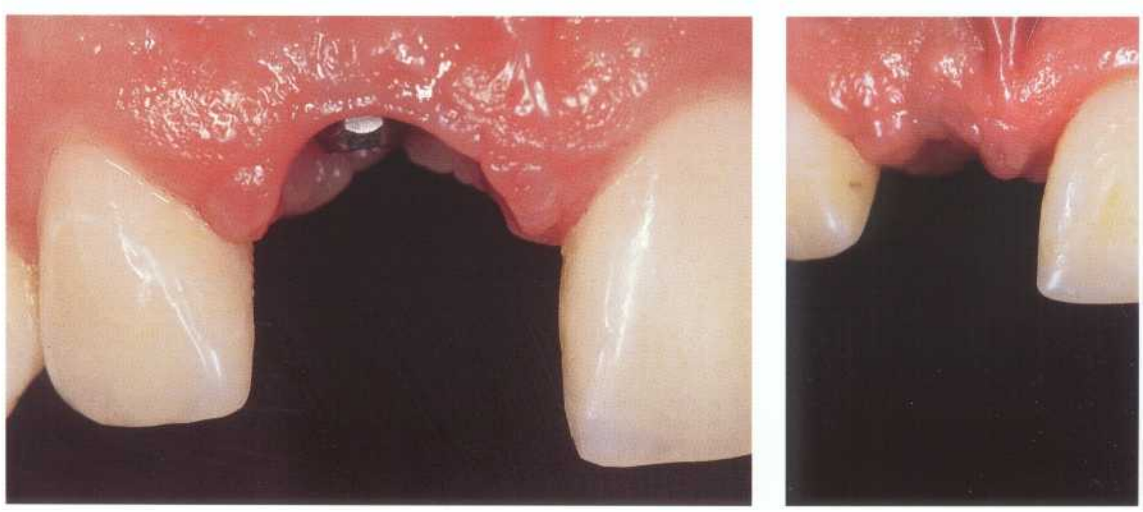
Approximately eight to ten weeks after the implantation, the implant is exposed by means of a gingivectomy and a long transgingival extension cap is inserted to form the definitive soft tissue canal that reaches from the soft tissue surface up to the implant shoulder. Three months after implantation, the secondary parts are placed and prosthetic treatment initiated.

On the basis of the above, it is of great importance that the implant screw is well adapted under the soft tissue level where it is generally located. It is also important that the cervical margins of the selected and attached suprastructure are optimally adapted. Metal-ceramic frameworks that are based on prefabricated, add-on castable parts are the best means of fulfilling the demands of these marginal regions, due to their high precision and their homogeneous structure. To fully benefit from prefabricated elements, the application of an octagonal secondary part is recommended (Octa System). With its proper precise transfer system (screwed transfer caps, integral laboratory analogue), it provides a secure transfer of the oral situation to the master model. Its mechanical stability guarantees optimal attachment between implant and super structure (Sutter et al. 1993). If the implant and prosthesis axes coincide, the units are screwed together transocclusally, otherwise transversally and lingually. A temporary replacement based either on an individually ground resin cap or a prefabricated titanium cap is placed to properly shape the soft tissue surrounding the tooth replacement. This is important to give the implant an aesthetic appearance.



519 Optimal soft tissue contour
The close-up of region 11 after two weeks use of the temporary crown shows the perfectly shaped soft tissue margin, which is desirable for an aesthetic result.

Right: The corresponding comparison of the same region at the start of the prosthetic phase. It clearly shows the excess soft tissue.



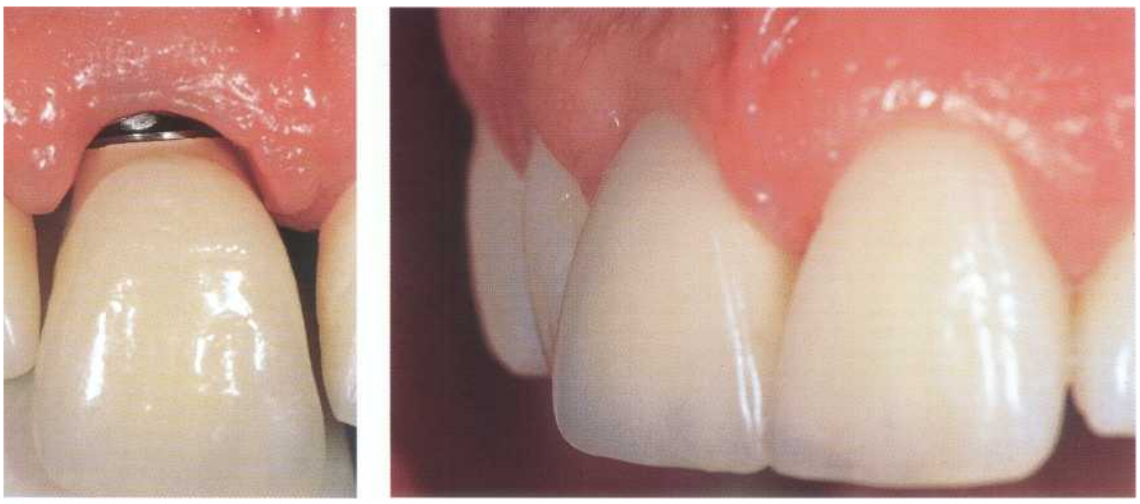
520 Harmonious mucosa profile
The transversal and vertical excess of soft tissue in the area of the missing tooth has made it possible to restore an arcade-shaped course of the mucosa.

Right: The postsurgical, preprosthetic detailed view of region 11 clearly shows the necessity for repositioning the interdental papillae, which collapsed towards the center of the tooth gap, and the need to apically reposition the soft tissue margin.

It's the Patient's Decision

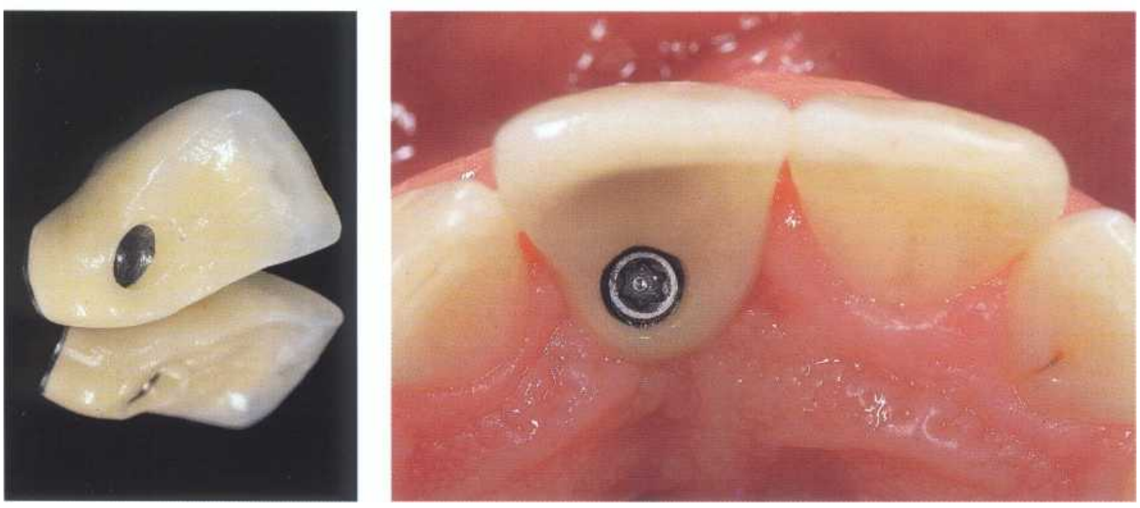
If a potential anterior implant site does not possess sufficient ridge width and/or soft tissue configuration for the prospective prosthetic suprastructure to be attached to the implant, the patient will be asked to select and decide, either in favor of a conventional solution, or in favor of being subjected to preparatory augmentative intervention. An implant restoration with adequate emergency profile must be the goal of therapy in this case.

If the surgical and prosthetic treatment steps presented here are followed in detail, aesthetically very beautiful results can be achieved.



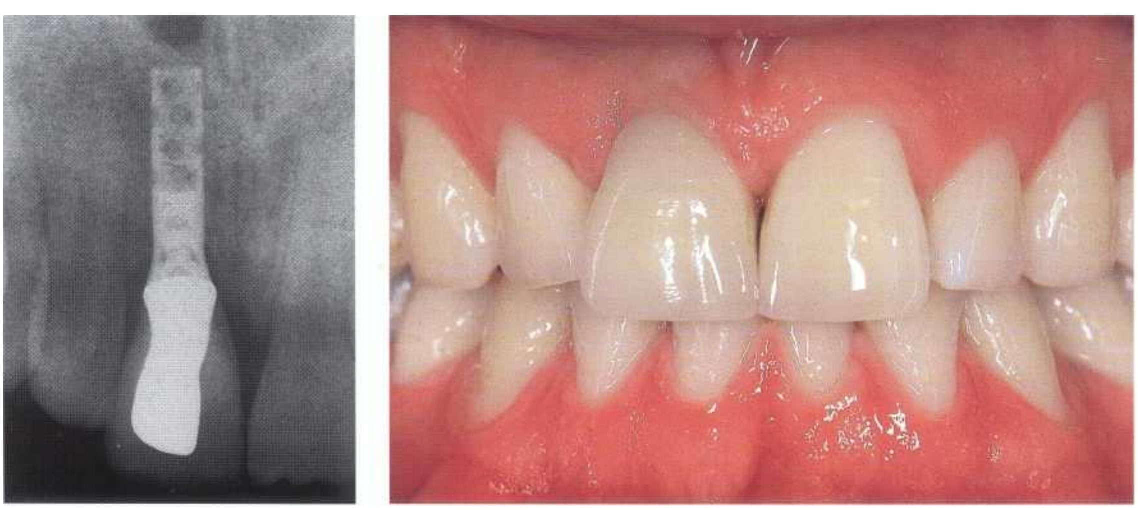
521 Implant crowns with emergency profiles
The side-view comparison between the implant carried superstructure 11 and the natural tooth 21 underscores the perfect integration of the metal-ceramic construction.

Left: The incompletely positioned metal-ceramic single implant restoration is characterized by the locally adapted axial contour. The emergence profile lends support to the peri-implant soft tissue.



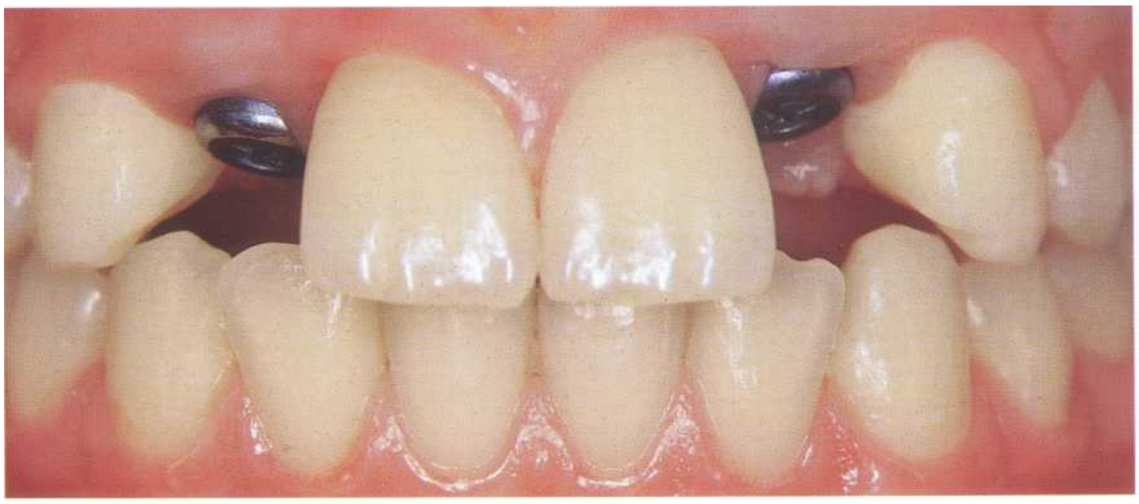
522 Screw attachment from occlusal
The slightly lingually located occlusal screw in no way interferes with the incisal design of the superstructure and allows an optimal framework to be constructed and good layering of the ceramic.

Left. With a correct three-dimensional implant positioning, access to the occlusal screw is in the cingulum region.



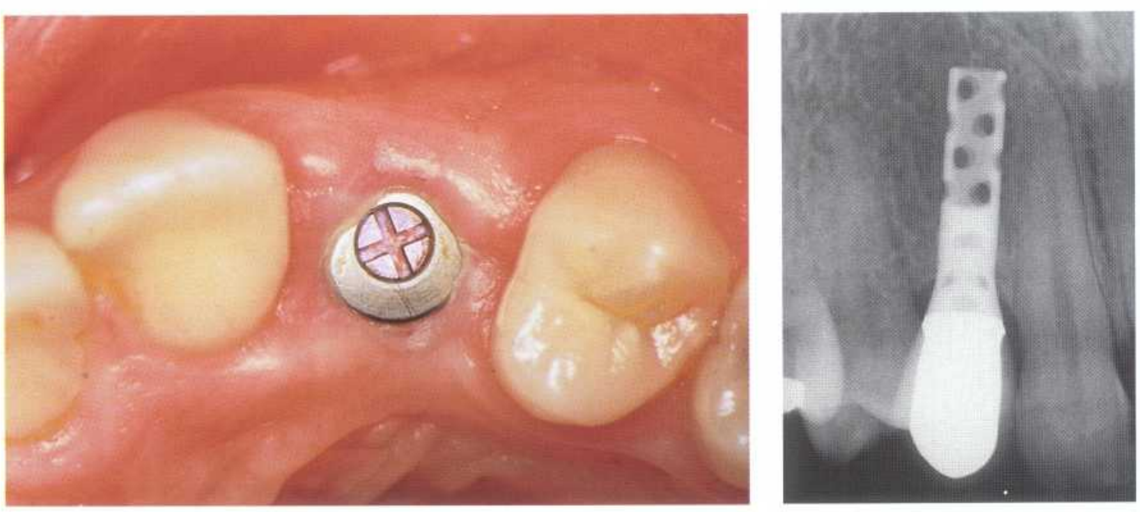
523 Result after two years
The implant supported superstructure 11 fits the existing dentition. Key elements, such as soft tissue contours, crown volume, crown shape, and surface texture lead to the desired illusion.

Left: The radiograph confirms the benefits of using a prefabricated tertiary part (add-on castable gold cap) that results in high marginal fit as well as stable peri-implant bone conditions.



524 Congenitally missing lateral incisors
Missing lateral incisors in the otherwise intact dentition represent a frequent indication for implants in this aestheticly sensitive area. Approximately three months have elapsed since two endosseous implants were placed in this 20-year-old patient. A single surgical protocol was followed.

525 Clinical result, five years after placement
Five years after their incorporation, the two screw-attached metal-ceramic single tooth implant restorations of teeth 12 and 22 are aesthetically appealing. It is particularly thanks to the shape and condition of the harmonic, stable soft tissue contour that one can talk of an almost perfect illusion in this respect, as the existing prostheses cannot easily be recognized as such even several years after being in place.

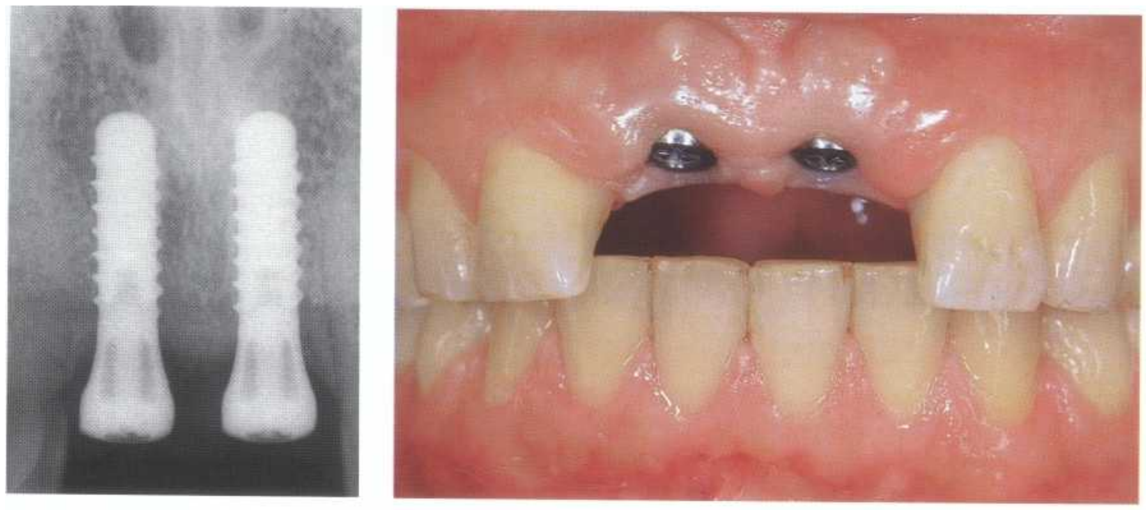


526 Importance of the amount of soft tissue
As this clinical example of region 23 illustrates, ten weeks after implantation it is crucial for the achievement of an aesthetic final result that sufficient keratinized mucosa is created, especially buccally.

Right: The radiograph after two years shows stable bone conditions in the region of the osseointegrated 12-mm ITI hollow cylinder implant, which exhibits a post angled at 15°.

527 Final clinical situation
Also, the frontal clinical view, taken in maximum intercuspation, confirms a satisfactory integration of the implant reconstruction of 13 and 23 into the otherwise intact dentition.

Right: The analogous clinical view documents an appealing aesthetic result. The buccal contour of the implant supported crown 23 harmoniously fits into the tooth row and the gingiva shows its regular arcade shape.



528 Anterior implants placed adjacent to each other

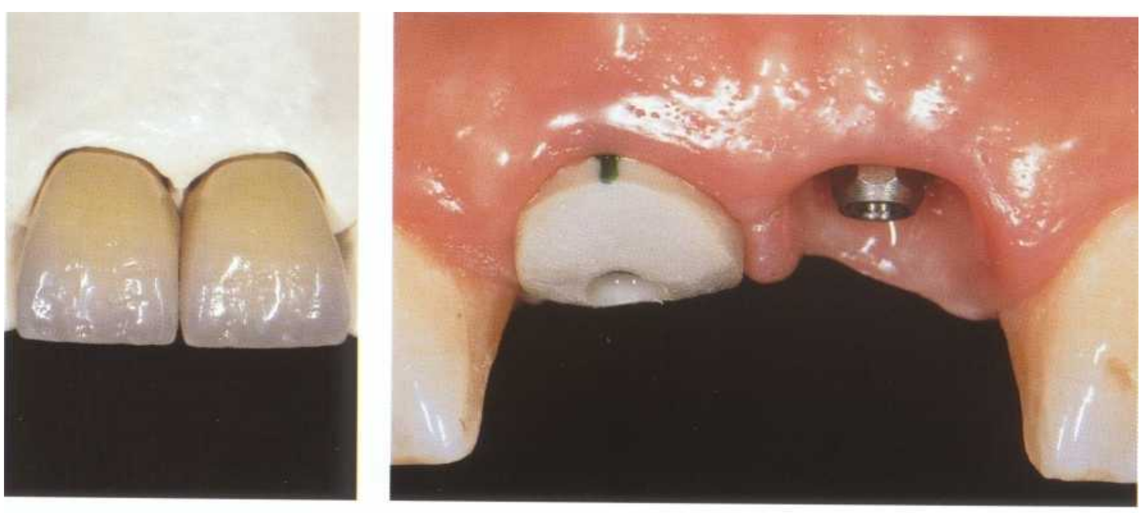
Neighboring implants in the anterior maxilla, e.g., regions 11 and 21 as depicted here, three months after implantation. This situation represents a special challenge for the clinician, because the edentulous jaw section flattens after the loss of several teeth, especially in the area of the interdental papilla. In this region soft tissue support is lost due to missing teeth.

Left: Radiograph three months after placement of two 12-mm-long ITI screw implants.

529 Plastic caps with individual axial profile

Prefabricated, occlusally rounded off plastic caps can contribute to shaping the peri-implant soft tissue funnel. They are used subsequent to attachment of the octagonal secondary posts and are used as an interim solution and protection and for making an attached laboratory-made temporary restoration or the final implant suprastructure.

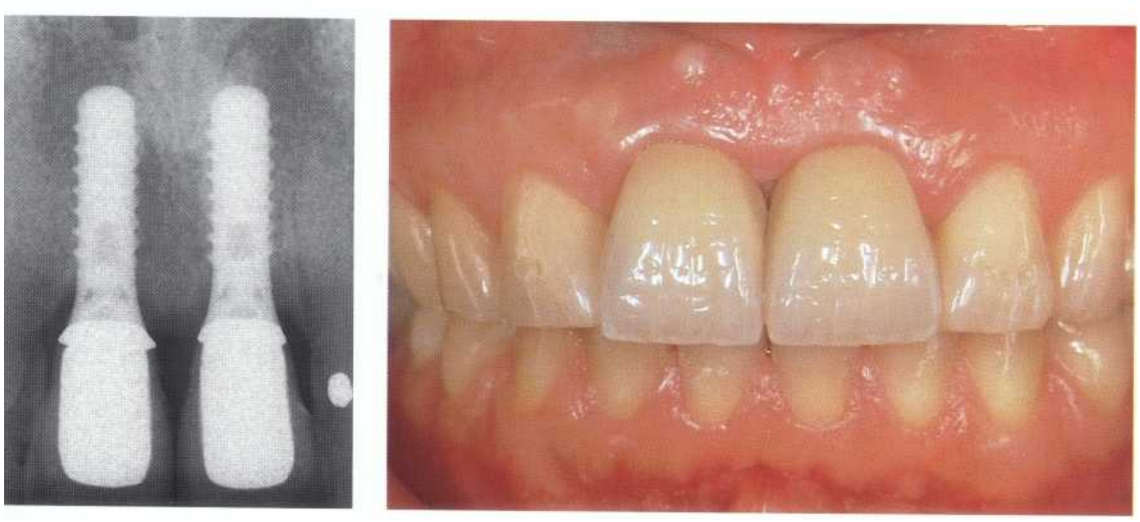
Left: After selection of the protection cap, the cap is individually ground.



530 Shaping the peri-implant soft tissue

In the area of tooth 11, a contoured protection cap is shown in situ. At implant 21, the effect of the protection cap on the peri-implant soft tissue is seen after one week.

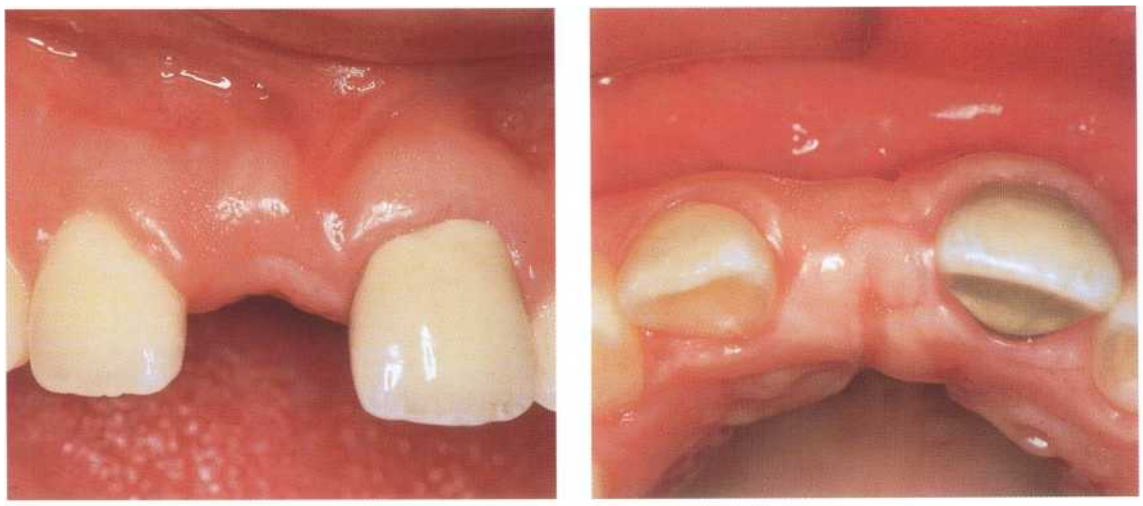
Left. The inidividual crowns placed on the master cast are in contact with each other in the common interproximal space. In order to achieve a natural look of the two implant restorations, edge effects were installed and the most cervical regions of the interdental surfaces were color saturated.



531 Final clinical situation and radiograph

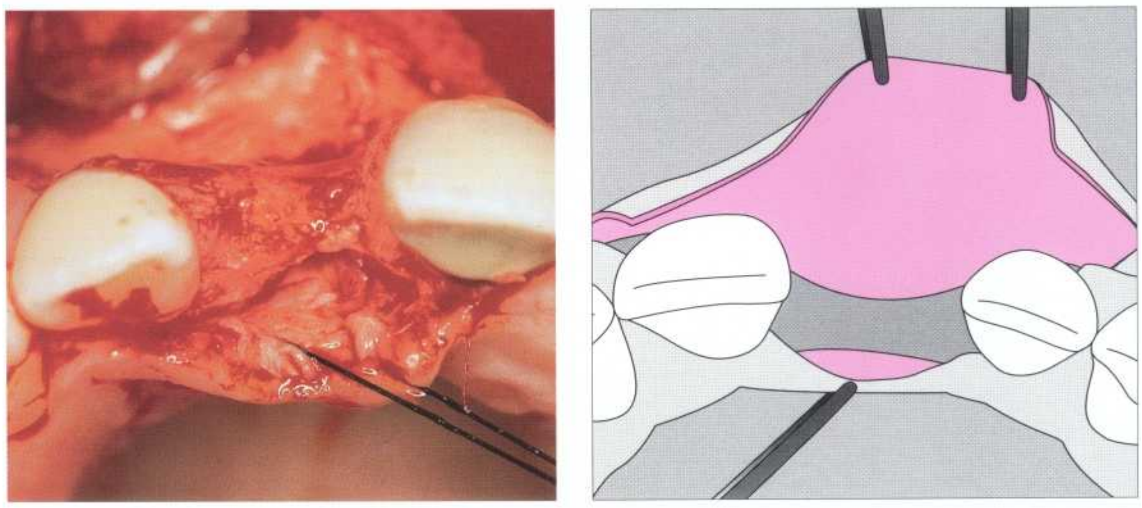
The final clinical situation shows the arcade-shaped gum line and a satisfactory insertion of the implant supported prostheses.

Left: The radiographic check-up after one year shows stable bone conditions in the region of the osseointegrated full screw implants. The application of castable tertiary parts enables prostheses with good marginal fit to be produced.

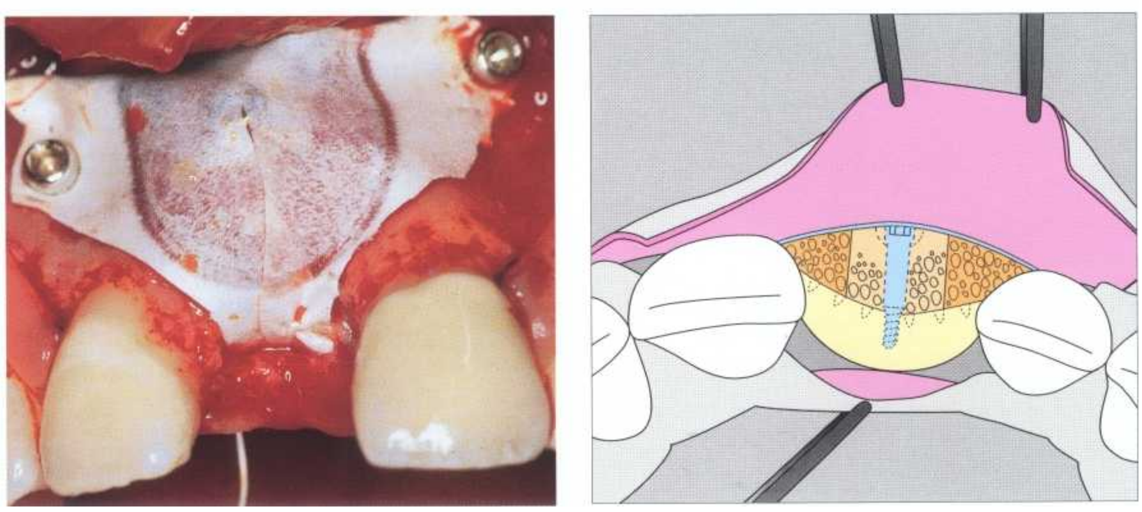


532 Anterior single tooth gap
Left: The close-up of the maxillary anterior tooth region shows favorable preprosthetic conditions regarding the soft tissue.

Right: The occlusal view illustrates a flattening of the edentulous jaw region. The bone projection (juga alveolaris), which typically covers the roots of the adjacent teeth, is missing.

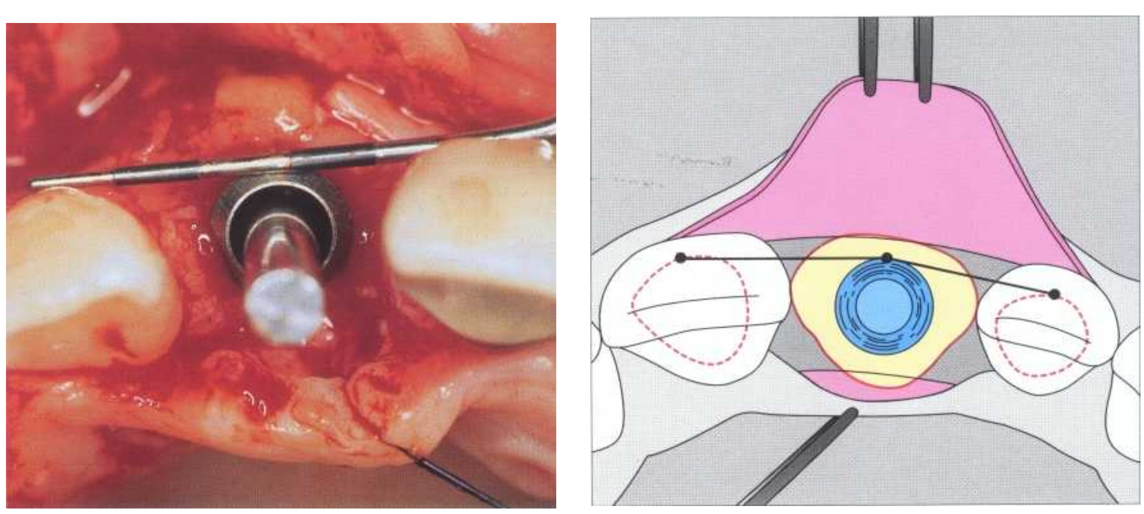


533 Alveolar ridge atrophy
Left: Proper implant positioning is not possible because of insufficient bone support, especially bucally.
Right: The buccal portion of an imaginary, positioned implant would, due to the extent of the bone defect, be practically completely exposed. The requirement of primary stability could not be fulfilled and the attempt of a simultaneous bone augmentation would clearly exceed the regenerative potential of this specific initial condition.

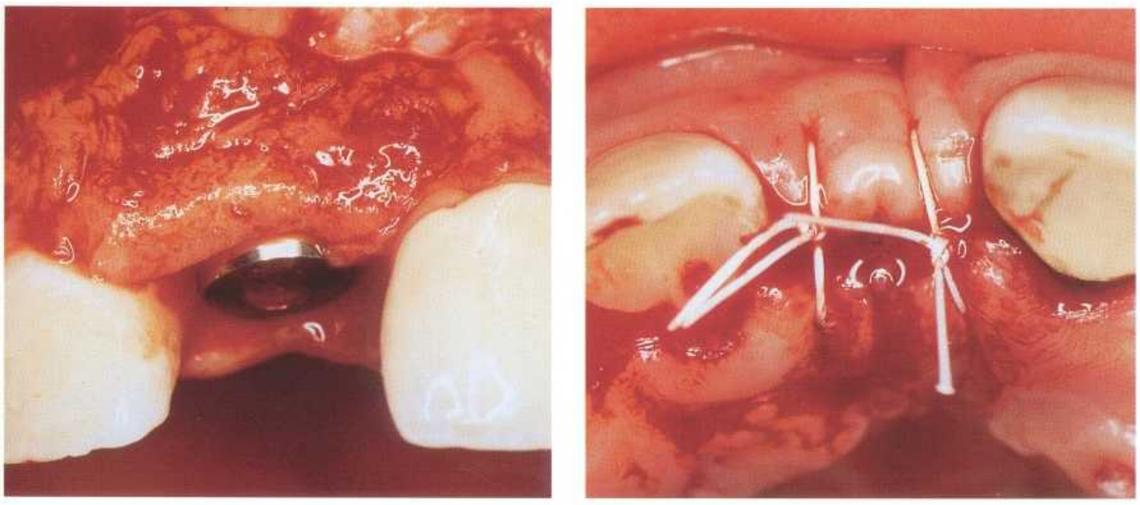


534 Guided bone regeneration
Left: The deficient area is ground drilled, filled with bone transplants, and covered and closed again by means of a membrane.

Right: Notice that the bone transplant consists of a central block transplant which was stabilized before membrane application. In order to prevent slight bone resorption from occurring, mild overcontouring of the alveolar ridge width is recommended.



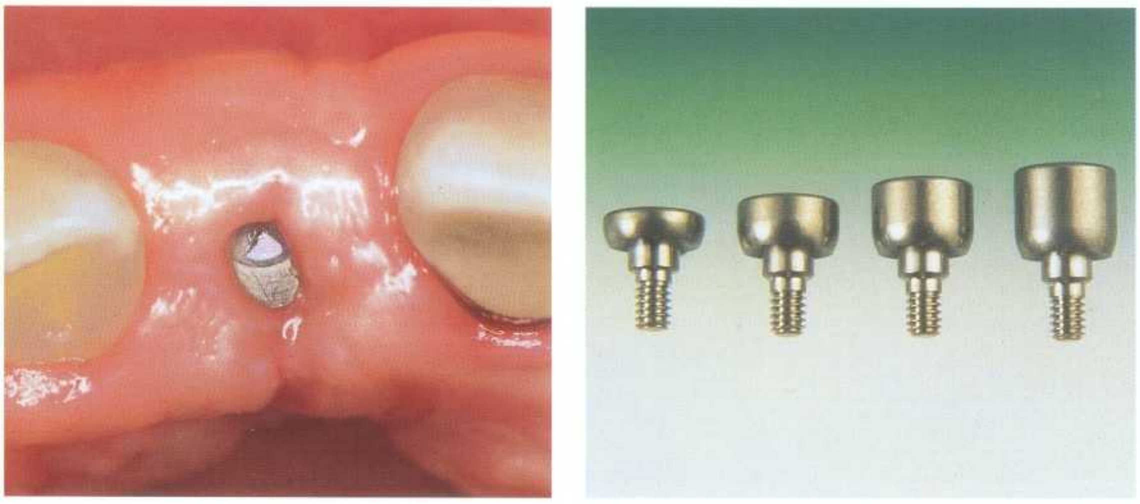
535 Restoration orientated implant placement
Left. The future implant should imitate the orofacial position of the neighboring teeth and be covered by at least 1 mm of labial bone.
Right: Seven months after ridge augmentation, optimum conditions exist for the implantation. To achieve the ideal orofacial implant position, the clinician uses a periodontal probe which is held in contact with the neighboring teeth. The occlusal positioning screw serves to check the implant axis.



536 Connective tissue graft

Left: To achieve the desired enlargement of the peri-implant soft tissue volume, a connective tissue graft has been removed from the palate and adapted to the buccal side of the implant.

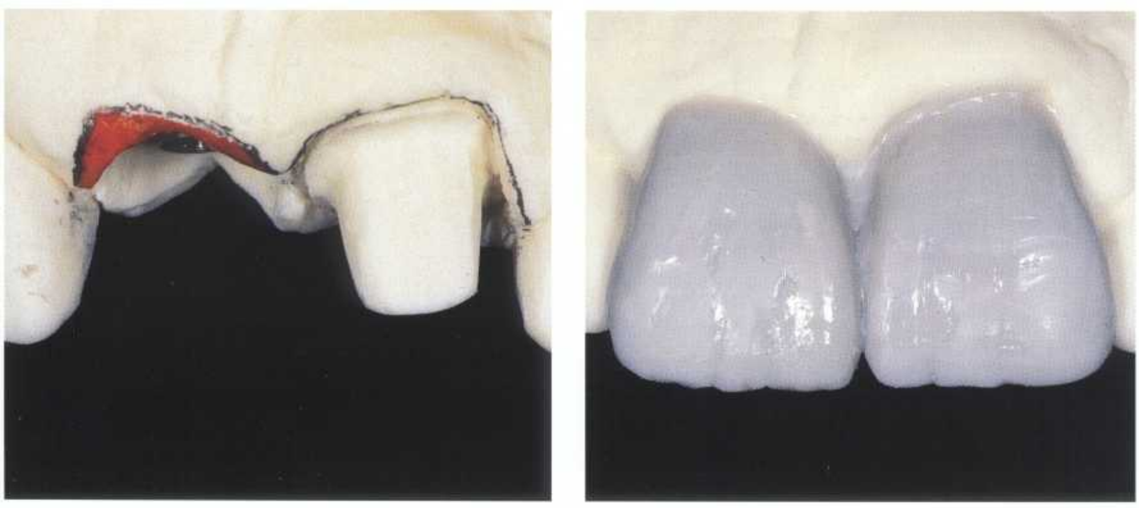
Right: Occlusal view after suturing of the mucous membrane. The slightly palately placed incision and the existence of a sufficient volume of soft tissue at the time of the implantation are clearly visible.



537 Soft tissue conditioning

Left: The incisal close-up shows the thickness of the existing peri-implant mucous membrane coverage. Under local anesthesia, the short healing cap is replaced with a longer titanium cap. The latter reaches slightly above the free mucosa margin. Excess soft tissue is excised with a scalpel.

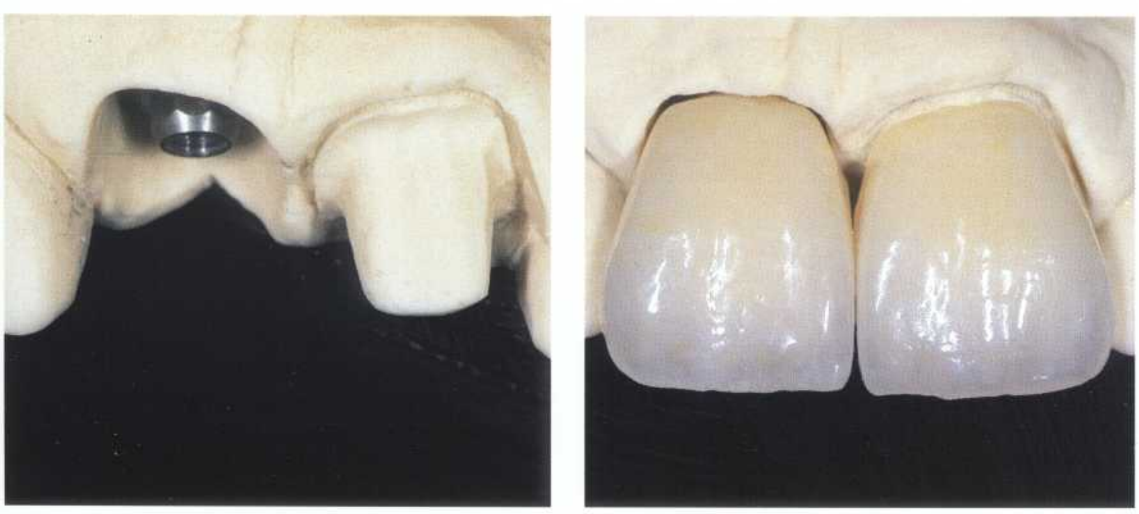
Right. The ITI Dental Implant System includes emergence profile titanium caps of various lengths for this purpose.



538 Diagnosis using the master cast

Left: In accordance with the diagnostic wax up of the planned implant restoration, the future soft tissue penetration site is marked on the cast and is then ground in from the center accordingly.

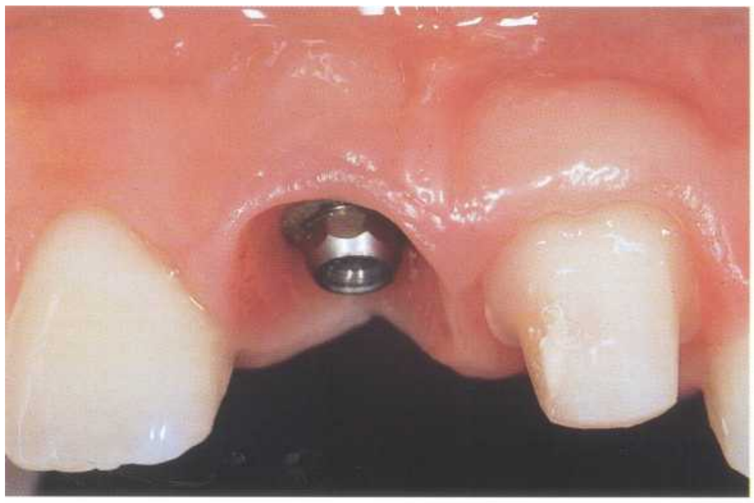
Right: The diagnostic wax-up of the future crown follows primary aesthetic criteria, where adjacent symmetry parameters are particularly taken into consideration as well as the functional aspect (anterior tooth guidance).



539 Metal-ceramic single crown restoration

After the correction is made to achieve an appropriate peri-implant soft tissue funnel, the working cast is prepared. Manufacturing of the metal-ceramic superstructure can begin.

Right: The crowns 11 (implant situation) and 21 (natural tooth) which were repositioned on the cast, show virtually perfect symmetry of the two differently supported restorations.




540 Comparison of implant and tooth abutments
The same peri-implant soft tissue configuration was generated in the mouth, as defined on the master cast.

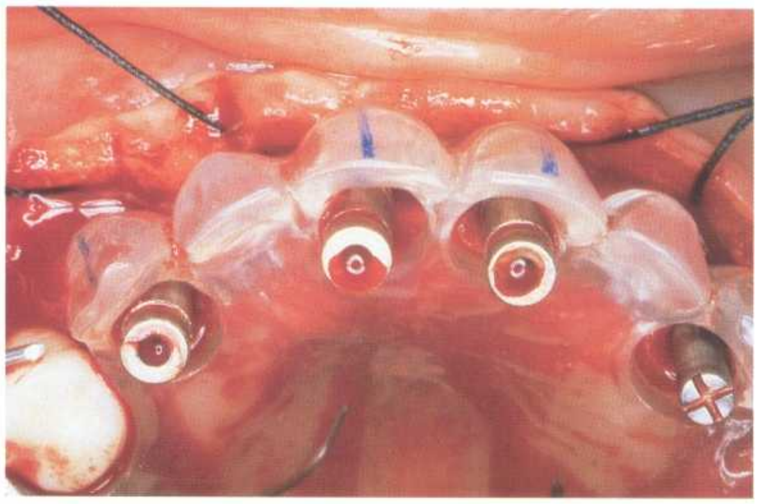
Right: In this apical view, the discrepancy between implant shoulder supported construction and tooth root supported construction is obvious. The congruence of the superstructure from the mucosa penetrating site up to the incisal edge is different, too.


541 Final clinical and radiographic results
In this clinical view it is difficult to recognize that preoperatively an incisor was missing in the 11 region and that this tooth has been replaced with an implant supported restoration.

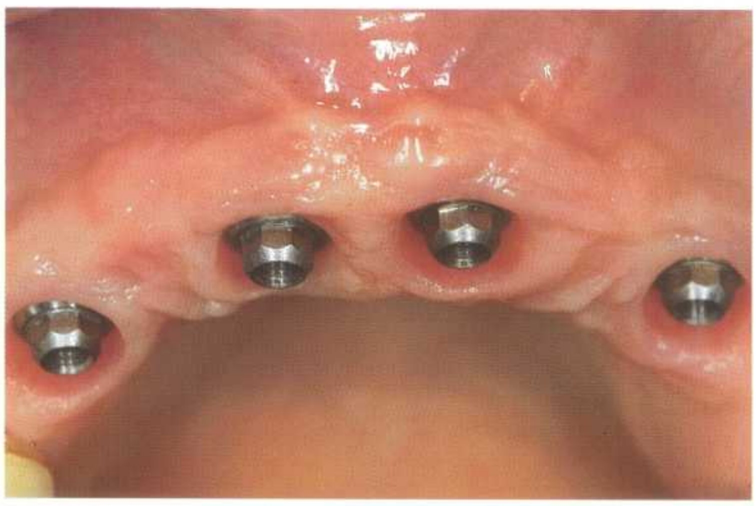
Right: The radiograph, taken one year after implant placement, shows other advantages, such as stable bone structures around the 10-mm screw implant and a precise marginal adaptation of the metal-ceramic superstructures.

542 Multiple missing maxillary anterior teeth
Anterior view of a 52-year-old patient with multiple missing teeth in the maxillary anterior and posterior regions. The tooth loss, which occurred a long time ago, has led to a flattening of the alveolar ridge and the disappearance of the aesthetically significant arcade-shaped gum line.
A removable temporary partial denture defined the elements that were needed for an aesthetic prosthetic reconstruction.

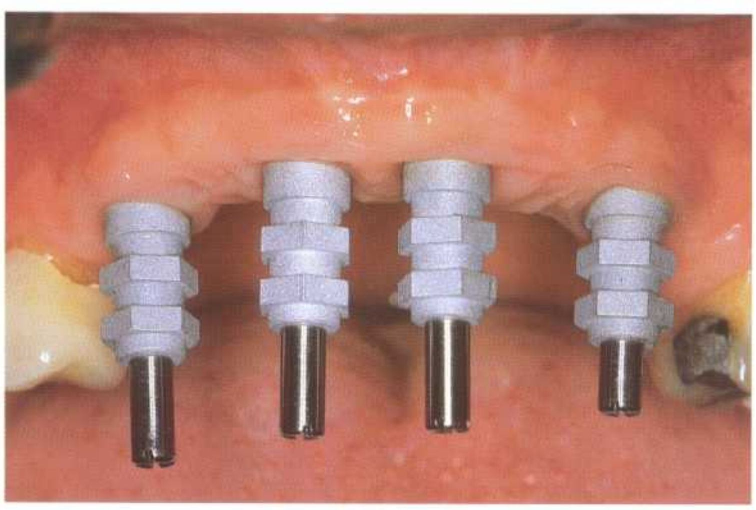
543 Surgical guide
A duplicate of the temporary partial denture was made in transparent acrylic and served as a surgical guide. This guide, anchored to the residual dentition in the posterior region, defines the mucosa penetration sites of the four implants as well as their respective longitudinal axes.



544 Checking the implant position, intraoperatively
The intraoperative view documents the benefit of the surgical guide. The four sites prepared for implant placement correspond with respect to location and axes to the diagnostically determined plan. This creates favorable conditions for preparing an aesthetically appealing fixed denture.



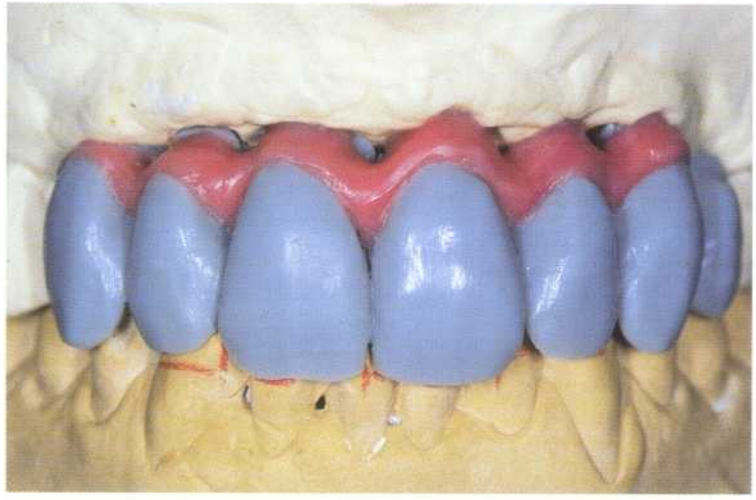
545 Placing secondary parts
As the next step, the titanium healing caps are removed and the octagonal secondary parts (Octa abutments) are installed for the partially removable superstructure. The peri-implant soft tissue adjacent to the implants is free from signs of any significant inflammation.



546 Transfer of the oral situation to the cast
In order to transfer as precisely as possible the oral situation to the cast, it is useful to use impression copings with occlusal screws. Such copings make it necessary to use individually fabricated impression trays with perforations at the implant sites.

547 Titanium copings used as a foundation for the temporary restoration
It is sensible to use a fixed temporary restoration for extended implant supported restorations in the maxillary anterior tooth region. Valuable experience and information can be gained and discussed with the patient before the final metal-ceramic superstructure is fabricated, and the temporary restoration can be modified. Prefabricated, high-precision titanium copings are used.

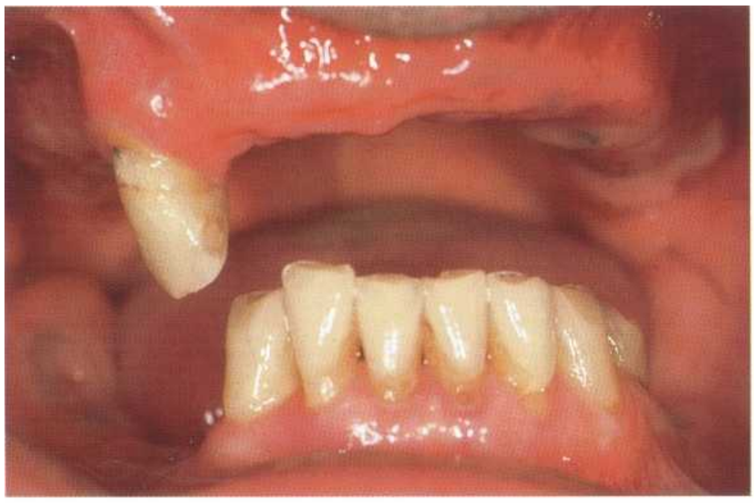
548 Diagnostic wax-up
A diagnostic wax-up should always be done in aesthetically delicate situations. As shown in this example, the increased inter-occlusial distance, which is due to advanced vertical resorption of the edentulous jaw, has resulted in clinical crowns that are too long. In order to deal with this aesthetically disadvantageous situation, a wax-up was designed that included a solidly integrated gingival mask covering the cervical region.



549 Final metal-ceramic reconstruction
After several months of using the temporary reconstruction, the experience gained was used to fabricate the final metal-ceramic reconstruction. The occlusal view of the completed work shown here on the master cast documents the easy access to the occlusal screws in the cingulum locations of 13, 11, 21, and 23, which is due to optimal implant positioning.

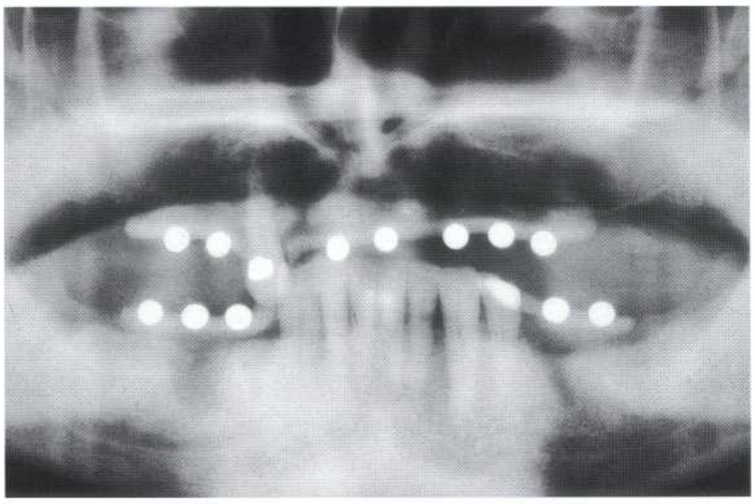
550 Anterior view of inserted superstructure
The clinical anterior view in maximum intercuspation permits the aesthetic disadvantages (clinical crowns too long) of the classical crown bridge design to be appreciated. The gingival mask is shaped in the transition region of the implant shoulder to have an emergence profile, which makes it accessible for oral hygiene.

551 Relationship between upper lip and superstructure
A long upper lip that does not expose the cervical part of the superstructure when the patient is smiling is a prerequisite for the described prosthetic procedure. If these basic conditions do not exist, either augmentation (bones and soft tissue) must be carried out or one may want to take recourse to the possibilities of hybrid prosthodontics available in the form of a conventional overdenture.



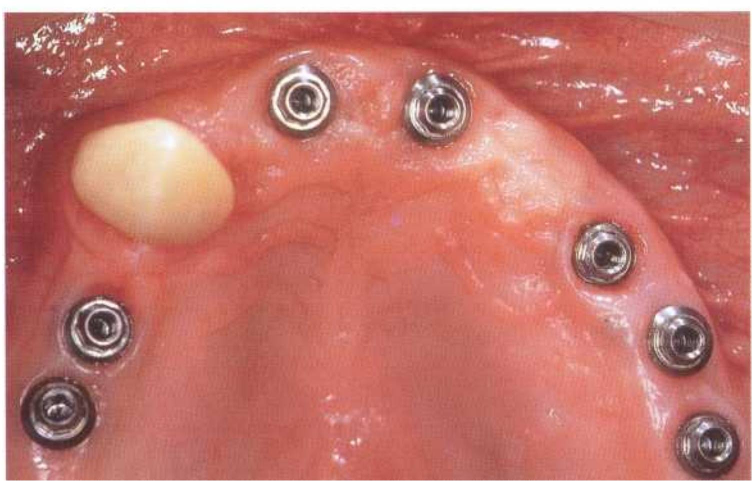
552 Clinical initial situation after multiple tooth loss in the maxilla

This 55-year-old patient could not adapt to his removable denture, which was inserted several months ago. It was especially the extensive coverage of the palate which was described as being intolerable.



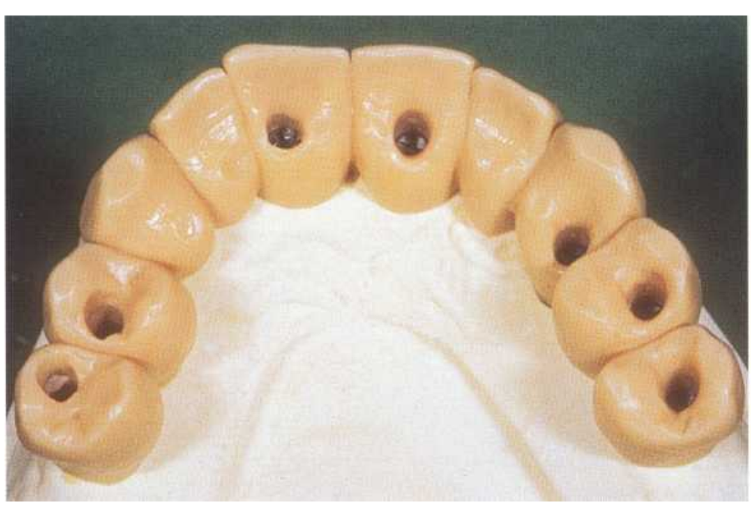
553 Radiographs

An acrylic palate plate was manufactured for the implant diagnosis. Metal spheres were attached at the sites of implantation.



554 Implant locations in the maxilla

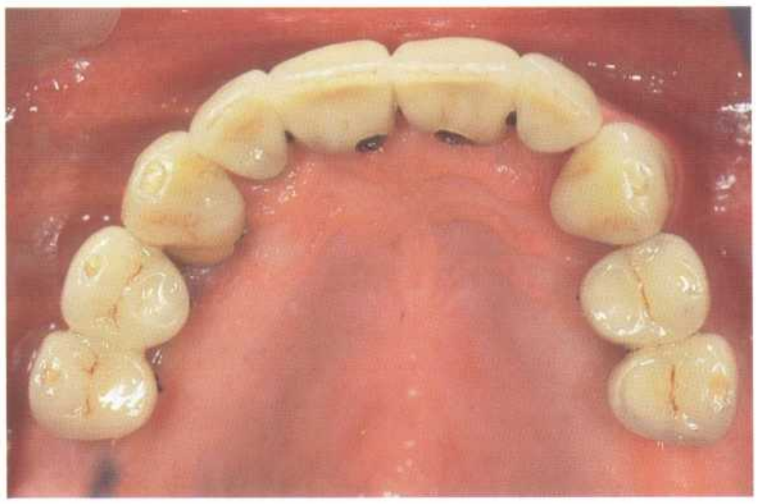
The clinical occlusal photograph was taken after the placement of the octagonal secondary parts. It confirms the successful translation of the diagnostic work-up with regard to the locations of implants. It also shows the dimensional discrepancy, particularly in orofacial direction, between implant size and diameter of the last remaining natural tooth 13.



555 Diagnostic wax-up

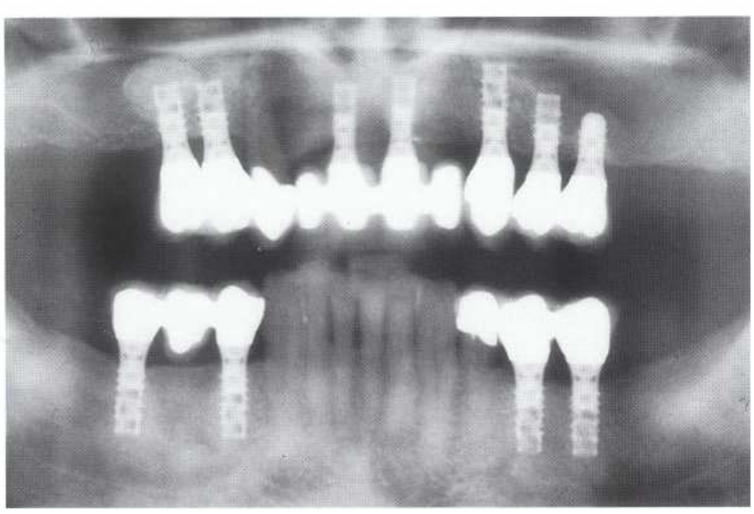
The diagnostic wax-up and its relationship to the underlying implants show that access to several occlusal screws is problematic despite careful diagnosis and presurgical planning. In order to fulfill the mechanical (framework construction, ceramic support, and occlusal contacts) and aesthetic (thickness of the ceramic layer) requirements, access to the occlusal screws should be from the center of the chewing surface or from the cingulum region.

556 Individually milled mesiostructures
A possible way to deal with the above-mentioned problem is by using specific milling cylinders selected in accordance with the requirements defined by the diagnostic wax-up. The superstructure support is milled individually and used as a mesiostructure for cementation or for the attachment of transversal screws.
Right: The prefabricated millable cylinders are too large, so that individual adjustments can be made in the parallelometer.

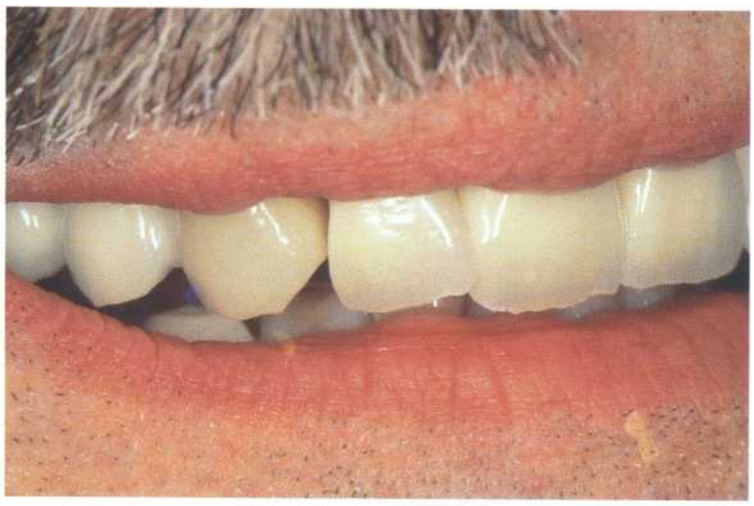


557 Conventional occlusal superstructure design
The finished, segmented 10-unit metal-ceramic superstructure underscores the substantial advantage of this telescope-like procedure: The occlusal as well as lingual surfaces of the implant reconstruction are not compromised by occlusal screws. This is advantageous for aesthetics and mechanical properties.

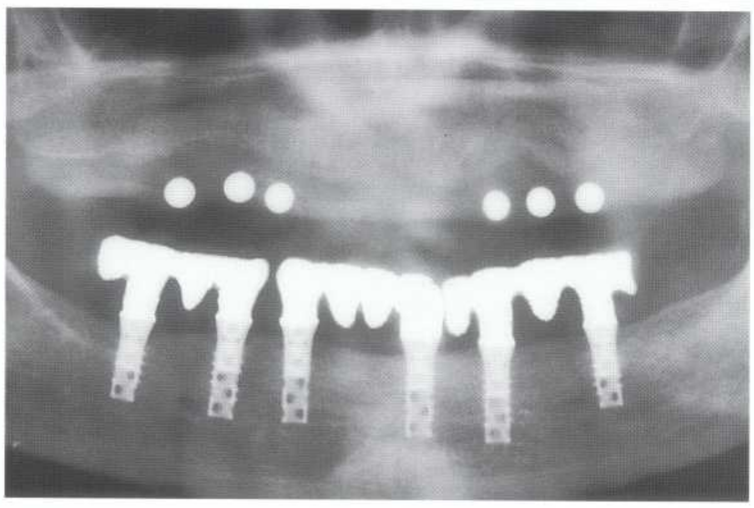
558 Clinical end result
The labial view also shows that the extended rehabilitation of this nearly toothless upperjaw as well as the lowerjaw buccal segments is acceptable. Before the specific therapeutic decision was made, the length of the upper lip and the dynamic smile line were analyzed. Because the apical third of the future reconstruction would not be exposed during a broad smile, the final prosthetic solution described above was chosen.



559 Final radiographs
The radiograph taken during the one-year check-up shows that as consequence of the consistent use of the surgical guide, there is an almost perfect parallel orientation of the eleven implants.The vertical peri-implant bone level is stable.

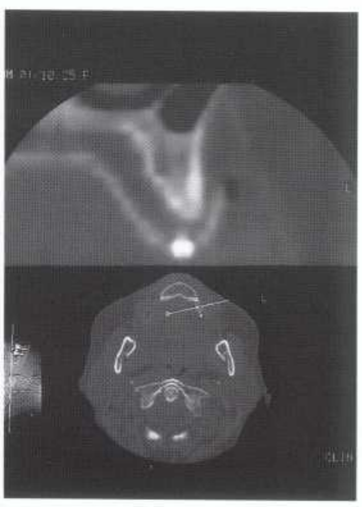


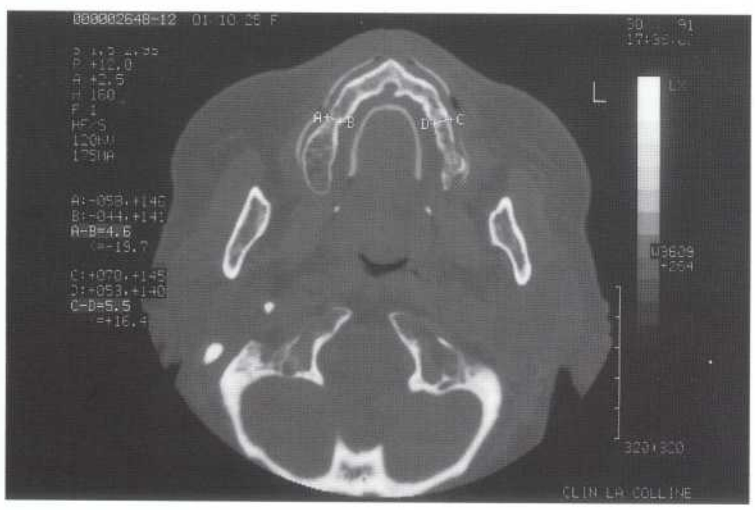
560 Natural integration of the implant prosthesis
The photograph taken of the smiling patient confirms that the aesthetically delicate transition between the suprastructure of the implant and the fixed prosthetic rehabilitation is not visible and fulfills the essential criteria of dental aesthetics and harmony.



561 Edentulous upper jaw-Radiographic diagnosis prior to implantation
A systematic radiographic diagnosis of the edentulous upperjaw serves to judge the vertical and transversal bone dimensions in the posterior jaw sections before implantation. For this, the radiograph was marked with metal spheres.

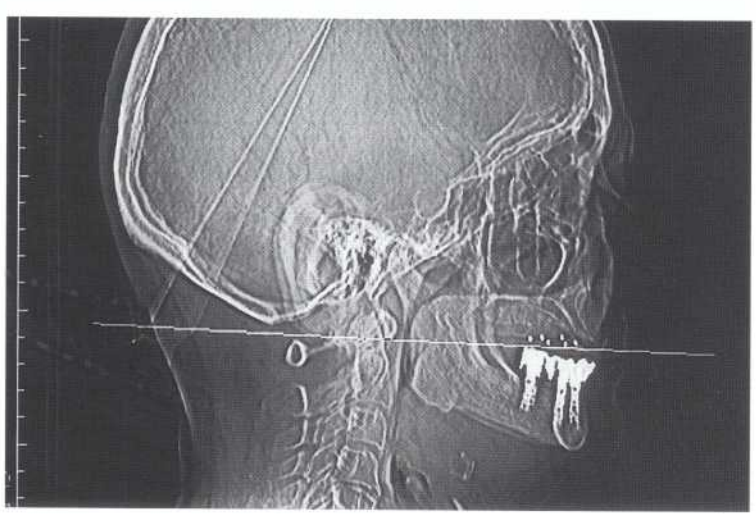
Left: A duplicate of the conventional complete denture is made in acrylic. Calibrated metal spheres are attached.





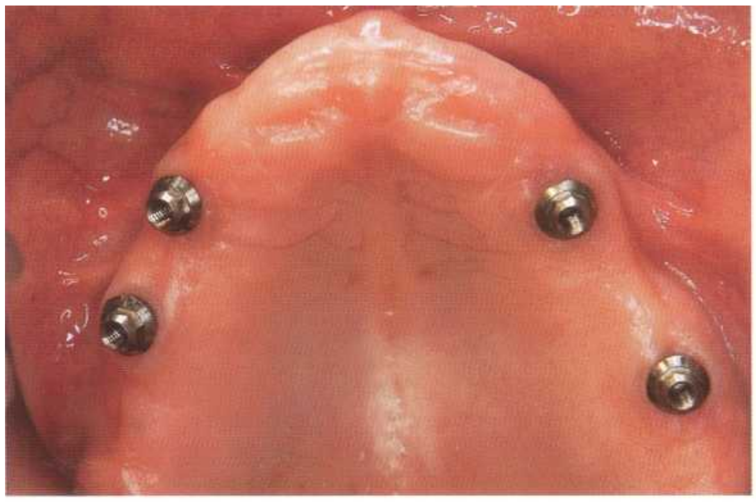
562 Computed tomography
In exceptional cases, when insufficient bone is available, potential implant locations can be identified using a targeted computed tomography. This procedure allows one to produce layers for precise three-dimensional analysis of the existing bone.

Left: The vertical and transversal bone support and most advantageous axis orientation can be determined for every potential implant location marked with a metal sphere.

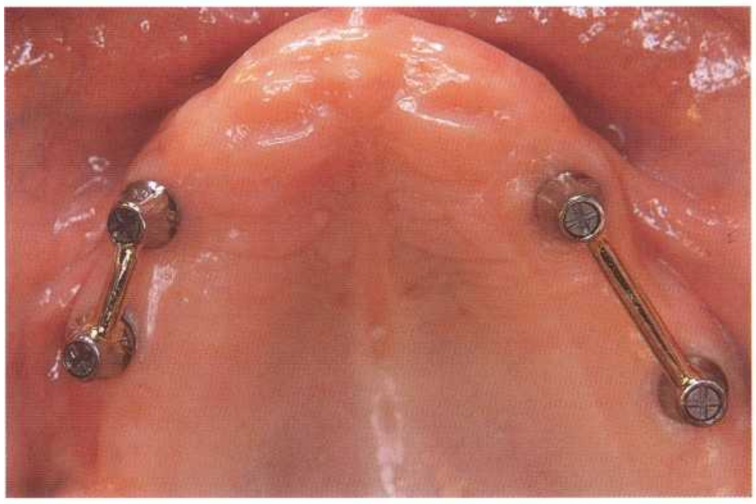


563 Determining the layer plane
On the basis of a lateral overview radiograph, the most sensible diagnostic layer planes are defined for the individual implantation.

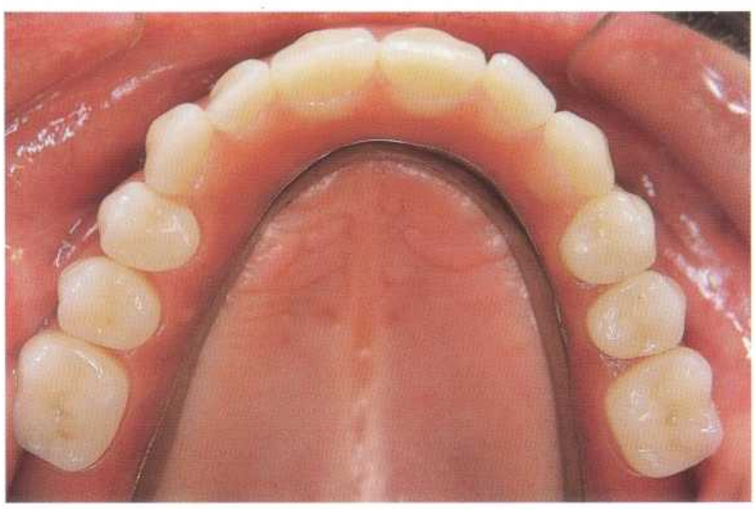
564 Implant locations in the edentulous maxilla
In this 65-year-old patient it was not possible to place implants in the anterior regions because of aesthetic and phonetic reasons, despite sufficient vertical and transversal bone being available. In the anterior region potential implants would have had to be placed too far lingually. This would have led, in addition to causing technical problems, to an unacceptable restriction of the tongue in the anterior palate.



565 Implant supported bar attachments
The four laterally incorporated implants were connected using bilateral bars.



566 Palate-free overdenture
This configuration allows the fabrication of a metal-reinforced overdenture that does not cover the palate. This procedure compensates aesthetically and functionally forthe resorbed anterior part of the alveolar ridge and soft tissues. Despite the removable character of this hybrid prosthetic solution, it is well accepted by most patients because of its high stability and remarkable subjective comfort.

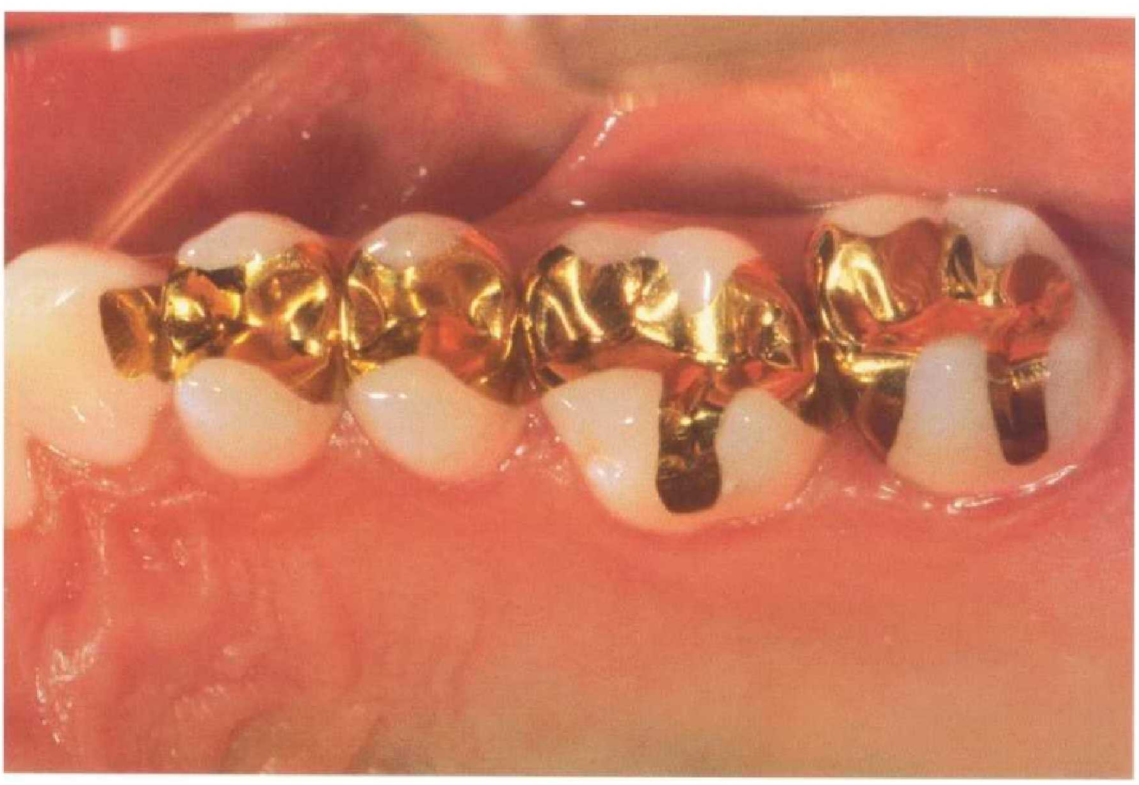


567 Aesthetic integration
The clinical frontal view was taken after incorporation in the edentulous upperjaw of the palate-free overdenture which is implant supported in the posterior regions. It underscores the main advantages of this solution, namely optimal aesthetics and soft tissue support in the anterior region.

Cast Gold Restorations

Should cast gold restorations today be considered as an alternative, given the numerous new tooth-colored materials that are available to the dentist? Has the technology used with cast gold restorations kept up with the general advance in dental technology and dentistry? Is not the use of gold in dentistry an antiquated method that no longer offers the average patient any advantages? This chapter will offer answers to these and additional questions. The **purpose, indications, as well as technique of making cast gold restorations will be discussed.**

Considering the existing alternatives, treatment with gold restorations, except for the treatment of the distal part of the cuspids, should be restricted to posterior teeth. The reason is simply that gold restorations are only aesthetically satisfactory if they are not visible when the patient speaks or laughs.



568 **Aesthetic gold restorations**
Gold inlays are still the most durable of all restorations and therefore dentists usually choose gold to restore their own teeth. However, many patients refuse to have gold for aesthetic reasons.

Gold Inlays

Initially, it seems obvious that materials must be white in order to fulfill aesthetic requirements. However, there are other aesthetic points of view. One of the most important aspects about gold is the fact that it neither discolors nor even darkens the tooth over time. Also, a correctly placed gold restoration is so durable that the necessity for further treatments is minimized and the destruction of dentin and enamel is hindered. Therefore, its longevity of 10, 20, or 40 years indirectly contributes to the aesthetic quality of gold.

Occlusal Inlays

In our "composite world", is there an indication for the occlusal gold inlay? The answer is "yes" when it comes to occlusal durability and stability, where gold remains the superior material. Of course, the use of gold is restricted by its aesthetics. However, on a second molar the use of a gold filling does not affect the self-esteem of most patients. Finally, the preparation of an occlusal inlay is very simple.

569 **Aesthetic gold restorations**
This patient's two very conservative gold restorations have been in service for more than 12 years. No aesthetic problems are obvious.

570 **Gold-the most durable material**
These gold restorations have served this patient for more than 40 years. It is certain that none of the modern restorative materials (ceramics and composites) will be so outstandingly durable.

571 **Dentists choose gold restorations to treat defects in their own teeth**
Results of a survey by the American Academy of Aesthetic Dentistry.

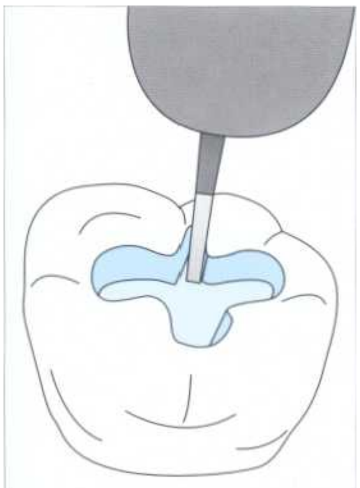
Name the materials you most frequently use to restore a moderately sized three-surface defect in an upper molar:		Name the materials that you use second most frequently:		Which materials would you use in your own mouth?	
Amalgam	27 %	Amalgam	25 %	Amalgam	13 %
Gold	18 %	Gold	18 %	Gold	33 %
Direct composite	36 %	Direct composite	28 %	Direct composite	18 %
Indirect composite	3 %	Indirect composite	5 %	Indirect composite	5 %
Porcelain	9 %	Porcelain	16 %	Porcelain	10 %
Ceramics, cast (Dicor)	0 %	Ceramics, cast (Dicor)	0 %	Ceramics, cast (Dicor)	0 %
Ceramics, milled (Celay)	0 %	Ceramics, milled (Celay)	0 %	Ceramics, milled (Celay)	2 %
Ceramics, pressed (Empress)	7 %	Ceramics, pressed (Empress)	7 %	Ceramics, pressed (Empress)	14 %
CAD/CAM (Cerec)	0 %	CAD/CAM (Cerec)	0 %	CAD/CAM (Cerec)	0 %
Others	0 %	Others	0 %	Others	0 %
		No answers	1 %	No answers	5 %

One- and Two-Surface Inlays

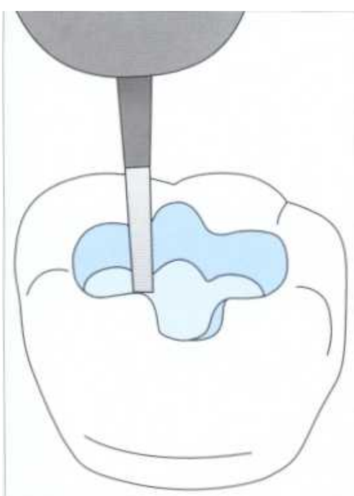
An incipient fissure caries lesion is treated by extended fissure sealing. Nowadays one uses composites for this purpose. If an occlusal lesion has become large, the indication is for inlay treatment. An inlay is always indicated if a lasting restoration is needed. With teenagers, whose teeth still need to do their job for a long time, emphasis must be placed on materials that have the best longevity. From today's perspective, this material is still gold.

Defects involving multiple surfaces on the first and second molars of teenagers should preferably be restored using gold. After an old restoration with caries has been removed, a *subfilling* is placed. The following materials are available for the subfilling treatment:

- composite with adhesive technology (formation of a hybrid layer)
- compomer and suitable adhesive
- resin-reinforced glass ionomer cement (e.g., Vitremer, Fuji II LCS)

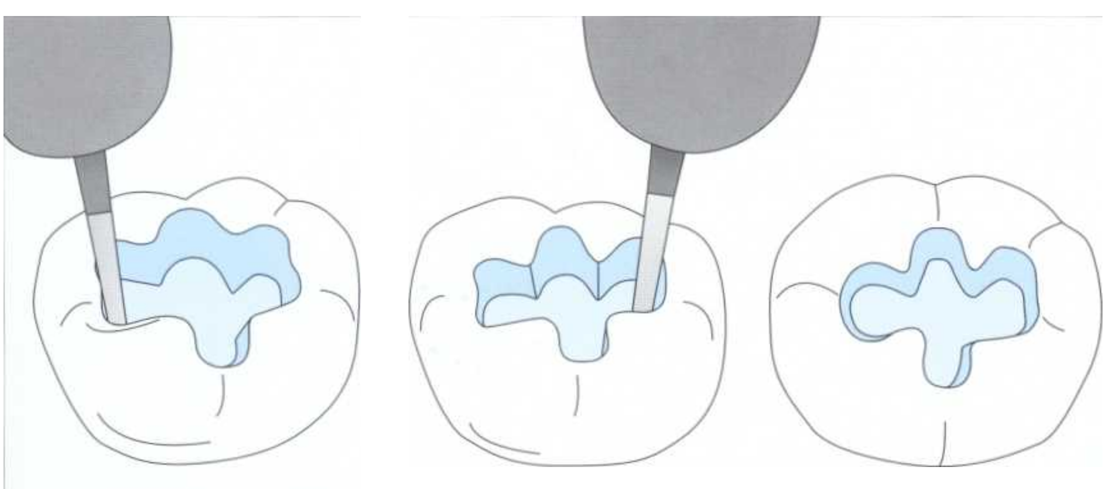


572 The occlusal inlay
Occlusal restorations in the patient's mouth.
It is clear that composite will be chosen as restorative material for an incipient fissure caries lesion. However, if a bigger defect exists and if the occlusion in this area should remain stable, the restoration of choice is still the occlusal gold inlay. In many cases, such a choice will mean no aesthetic restriction for the patient.
Left: The preparation of an occlusal inlay begins with widening of the fissures.



573 "Invisible" cast gold restorations
A two-surface and a one-surface inlay have been in the mouth of this patient for more than 14 years.

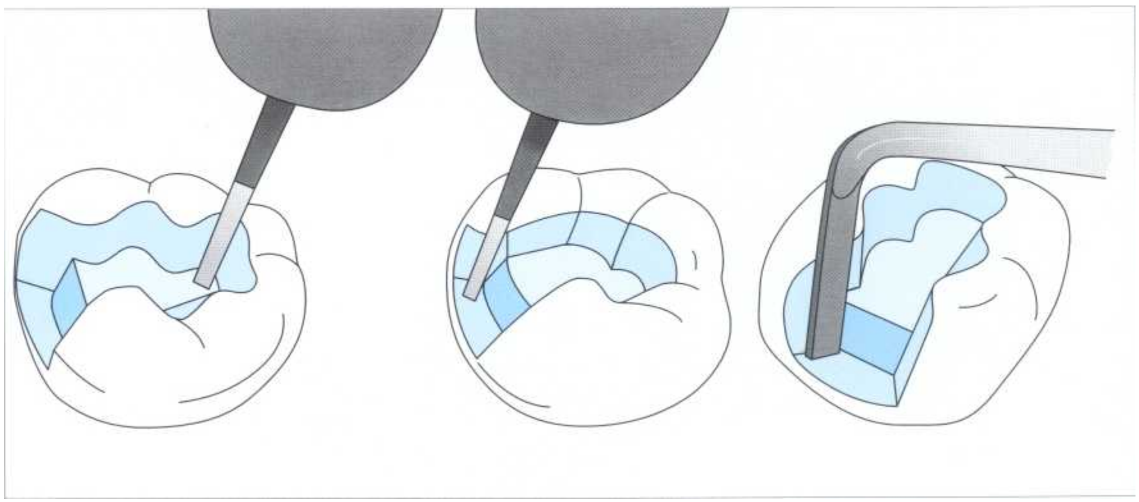
Left: During the preparation of one-surface inlays, it is important to make sure that the walls diverge by 3-4°.



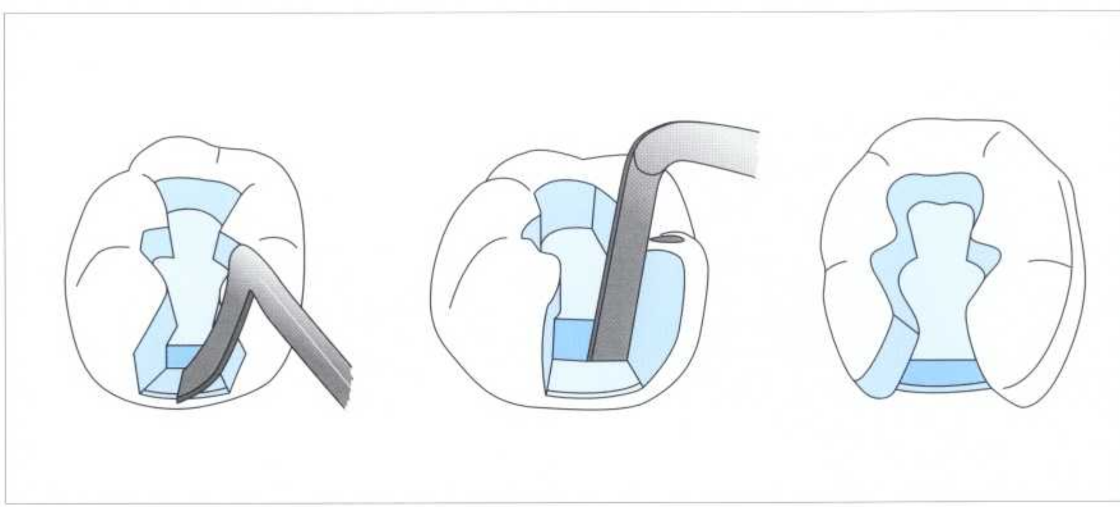
574 Preparation of one-surface inlays
The fissures should be opened as wide as possible. The walls are slightly diverging (3-4°) and the bottom of the cavity should be as smooth as possible.

This construction enables a tooth conserving preparation, whereby the entire healthy tooth tissue is retained, and it forms the prerequisite for an aesthetic gold restoration.

The preparation of such an inlay is performed with a No. 57 carbide bur. Both the occlusal surface and the box of the inlay are prepared with the same hard metal bur. The preparation is refined with chisel Nos. 42 and 43 (Suter). The goal of the hand-held instrument preparation is to smooth the walls and the enamel rods and to create the perfectly defined preparation form. It enables the technician to remove the wax pattern from the die without distorting it. A clearly defined, smooth preparation is a prerequisite for a high precision casting. The use of hand-held instruments, shown in the illustrations on p. 264-267, does not require much time. It is important, however, that the hand-held instruments are sharpened before each application.



575 **Preparation of a two-surface inlay**
Preparation is begun on the occlusal surface (left) which is then widened in the proximal region (middle). The proximal walls are smoothed with an enamel chisel (right).



576 **Use of hand-held instruments during inlay preparation**
Left: A cervical feather edge can be created by moving the gingival margin trimmer diagonally.

Middle: The axial wall of the box is smoothed with the same instrument.

Right: Completed preparation.

577 **Two-surface gold inlay in the patient's mouth**
In general, conservatively prepared two- or three-surface inlays do not cause any aesthetic problems.

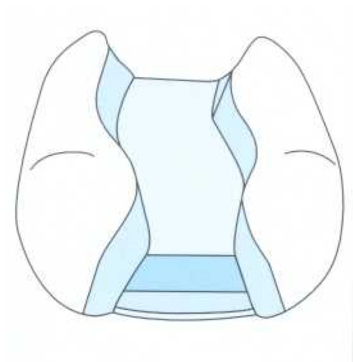
Three-Surface Inlays (MOD)

An incipient caries lesion in the posterior region that stretches over several surfaces and allows a very small conservative preparation can be optimally treated with a direct composite restoration. However, if a large amalgam restoration needs to be replaced or a defect has reached a considerable size, gold can be the treatment of choice.

The practicing dentist should be in the position to make gold restorations that satisfy the aesthetic demands of today.

Many colleagues have gold inlays, because they want to restore their own teeth once and for all, without any ensuing problems. Therefore, when one is tretating a teenager's molars and the defect has reached a certain size, the parents must be informed that the most long-lasting of all treatments for this tooth is the cast gold restoration.

The preparation of an MOD inlay is not significantly differ ent from the preparation of a two-surface inlay.



578 **Preparation of complex surface inlays**
The old restoration with associated caries is first removed.

Left: Schematic representation of an MOD inlay preparation.

579 **Reconstruction filling and subfillings**
After the old restoration and the caries have been removed, a reconstruction filling, allowing optimal inlay preparation, is inserted.

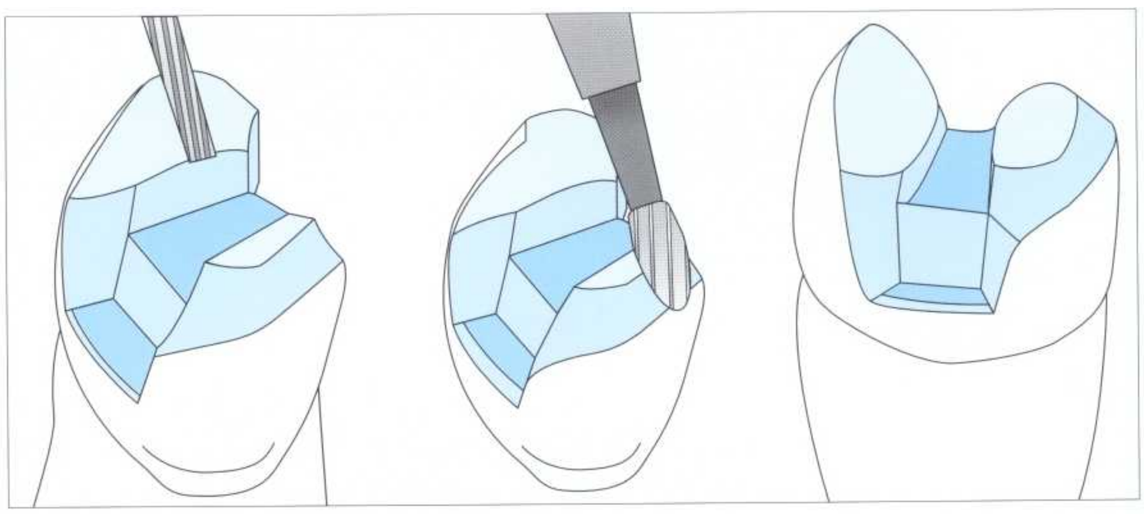
580 **Aesthetically acceptable inlay treatment**
The completed inlays in this mouth do not mean any reduction in the patient's well-being. He desired an aesthetically acceptable and long-lasting restoration.

Gold Onlays

For a long time, the general opinion within the profession was that the occlusion should be reconstructed with onlays cast out of gold. As experience has shown, well-crafted occlusal gold onlay reconstructions have lasted for many decades. Today, these reconstructions can also be made as ceramic partial crowns. However, it will be a few decades before we know whether these restorations are as durable as the gold onlays. Therefore, it must be part of the basic repertoire of every dentist to be able to create such restorations with the best possible aesthetics.

The basic preparation for an onlay is the MOD inlay. If the buccolingual dimension of such an MOD inlay is too big, the cusps must be reduced and onlay preparation carried out.

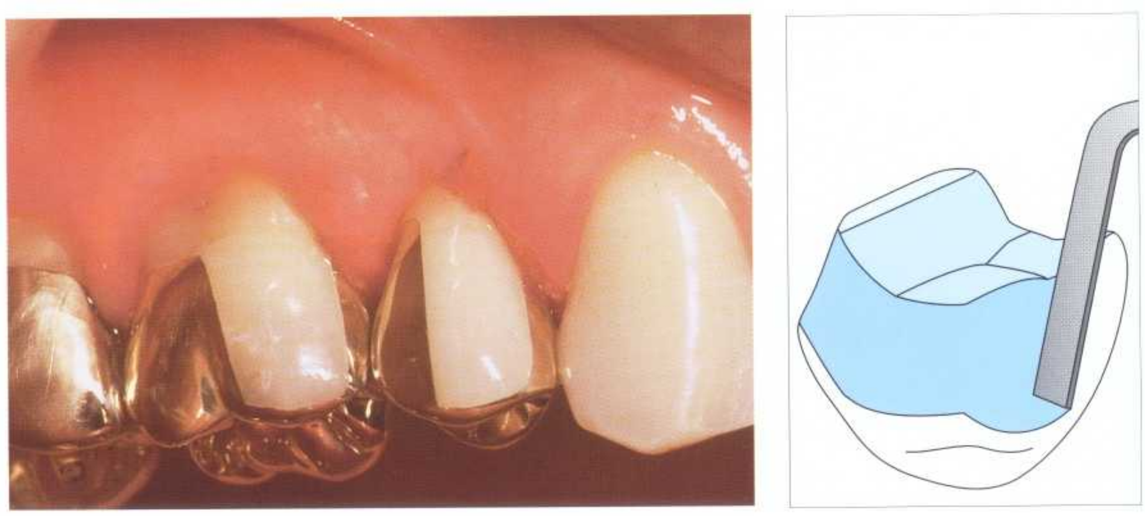
Since even thin layers of gold can also uphold the chewing function for decades, the cusps do not need to be significantly shortened, as is the case with tooth-colored restorations. A bullet-shaped carbide finishing bur is most suitable for cutting the cusps.



581 Preparation of a partial crown
Left: The preparation of a partial crown begins in the same way as the preparation of a MOD inlay. After the MOD inlay preparation is completed, the cusp that is not exposed to pressure is beveled, while the pressure-bearing cusp is shortened.

Middle: The bevel is prepared with a bullet-shaped carbide bur.

Right: Completed partial crown preparation.



582 Preparation of a three-quarter crown
Three-quarter crowns in the patient's mouth.

Right: The distal wall is prepared using a hand instrument.

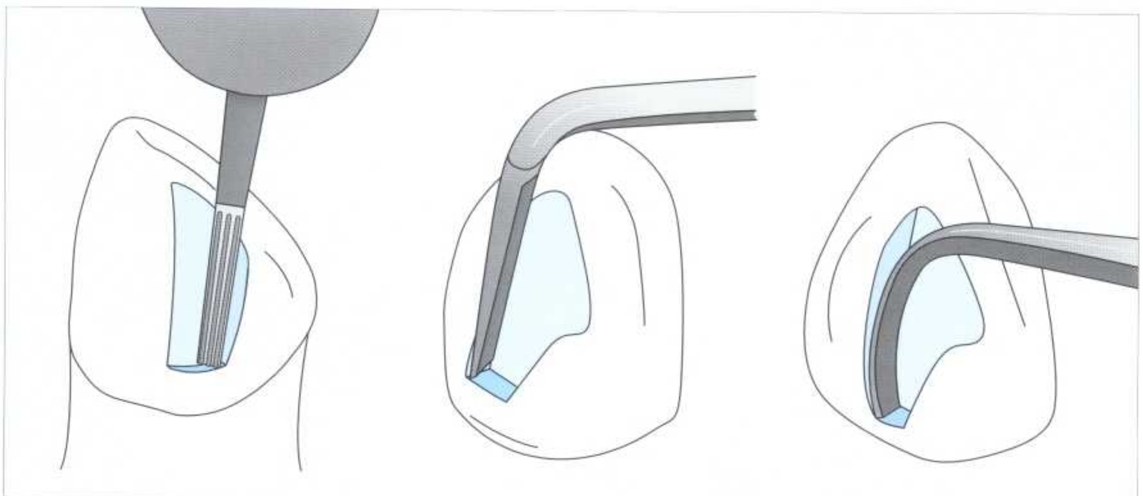
583 Partial crowns in the patient's mouth
Such partial crowns present no aesthetic restrictions for many patients.

Treating a Distal Defect on an Upper Canine

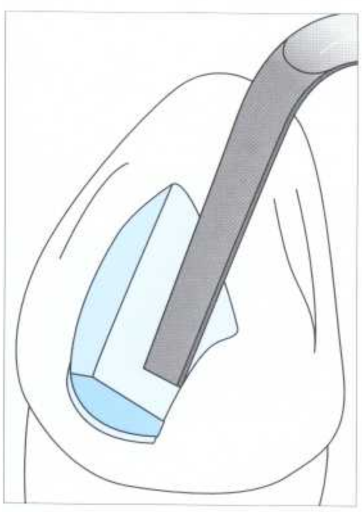
The normal treatment for a distal lesion on an upper canine is a direct composite restoration, but a cast gold restoration that fulfills all aesthetic requirements can also be produced. Usually, such defects are relatively small and the inlay preparation is challenging. Sufficient retention must be created, but without preparing a dovetail. Here the choice is to prepare a slot in the cavity. The advantages of such an approach include the fact that only little tooth substance is removed and the preparation is very retentive.

Cementing Technique

Over the past few years, gold restorations have been cemented with zinc phosphate cements. Using zinc phosphate cement has meant using an active cementing technique, during which the margins are treated with special disks. This was done to achieve as perfect a transition from the restoration to the tooth as possible. Today, adhesives are available as well as this classic cementation method. In addition to zinc phosphate cements, resin cements or resin-reinforced glass ionomer cements are now being used (see chapter entitled "Bonding").



584 Treating a distal defect in an upper canine
The goal is to conserve the periodontal health and function of the teeth. To achieve this goal, an inlay is prepared that is not visible from a facial view.
Left: A distally cut box is prepared using a carbide bur.
Middle: Using an enamel hatchet the box is prepared with an inner divergence in order to provide sufficient retention.
Right: The cervical margin can be created with a gingival margin trimmer.



585 The "invisible" inlay in an upper cuspid
Completed inlay in the mouth.

Left: Preparation with a hand instrument of the distal box in the upper cuspid.

586 Buccal view of the restoration
The restoration of tooth 23 is not visible from anterior.

Checklist—Cast Gold Restorations

1. Place the rubber dam

2. Remove old restorations

3. Composite construction filling

- After the total etch technique has been applied, the entire cavity is covered with a composite layer. The initial composite reconstruction treatment permits ideal cavity preparation. Also, conservative preparation can be carried out with this treatment.

4. Preparation with rotating instruments

- The occlusal box and with it the pulp wall are prepared with a straight fissure bur (H21.010 on molars and H21.008 on premolars) to an optimal depth with smoothing movements. During the preparation, the bur is slightly tilted buccally and lingually so that the vertical walls of the box have an diverging angle of approx. 10°. The buccolingual dimensions of the cavity should be held as narrow as possible in order not to weaken the tooth structure unnecessarily and to avoid the need for cusp protection (onlay). The proximal boxes are created using the same bur (H21.010 or H21.008). The gingival wall cut during this step must be placed at least a few millimeters under the contact point. Also, here the piece is slightly tilted when the gingival wall is smoothed and simultaneously the proximal box walls are cut with an apical convergence (approx. 10°). As long as the gingival wall is kept narrow, the outer form of the cavity should not be extended unnecessary whilst preparing the box.

5. Preparation with hand instruments

- The use of hand instruments must be restricted to smoothing of the walls (that were already smoothed during preparation with the rotating instruments) and targeting transitions and corners. The following selection of hand instruments should be sufficient for most cavity preparations:

No. 36/37	Ferrier Excavator
No. 38/39	Ferrier Excavator
No. 3/4	Ferrier Wedelstaedt
No. 5/6	Ferrier Wedelsteadt
No. 15/16	Ferrier chisels
No. TB42s	angled chisel
No. TB43s	angled chisel
No. TB44s	angled chisel
No. TB45s	angled chisel
No. TB232	gingival margin trimmer
No. TB233	gingival margin trimmer
No. 5	probe

A prerequisite for the application of all hand cutting instruments is that they are resharpened after each application.

6. Preparation of the buccoaxial and lingoaxial line angles in the distal box with the TB42s enamel chisel

- The buccoaxial angle in the distal box is defined with the TB42s enamel chisel. The buccal wall is smoothed and the buccoaxial angle is sharpened simultaneously.

7. Smooth the axial wall and sharpen the angles in the distal box with the TB42s chisel

- As soon as the angles in the distal box have been sharpened, the axial wall is smoothed with three to four strokes of the chisel.

8. Place the buccoaxial and linguoaxial angles in the mesial box with the TB43s chisel

- Similary, the mesial box is prepared using the angled TB43s chisel. Make sure that the number of chisel strokes are restricted to one to two per tooth surface to assure that no new irregularities arise on the edge.

9. Smooth the axial wall and sharpen the angles in the mesial box with the TB43s chisel

- To smooth the axial wall and to sharpen the angles, produced as described in step 7.

10. Place the gingival feather edge margin with the modified TB232 gingival margin trimmer (if desired)

- If the aim is to place a feather edge margin gingivally of the distal box, place a bevel with the TB232 gingival margin trimmer. With a few cuts first the buccal wall, then with the other end of the knife the feather edge is cut from buccally to lingually. In this way a uniform, equally wide feather edge of approx. 45° can be created.

11. Placing the mesial feather edge margin with the modified TB233 gingival margin trimmer (if desired)

- The mesial feather edge margin is placed with the TB233 gingival margin trimmer. It is difficult to prepare a 45° bevel in the mesial part.

12. Occlusal feather edge margin is cut with the fissure bur H21.008 or H21.010 (if desired)

- The occlusal feather edge margin can be placed with the H21.008 or H21.010 bur at an angle of 15°. The occlusal feather edge margin should not be too long and should not coincide with the cusp slopes because then the box will be too poorly defined. If the cusps must be covered (onlay), all necessary margins are prepared with the H379.028 bur.

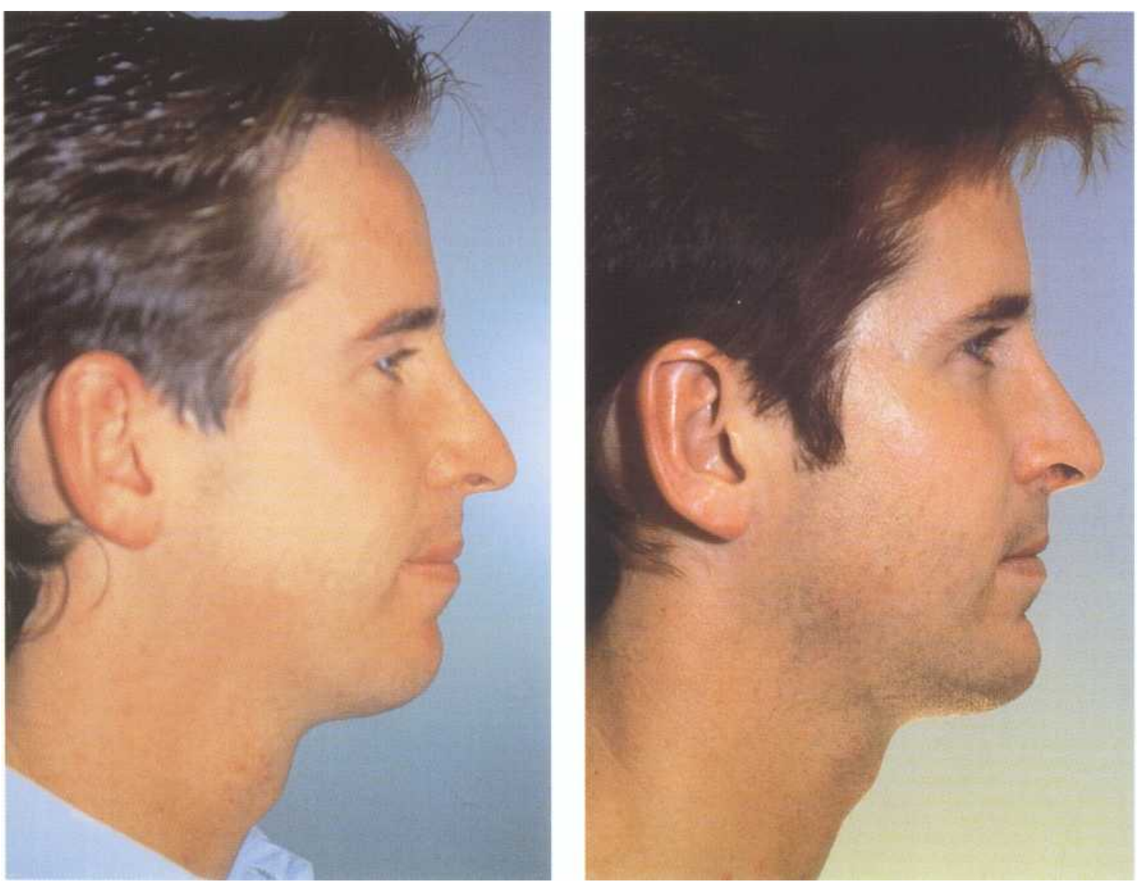
13. Creating the proximal wall with a cutting disk

- The slightly sigmoidaly curved proximal wall is easily removed with a medium grain Moore disk. The disk must be placed parallel to the existing wall, in order to avoid undercuts. It is thus possible to simultaneously smooth sharp and easily breakable enamel parts by slightly rounding and smoothing the inlay margins. The disk should be used to create a right angle between the inlay and the course of the enamel rods.

Aesthetic Facial Surgery

The goal of aesthetic facial surgery is to carefully evaluate facial characteristics and to treat bone and soft tissue structures. There is a close relationship between aesthetic dentistry and aesthetic facial surgery. In the process of planning a tooth correction, an evaluation of the entire appearance of the face should take place based on aesthetic criteria.

Aesthetic facial surgery is based on the mastery of plastic-surgical techniques and on extensive knowledge in otorhinolaryngology, plastic eye surgery, dermatology, and maxillofacial surgery. The ideal procedure for improving facial structures begins with an extensive examination, consisting of an individual analysis of the interplay of soft tissues, skeletal and dental structures, in order to define the aesthetic conditions of the physiognomy.



587 **Possibilities with aesthetic facial surgery**
Left: This 25-year-old patient is unhappy with the geometry of his face and his fleeing chin.

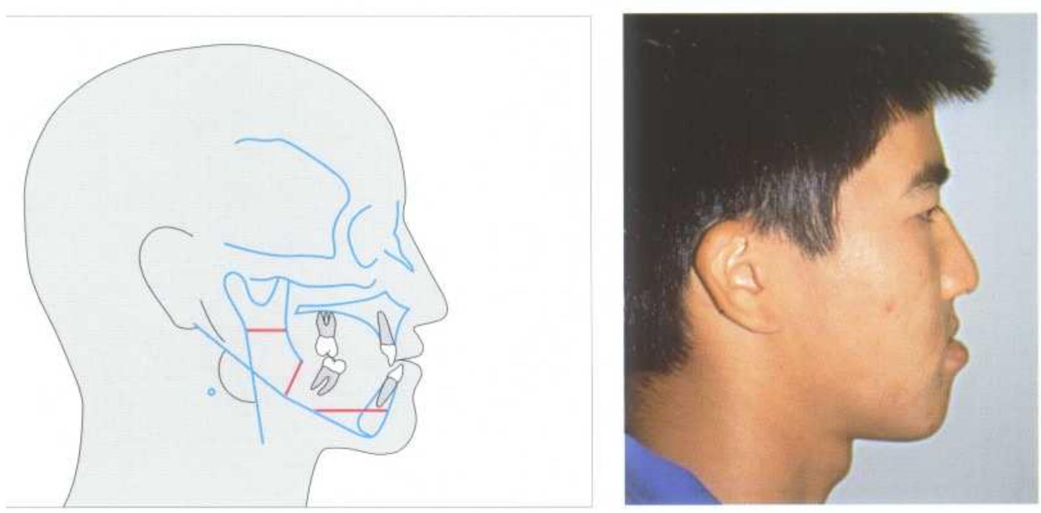
Right: The surgical treatment of the chin has significantly changed the patient's appearance (situation six months after surgery).

Abnormalities of the Chin

The shape of the chin allows for numerous deviations that are aesthetically acceptable. However, distinctive deviations in reference to height, width, or projection of the chin negatively influence the appearance of the lower third of the face. An unduly long (superior-inferior) chin with normal skin and soft tissue can restrict normal lip closure and cause the anterior mandibular teeth to become overemphasized. A hypoplastic (anterior-posterior) chin is often regarded as a "sign of weakness" and can have significant effects on the psychosocial situation of the patient.

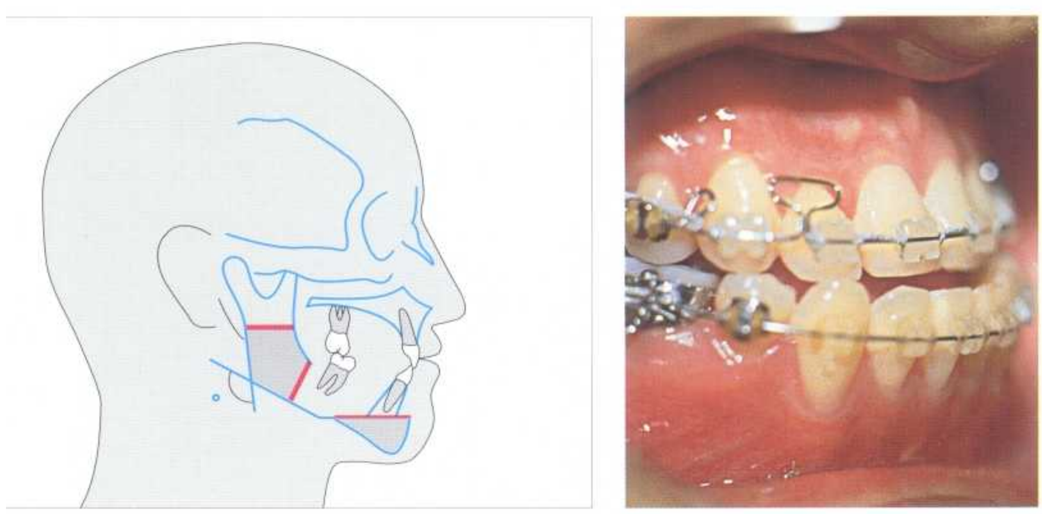
The currently available genioplastic measures allow changes to the chin in all three dimensions, namely height, width, and projection. An anterior mandibular-vestibular (intraoral) cut enables the horizontal osteotomy of the anterior mandible.

The osteotomy is executed below the apex of the mandibular teeth, below the N. alveolaris inferior, and below the mental foramen and enables the mobilization of the chin. This cut creates a pedicle flap. The blood supply leads from the muscle insertions to the posterior and inferior surfaces of the chin. The bones are fixed by means of osteosynthesis wires, titanium screws, or plates. This allows a secure positioning of the segment during healing. If indicated, a midline cut enables the chin to be narrowed or widened. An increase or decrease in the length of the chin is done through bone transplantation or bone excision.



588 Abnormalities of the chin
The illustration after cephalometric evaluation of the radiograph confirms a class III malocclusion.

Right: The profile of the 20-year-old patient shows a distinctive progeny.



589 Bilateral horizontal mandibular hyperplasia
With the help of a lateral cephalometric radiograph (illustrated here) a bilateral sagital osteotomy has been planned. The lower jaw is to be moved about 3 mm dorsally/caudally and the chin will be protruded 7 mm for aesthetic reasons.

Right: The lateral view of the occlusion of the patient confirms the diagnosed progeny in the presence of a class III malocclusion.

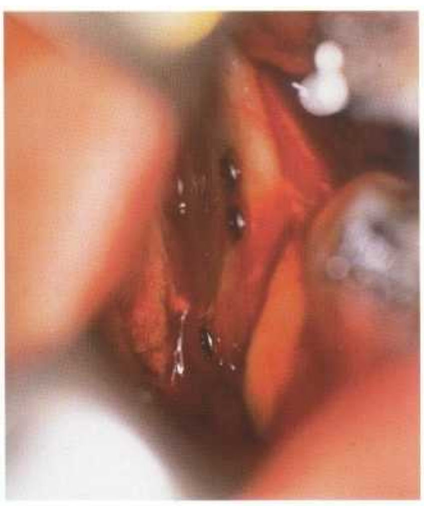
Bilateral Horizontal Mandibular Hyperplasia

A class III malocclusion can be the result of a vertical or horizontal maxillary hypoplasia, a horizontal mandibular hyperplasia, or a combination of these deviations. The clinical examination and cephalometric analysis enable the anatomical discrepancy to be exactly localized. If the class III malocclusion is due only to bilateral hyperplasia, the corresponding treatment consists in a reduction of the maxillary excess combined with mandibular osteotomie.

The most widely used technique for correcting a horizontal mandibular hyperplasia is undoubtedly the bilateral sagital split osteotomy that was first described by Trauner and Obwegeser (1957). This versatile osteotomy technique allows for the bilateral division of the mandibular ramus under careful protection of the inferior alveolar nerve vessel bundle.

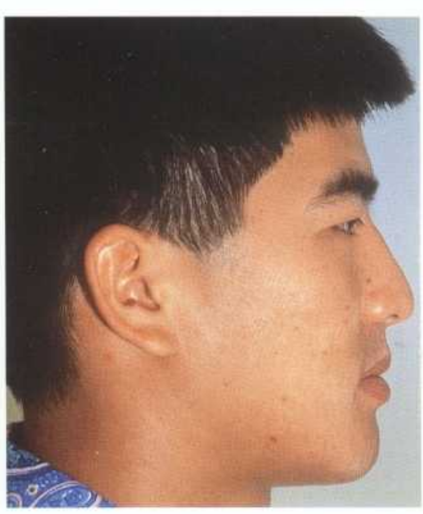
The mobilized distal segment of the mandible is positioned in optimal occlusion and stabilized by means of a temporary intermaxillary fixation.

The mandible is fixed using titanium screws and plates. The intermaxillary fixation is removed intraoperatively, so the mandible can be manually repositioned in order to obtain a perfect occlusion. A crucial component of this intervention is the careful positioning of the proximal fragments as well as the proper positioning of the condylar process of the mandible in the mandibular fossa. Elastic ribbons are placed to affix the mandible to the maxilla during the healing process. The mandible has generally healed approximately eight weeks after the intervention. The patient can resume normal eating habits as well as active oral hygiene measures.




590 **Surgical sagital osteotomy and dorsal displacement of the mandible**
Model of the planned osteotomy, the dorsal displacement of the mandible, and the protrusion of the chin.

Left: The intraoperative view shows the screw attachments of the ramus of the mandible.




591 **Postoperative clinical results**
The patient now has a normal class I occlusion.

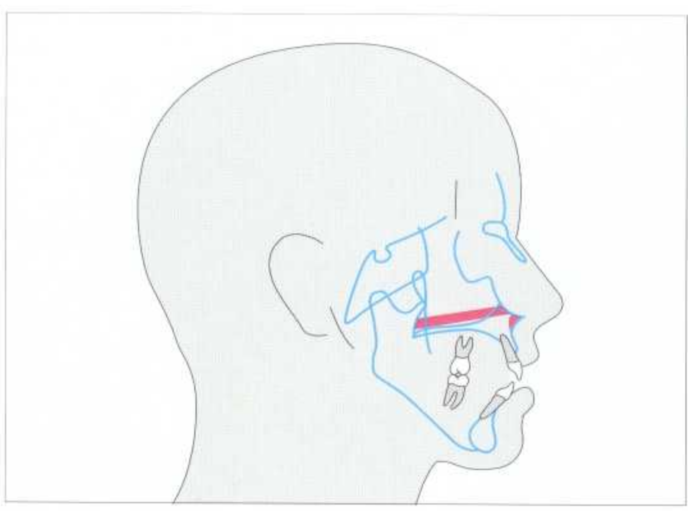
Left: Postoperative profile of the patient with retracted lower jaw and protruded chin.

Vertical Maxillary Hyperplasia

An excessive vertical length of the maxilla can result in a variety of symptoms. A vertical maxillary hyperplasia in the area of the posterior maxilla alone will lead to an anterior open bite and a reduction in occlusion in the posterior tooth region. If the entire maxilla is involved by the hyperplasia, the consequence is a maxilla with excessive visibility of the teeth as well as impeded lip closure (lip incompetence). High palate vaults, restricted nasal airways, and relative mandibular retrognathia are also frequently observed in connection with vertical maxillary excess. Deflection of the septum, narrow nasal airways, hypertrophy of the conchae, mucousal inflammation, or a combination of these factors can cause a hindrance of the nasal airways. The relative mandibular retrognathia is based on the downward rotation of a mandible of normal length, which is forced into a more retruded position by the vertical maxillary excess.

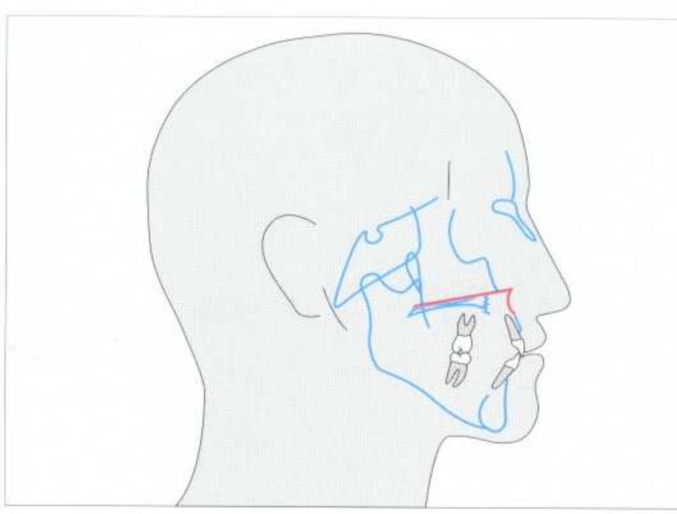
The vertical maxillary hyperplasia can be surgically corrected with LeFort I osteotomy. An intraoral cut in the vestibulum permits horizontal osteotomy of the maxilla above the root tips, below the infraorbital foramen as well as the zygomatic bone. Then, resection of the maxillary segment permits an upward repositioning of the entire maxilla in habitual intercuspation or in a position according to a prefabricated surgical-occlusal splint. A vertical reference point determines the exact vertical dimension. A small screw is placed at the midline in the area of the glabella. This initial point of intervention is determined as the vertical distance from the reference point to the central incisal edge of the maxilla. The distance is measured with a ruler.

The size of the reduction in vertical dimension is precisely determined preoperatively and the reference point serves as a marker to ensure that the outcome is perfect.



592 **Vertical maxillary hyperplasia**
The cephalometric analysis confirms a vertical maxillary hyperplasia and a relative mandibular retrognathia.

Right: The profile of the 30-year-old woman shows a retrognathic lowerjaw. She has difficulties in closing the lower jaw and the chin is retruded.



593 **Postoperative clinical result**
The treatment goal of the maxillary correction is determined on the basis of the tracing (lateral cephalometric radiograph).

Right: One year after surgical rotation and repositioning of the maxilla, the upperjaw of the patient is normally positioned.

After exposing (down fracturing) the maxilla, a septum plasty can also be done, because now the entire septum is visible. After the corresponding incision into the nasal mucosa, it is possible, if necessary, to shorten the inferior nasal conchae. Moreover, it is also possible to increase the pear-shaped opening or to widen and to lower the roof of the palate if necessary. The maxilla can be segmented in order to change its width or the relationship of the alveolar segments to one another. These different treatment options increase the versatility of the LeFort I osteotomy. After execution of the necessary measures, the maxilla is rigidly fixed internally for stabilization.

The fixation plates are thin, but nevertheless rigid. The screws are, depending on the bone, only 3 mm short or longer. A second intervention to remove the plates is normally not indicated.

Vertical Maxillary Hyperplasia, Mandibular Retrognathia, and Nasal Deformation

Patients frequently suffer from multiple anomalies that can be improved through cosmetic maxillofacial surgery. Most of these patients prefer to have all the different surgical procedures conducted simultaneously, which also shortens the postoperative healing process. This advantage must be weighed carefully against the possible disadvantages. The main focus is on rhinoplastic surgery, which normally has the most reliable results when it is executed as the finishing procedure and timing of the procedure is appropriate. Although rhinoplastic and orthognathic treatments can be executed simultaneously, it is better if they are performed one year apart. In fact, the soft tissue changes are normally assessable as a consequence of jaw and facial surgical interventions. However, because of the variability of the physiological healing process it is not possible to predict changes accurately. If rhinoplasty is performed later, the surgical procedure can be adjusted to the previously obtained result.

594 **Corrections to the upper jaw, lower jaw, and nose**
Left: The patient has a prominent nose and upperjaw and a fleeing chin.

Right: View of the patient after the nose has been straightened, the upperjaw slightly corrected, and the lower jaw moved forward.

595 **Frontal view of the same patient**
Left. The frontal view shows the patient's underdeveloped mandible.

Right. The improvement is clearly visible: a full chin and altogether harmonious facial features.

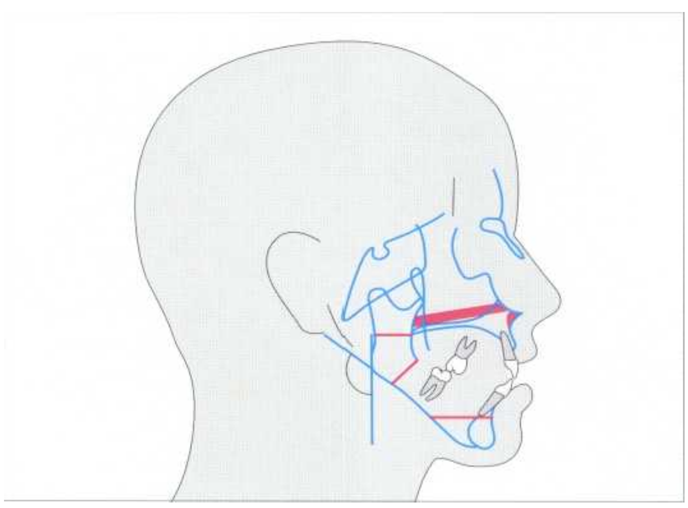
Orthognathic Surgery

Class II malocclusion is often accompanied by other functional defects. For example, a maxillary overbite is often associated with obstructed nasal airways, lip incompetence, and hyperactivity of the *mentalis muscle.* Mandibular retrognathism (symmetrical mandibular hypoplasia) can be accompanied by temporo-mandibular joint dysfunction and myofacial pain. Patients often seek help because of this problem.

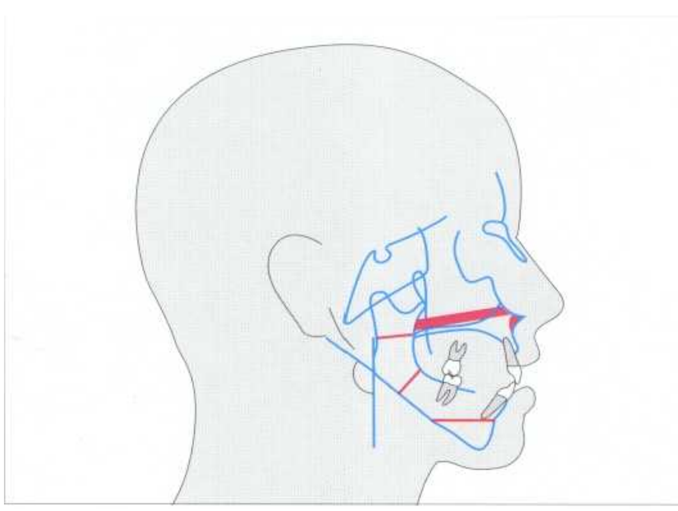
Approximately 15% of the population suffer from class II malocclusion, while only approximately 2.5% of the population exhibit class III malocclusions (Tucker 1993).

The decision as to whether orthognathic surgical treatment is necessary or not should be based on appropriate diagnoses, including a clinical examination of the face in connection with careful photographic and cephalometric analyses, evaluation of casts as well as orthodontic and maxillofacial surgical consultations. The combination of cosmetic dental measures, orthodontic therapy, and maxillofacial surgery permits a correction of the malocclusion and its associated disturbances. The middle face, mandible, chin, and dento-alveolar segments can be moved and placed in any desired position and fixed.

Most patients with skeletal malocclusion usually suffer from additional facial growth disturbances and consequently require further surgical interventions. In the following section, five surgical possibilities for improvement are discussed in more detail.



596 **Preoperative cephalometric analysis**
The illustration shows the skeletal condition of a class II bite with a maxillary hyperplasia. The mandibular retrognathia has concomitant incompetent lips and a retruded chin.



597 **Treatment planning with a cephalometric analysis**
The illustration shows a vertical reduction of the maxilla which is to be treated with broad maxillary superior reposition. A bilateral sagital split-osteotomy is planned in the upper jaw in order to position the lowerjaw anteriorly. Chin and a cheek augmentation will be carried out at the same time.

Rhinoplasty

Rhinoplasty enables bone and cartilage structures of the nose to be recontoured and can greatly enhance a patient's appearance. Rhinoplasty can be done alone or in combination with other maxillofacial surgical procedures.

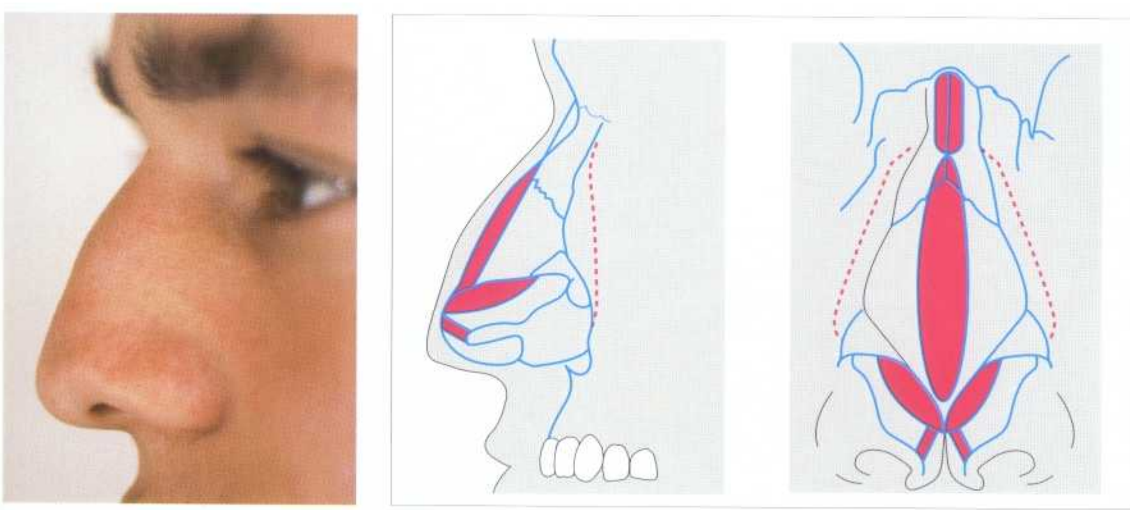
Rhinoplastic surgery is most frequently executed through internal nasal cuts. Consequently, no outwardly visible scars remain. In some cases the open technique with intranasal cuts and an additional incision across the collum can considerably improve visibility for the operator. The *closed* technique is applied much more frequently than surgery through *open* access, since the incision through the mandible leaves scars on some patients. The techniques are described below.

First, a careful examination of the nose takes place and a list of problems as well as the surgical objectives is drawn up. Detailed discussions with the patient are imperative so that the surgeon exactly understands the patient's aesthetic desires and ideas.

The parts of the nose which are accessible to change include the projection of the dorsum of the nose, the shape of the nasal wings, the tip of the nose, its contours, the width of the nose, the shape of the nostrils, and the nasiolabial area.

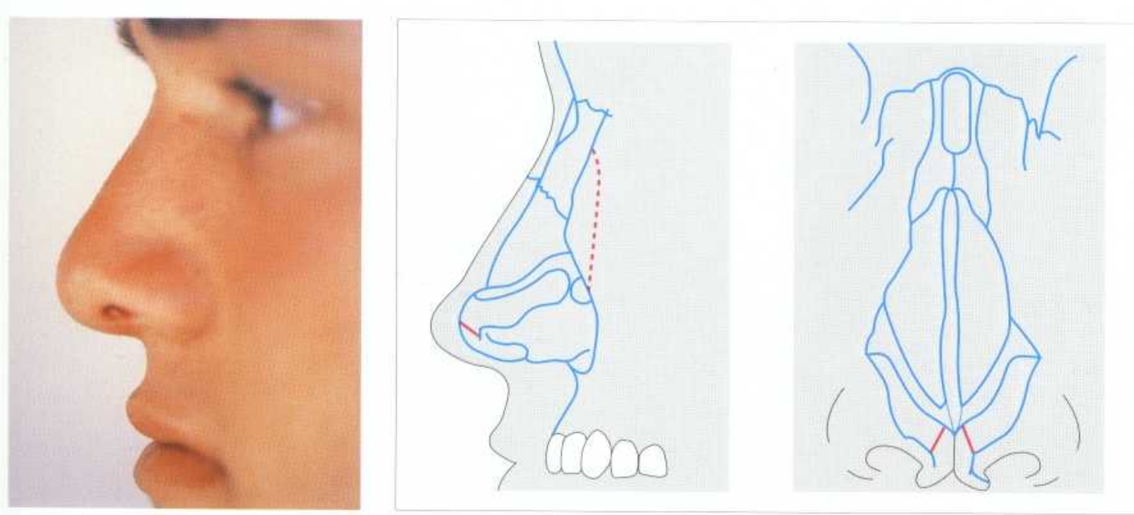
It is particularly interesting to observe that a reduction of the anterior dorsum of the nose as well as some changes to the tip of the nose can cause a slight extension of the upper lip. This influences the line of a person's smile and the amount of upper incisors visible at rest and during speaking. If a cosmetic change in the length of the upper teeth is planned in addition to rhinoplastic intervention, one should execute the dental changes a few months after the rhinoplastic surgery is completed.

Rhinoplasty can be carried out under general anesthesia or under local anesthesia with intravenous sedation. The final result can be assessed only several months after the intervention. Even years after surgery small changes in the appearance of the nose are still possible (Sheen 1987).



598 **Rhinoplasty**
Left: Preoperative profile.

Middle and right: Schematic representation of the patient's nose. The rhinoplastic procedure includes the aesthetic reconstruction of the bone and cartilage structures of the nose. The surfaces marked in red indicate the parts planned for resection. The dotted lines represent the lateral osteotomy.



599 Result
Left: Postoperative profile.

Middle and right: Schematic representation of the executed surgical corrections.

Otoplasty

Prominent ears can be corrected easily by means of cosmetic intervention. Over 35 surgical procedures have been described in the literature for the correction of prominent ears (Brenda 1995). Most procedures consist of a cut behind the ear (creation of a new anthelix) that can also be combined with a reduction of the external ear (Mustarde 1963).

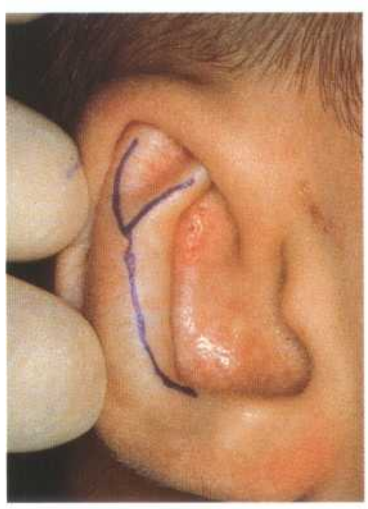
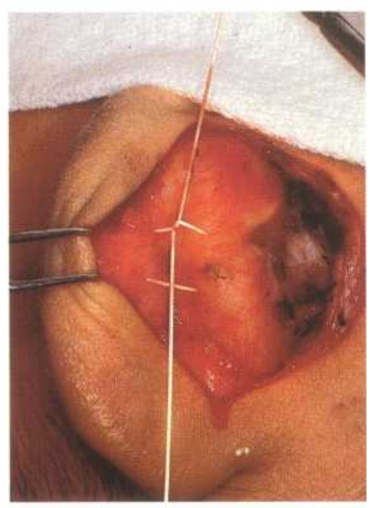
A retroauricular cut is made in order to weaken the cartilage in the anthelix. The anthelix is moved backwards effortlessly and is fixed with intercartilaginous sutures or sutures involving cartilage and mastoid.

Several techniques are available for the surgical correction of enlarged ears. These include cutting out excess in the shape of a wedge or half-moon in order to maintain the parts of the outer ear that are aesthetically important and at the same time to reduce the size of the ear (Converse 1977).


600 **Situation before otoplasty**
Protruding ears are very easy to correct surgically.

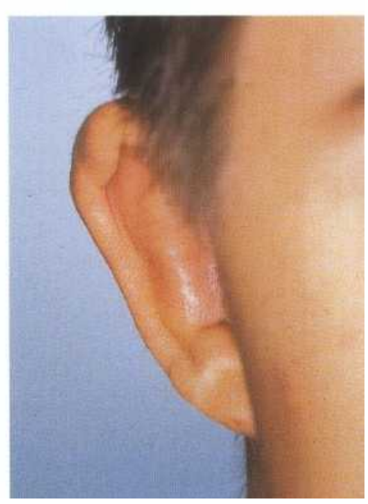
Left: Young patient with extremely protruding ears.

Right: Close-up of the right ear.

601 Surgery
Left: Pencil marks of the planned cuts.

Right: Intraoperative photograph of the cartilage structure corrections.

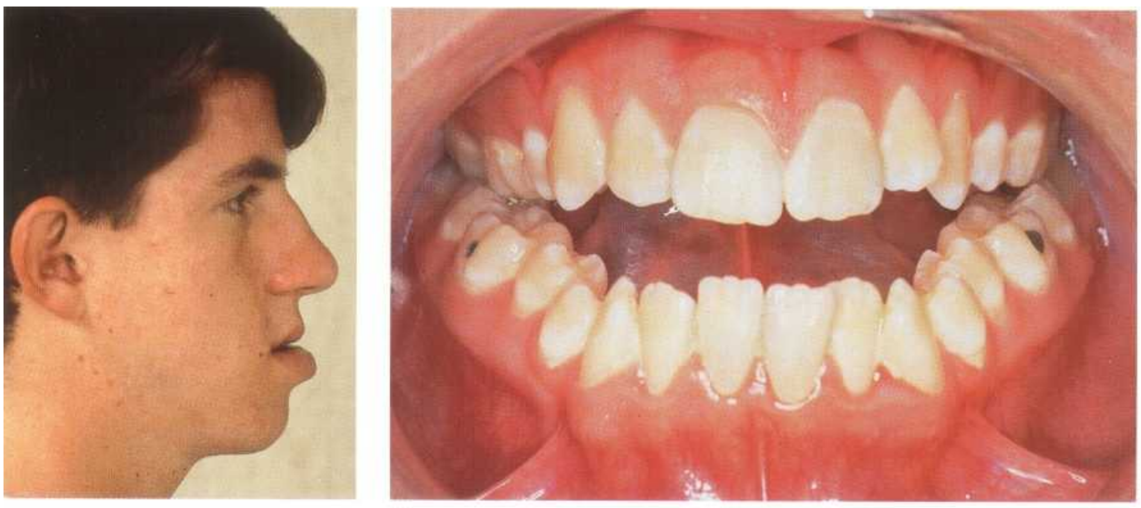
602 **Patient after surgical treatment of the ears**
Left: Treated ears after a successful surgery.

Right: Close-up of the treated right ear.

Malar Augmentation

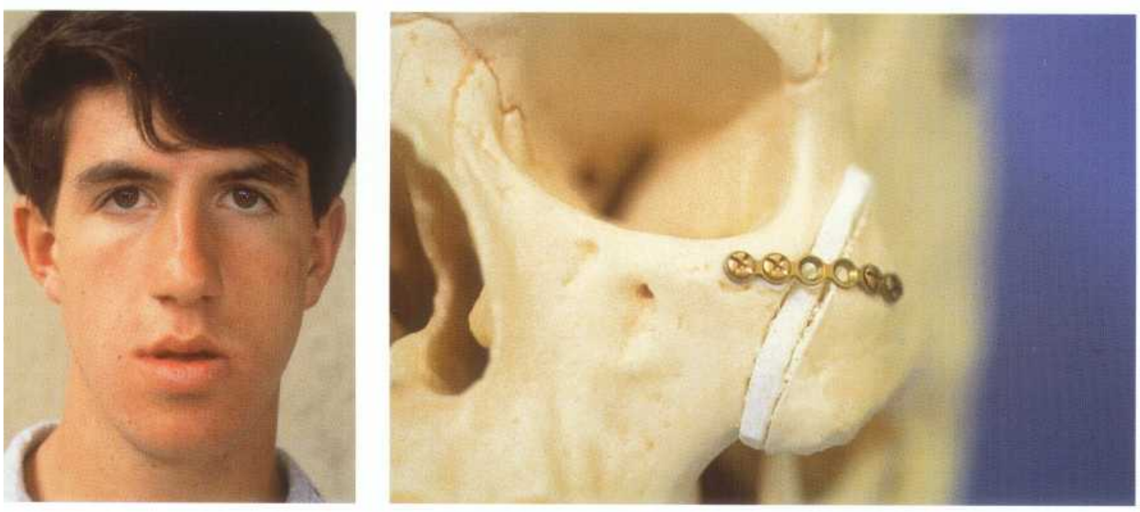
The prominent structures of the face are eyes, nose, and cheeks. The overall appearance of the face is determined by the distance between the cheeks, the so-called transzygomatic spacing. An indication of a malar hypoplasia is the visibility of the sclera at the inferior part of the iris. Moreover, the contours of the cheeks appear weak in a slanted position.

Several procedures are available for augmentation of malar contours. Alloplastic materials, such as Silastic, Gortex, or high-density polyethylene, which can be attached with screws or sutures have been used for a long time. The transversal zygomatic spacing can also be enlarged by means of osteotomy. This technique uses a maxillary LeFort I incision before separating and moving and firmly attaching the bone transplant. Unfortunately, the result of the bone transplantation is not reliable, since more than 50% of the transplanted bone volume is resorbed (0'Quinn and Thomas 1986; Tobin 1986; Whitaker 1991).



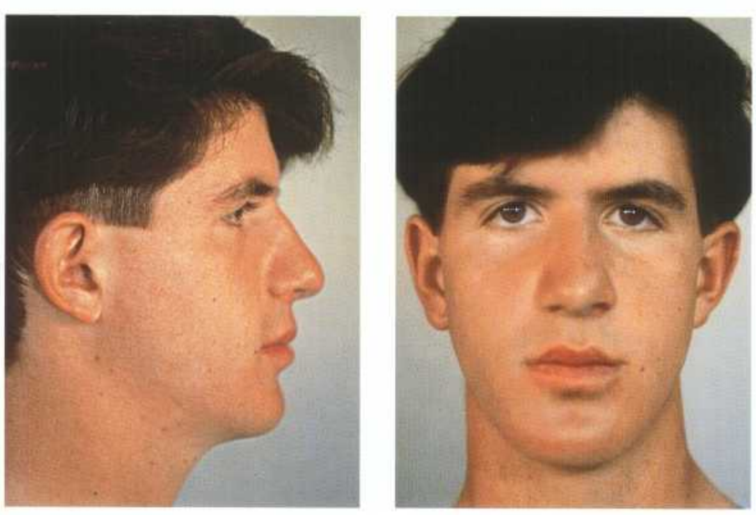
603 Reconstruction of the middle face
The intraoral view reveals an anteriorly open bite with class III malocclusion.

Left: The profile view shows a hypoplasia of the infraorbital region, a prominent nose, a retrusion of the upper lip, and a prominent lower lip.



604 Model reconstruction of the osteotomy
The model shows the planned surgical intervention to broaden the middle face using an osteotomy of the zygomatic bone. A bone transplant is attached with a titanium plate and titanium screws.

Left: The frontal preoperative view shows the hypoplasia of the middle face region and a narrow transversal distance.



605 Postoperative result
Left: Postoperative profile.

Right: The frontal view shows altogether harmonious facial features.

Neck Liposuction

Young patients with elastic skin and excess subcutaneous fat tissue are the most suitable for aesthetic improvements of the cervical facial profile through liposuction. The area to be reconstructed by liposuction is prepared with an infusion solution containing local anesthetic, saline, and corticosteroids as well as a strongly diluted epinephrine solution. This facilitates the removal of fat and minimizes the risk of postoperative scar and edema formation (Elam and Burkowitz 1988; Illouz 1983).

Blepharoplasty

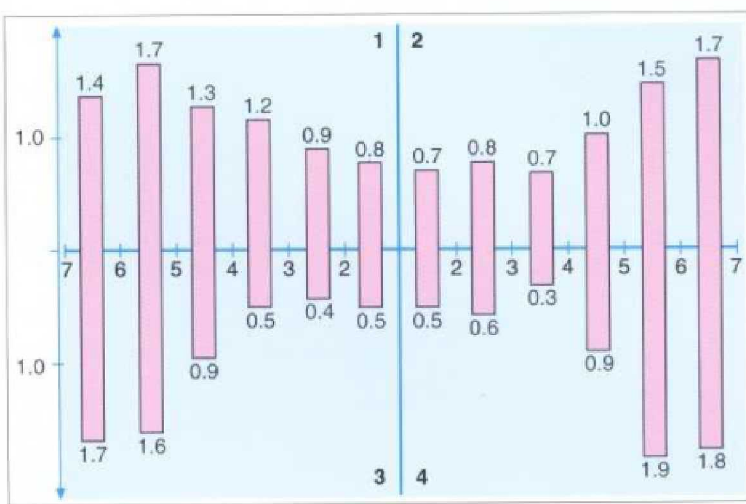
Surgical correction of the eyelids is indicated in the presence of excess or if the eyelids are swollen because periorbital fat has penetrated from outside the orbital fascia into subcutaneous layers. The eyebrow drops over the course of time. Ptosis of the eyebrow also contributes to excess skin on the eyelid. If such a ptosis is present, this should be treated before or at the same time as a blepharoplasty operation (Holt and Holt 1985).

606 Patient with chubby face
Condition before bilateral, sagittal split-osteotomy of the lowerjaw, protrusion of the lower jaw, and cervical liposuction.

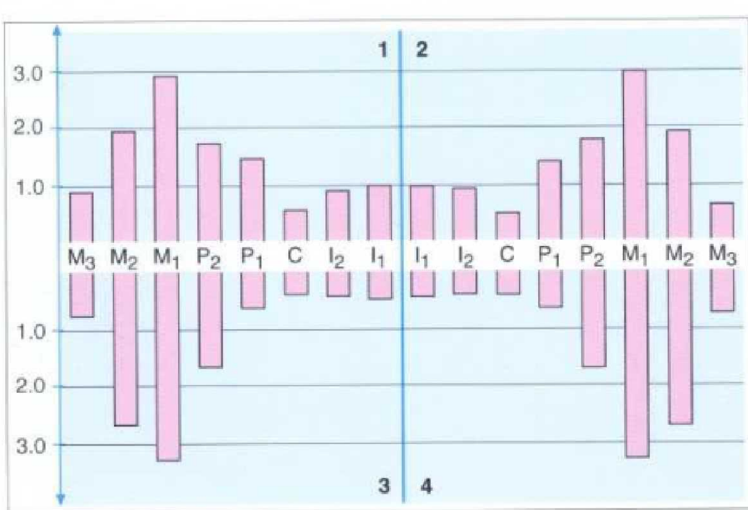
607 Postoperative view
Overall an outstanding operative result.

The Future of Dentistry

The future of dentistry has already begun. This book describes many techniques which one would not even have dared to dream of a few years ago. Nevertheless, it took 20 **years for Buonocore's acid etch technique to become generally accepted** and 15 **years until Fusayama's total etch technique was accepted.** Why? **Academic chairs at teaching institutions are normally "blocked" for** 15-20 **years. If one looks at the level of science and not at the level of teaching, one can identify trends and extrapolate these into the future. Furthermore, preventive dentistry has shown significant successes in the past** 50 **years. Fluoride is used in combination with various oral hygiene concepts, and fluoride has been added to water supplies and to some foods. The use of extensive preventive measures has resulted in a clear decline in caries and its consequence of tooth loss with aging. Another important factor is the higher life expectancy of the people as a consequence of improved health care, better environmental and living conditions, and better nutrition.**



608 **Comparative frequencies of Streptococcus mutans on all proximal surfaces in the upper and lower jaws (mean values)**
The goal of future dentistry will be to completely eliminate the infectious disease called caries.



609 **Number of fillings among Finnish civil servants**
The average distribution of carious defects in the oral cavity is similar to the distribution of bacteria (see Fig. 608 above). The caries incidence has declined rapidly over the past few years in many developed countries through preventive measures.

(Adapted from Ainamo 1970.)

Developments in Dentistry

In the past, people primarily went to the dentist when they had toothache. Aesthetic measures were virtually unknown. Patients did not expect to keep their natural teeth up to the end of their lives. The awareness that a smile also creates the impression of youth and health in mature people had not yet developed. Today, dentistry is no longer exclusively pain-oriented. Patients whose teeth are maintained well in modern dental practices by doctors and dental hygienists may possibly never experience toothache during their entire life. Modern dentistry has moved toward *preventive medicine* and by doing so contributes significantly to the improvement of the patients's quality of life.

The standard of education of the population has continually increased over the past decades. It has thus also been possible to improve training in the area of *oral health* and to teach the preventive measures that dentistry offers.

Dental technology has developed impressively over the past decades. Dentists are today in the position to perform dental treatments more quickly, more easily, and qualitatively better than just a few years ago. In addition, dental assistants are better trained and substantially better qualified. All these considerations have led to optimized dental treatment.

Negative Future Trends in Dentistry

Unfortunately, a negative development which is influencing the profession and which will also shape the future of dentistry is apparent in countries such as Germany. Long-term questions are being raised, such as how everyone can have access to dental care and who should bear the expenses. Dentistry too is governed by officials and is controlled by ministries, unions, and universities. Some know exactly what is not feasible, but they don't know what is practicable. This is hindering development.

Great Britain is a good example of how government influence can have a negative impact on the provision of dental care. The program for minimum dental care was a flop. Today, dentists are turning away from this program and are opening private practices where they can offer patients better quality and a broader range of dental treatment.

Nevertheless, there are many countries that prefer very narrowly defined socialized *oral health programs.* They frequently permit neither high quality care, nor free choice of care provider, nor free choice of treatment, nor expansion of the care, as provided by modern dentistry.

The dental *professional organizations* should find a way to allow care for all patients, something which is best accomplished under conditions of free entrepreneurial competition. But this is often prevented by the rules set by the dentists themselves.

Another negative influence in some industrialized countries is the short-sighted orientation of many doctors who only wish to maximize profit. For example, treatments are offered that do not necessarily serve the patient's health. Medical ethics is not always the basis for a doctor's actions.

Positive Future Trends in Dentistry

During the past decades, the amount of restorative work being carried out in dental practices has clearly decreased. Previously, restoring teeth with amalgam or composite contributed with 50-70% of all therapy measures in a practice. This percentage has been halved. The previous main focuses of dentistry were tooth extraction, restorative dentistry in children, and removable dentures. This has changed decisively and the process is still ongoing.

The following positive trends can be observed:

- Patients are getting older.
- The bulk of their natural teeth remain in situ.
- They are increasingly ready to pay for dental treatments out of their own pockets.
- They are better educated and demand select dental treatments.
- Dentists are in a position to perform dental care relatively inexpensively and promptly.

To conclude, one can say that the factors influencing the future of dentistry can be assessed as being mainly positive, with exception of plans regarding financing and access to dental care.

Diagnosis and Treatment Planning

In times when dental treatment was purely pain-oriented, making a diagnosis was simple and the painful tooth was either repaired or extracted. Those times are now finally over and dental treatment has become controlled and oriented toward prevention.

Small carious lesions are difficult to identify on radiographs. Therefore, it has become necessary to use optical aids during diagnosis and therapy. Two- to four-fold *magnifying glasses* are no longer the exception and they will become generally accepted in the dental practice.

Dentists also rely on radiographs as an aid. Conventional radiographic appliances will soon be a thing of the past. *Digital radiographs will* replace the traditional technique. The former are still relatively expensive and the technique is not yet fully mature. However, dentists who are already working with the new technology are impressed by its speed and the extent to which it makes work easier (Christensen and Christensen 1994c). Modern appliances enable the dentist to stop work at any stage, to enlarge a portion of the picture and to view the result directly on the screen. It is very probable that this concept will be developed further so that it can be employed during the active therapy phase and not only, as now, as an isolated step of the diagnosis. Furthermore, the radiation load is clearly reduced with the new digital appliances.

Patients who are concerned about their dental care must be educated. The best means of *providing patients with information* are intraoral cameras, regular distribution of patients' newsletters with information about the practice and new treatments, a practice brochure, and a picture atlas containing the dentist's own cases. It is important that these are the dentist's own patients, since the dentist should back the information completely.

At present, the concept of intraoral cameras (Christensen et al. 1994b) has been developed further than digital radiography. *Intraoral cameras* are suitable:

- for informing patients
- for producing documentation for families or third parties
- for improving vision during difficult treatments, and
- to a certain extent in cases when a direct view is not possible

The appliances have already become substantially less expensive, suggesting that practically every practice will have an intraoral camera at its disposal in the future. Patent applications have been registered for hand-held intraoral cameras. These will constitute another important step forward in dentistry.

In addition, dentists of the future will use many already known aids to inform their patients of various select dental treatments. Given the number of dentists in most Western countries, there will always be sufficient access to economic basic care. But what is defined as sufficient? Teeth are not, after all, a prerequisite for survival.

With increasing improvement of diagnosis and therapy of smaller carious lesions, more weight will be placed on the mechanical, biological, physiological, and other causes of oral diseases. The therapies will be able to increasingly target *eliminating the causes* and no longer only target eliminating the symptoms according to the "drill and fill" principle.

Although *occlusion,* beside caries and periodontal disease, is the third main area with which the dentist is occupied, it is often overlooked in a strongly caries-oriented practice. However, more than a third of the adult population suffers from bruxism. Nevertheless, dentists are inclined to neglect serious cases of tooth grinding and clenching. The future development of dentistry suggests that prevention, diagnosis, and treatment of functional illnesses will have to be taken into consideration more in the future.

Since people are now getting older and keep their teeth until well into old age, prevention, diagnosis, and treatment of periodontal diseases and defects will continue to be important in the future.

Operative Dentistry

G.V. Black's classification of cavity preparations groups the locations where caries appeared in descending order of frequency into classes 1-5. This somewhat obsolete classification is still in use today. However, it is not enamel caries that is being increasingly observed. Most carious lesions in adults today are located at the cemento-enamel junction, or on the incisal or occlusal surfaces where the enamel is abraded and dentin lies exposed. Because people will continue to grow older and keep their natural teeth longer, the *treatment of caries will* be more frequent among older patients. Typical enamel lesions (Black's classification) will further decrease. Restoring carious lesions in the dentin is best done with cariostatic materials that are enriched with fluoride or other caries-reducing substances that still need to be discovered.

Tooth-colored, nonmetallic restorative materials will be the filling material of choice in the future. The use of amalgam will continue to decrease. Even though a cast gold restoration is an outstanding and long-lasting therapy, more and more patients prefer to abstain from metal fillings. Besides, cast gold restorations are expensive.

Rotating instruments will for a considerable time continue to be the most important aids to treating tooth substance. However, one can foresee that micro-abrasion appliances and lasers will replace burs over time.

Endodontics

Since more and more teeth are lasting a lifetime, a not insignificant increase in endodontic measures has been noted. Although many of the endodontic treatments in use today are obsolete forms of therapy, they are still successful. In the future, digital radiography will contribute to progress in endodontics. Filling materials should contain components that regenerate bone and dentin and seal accessory root canals that were missed by the standard therapy.

In some countries, endodontic treatment has become too expensive for patients with average incomes. More affordable, faster, and easier therapies must therefore be found. The increased application of optical enlargement technologies will enable better, more thorough treatment.

Necrotic teeth contain numerous micro organisms that could be associated with systemic diseases. This theory will increase in importance and in the end will lead to the development of methods that can seal all dentin canals sufficiently. Endodontics will continue to remain one of the most important areas of dentistry.

Periodontology

Bone augmentation: New bone substitute materials (e.g., tricalcium phosphate) are being tested. The goal is that these materials will replace lost bone.

Regeneration of periodontal tissues: The development of guided tissue regeneration (GTR) has during the past 10 years led to new treatment modalities. Today, substances are already available that regenerate lost attachment. In the future, new membranes requiring less skillful surgical methods will be available.

Bacteriology: A bacteriological examination of the subgingival plaque is part of every diagnosis and differential diagnosis of periodontal disease. Genetic probes will enable a bacteriological status report to be available before treatment begins. The result of this examination has an impact on treatment planning-and further therapy (e.g., antimicrobial therapy with local or systemic use of medication).

Immunology: The biological parameters of periodontal disease are being intensively explored worldwide. This will first benefit the diagnostics and over time it could lead to the development of a vaccine against periodontal disease.

Orthodontics

People have always suffered from malpositioned teeth. Today, occlusal disturbances and malpositioned teeth can be corrected relatively simply with modern orthodontic methods, through moving the tooth within the bone compartment.

A future trend is to develop computer-aided diagnosis and treatment concepts that draft an optimal treatment plan after input of all recognizable aspects by the dentist. They will also help to oversee the course of the treatment. It is to be expected that simple and invisible orthodontic devices, which affect the normal life of the patient only negligibly, will be developed at the same time. In the future, improved cements can be removed easily after completion of the orthodontic therapeutic measures.

Pedodontics

Caries among children has declined significantly over the past few years. Children from regions with an optimum fluoride level have almost no caries. This trend will spread. Parents who apply available preventive measures properly will enable their children to grow up without cavities.

The task of the pedodontist will be to oversee the development of teeth and jaws and to refer those who require additional therapies. Loss of baby teeth and permanent teeth, high caries activity, treatment with steel crowns and the baby bottle syndrome will be a thing of the past.

Oral and Maxillofacial Surgery

Surgery is one of the areas of dentistry that will change most dramatically. In the past, many teeth were extracted-often for no obvious reason-and many surgeons were very busy. Under the influence of preventive dentistry, these surgeons had increasingly less work to do. Approximately at the same time, maxillofacial surgery emerged and new jaw and facial surgical intervention methods were developed. Today, dentists extract most teeth, while oral surgery has changed its objective.

Maxillofacial surgeons are increasingly occupied with implantation, an area that is expected to broaden its scope. But also general dentists, prosthodontists, and periodontists are moving into this field. It seems as if maxillofacial surgery will be increasingly linked to dental clinics. In contrast to other areas of dentistry, forecasts are hardly possible for the future of surgery.

The maxillofacial surgeon will be left to perform
- more extensive and very specialized oral surgical interventions
- jaw and facial surgery that was previously conducted by oto-rhino-laryngologists or plastic surgeons
- tooth implantations as well as
- classical jaw surgery

Prosthodontics

Materials

Biocompatibility of dental materials is a very important aspect in dentistry. New metal-free materials are being introduced. Results that do not differ from the those achieved with conventional ceramic materials will be achieved with completely new plastic materials. Simultaneously, new high-strength ceramics will be on offer (e.g., zirconium oxide). New cementing techniques will form durable connections between the restoration and the tooth surface.

CAD/CAM

Divers CAD/CAM procedures have been at dentists' disposal. Thanks to modern computer technology it will be possible to produce optimal restorations from each material and simultaneously design color, shape (aesthetics), occlusion, and function individually. The dentist will communicate via a modem with a CAD/CAM center and will usually be able to place complex restorations at the same session.

Concepts

The demand for removable dentures will decrease. Implantology will enable a fixed denture to be used in all situations. The new method of guided bone regeneration (GBR) will allow artificial roots to be implanted where they are needed from a prosthetic point of view. The requirements made of dentures will greatly increase. Patients will be informed about new treatments by the media. Not only technical requirement made of dental reconstruction will be important, but also criteria such as biocompatibility (periodontal and holistic aspects) and aesthetics.

Preventive Dentistry

In fact, dentures will be the exception because of the decline in caries in young people, but with the increase in life expectancy, the caries problem will recur in older prople. Public health reforms will turn dentures into a luxury item. Patients expect their dentist to provide a warranty that can only be given within a concept of comprehensive care that includes the assessment of periodontal and caries activity just as much as excellent follow-up care.

Caries and periodontitis are infectious diseases and must be treated as such. The existing defect is only a symptom. It is not sufficient to eliminate the symptom. The existing illness must be treated according to the level of scientific knowledge.

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