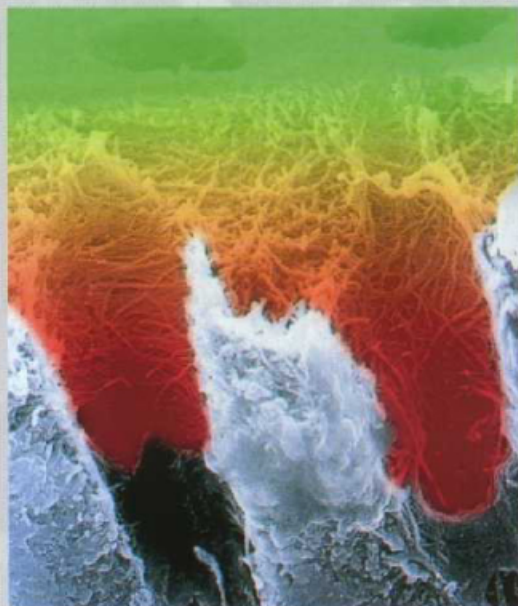


# ***Advances in Operative Dentistry***

Contemporary Clinical Practice



## ***Volume 1***

Edited by

Jean-François Roulet  
Prof Dr Med Dent

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PhD, MSc, BDS

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DMD

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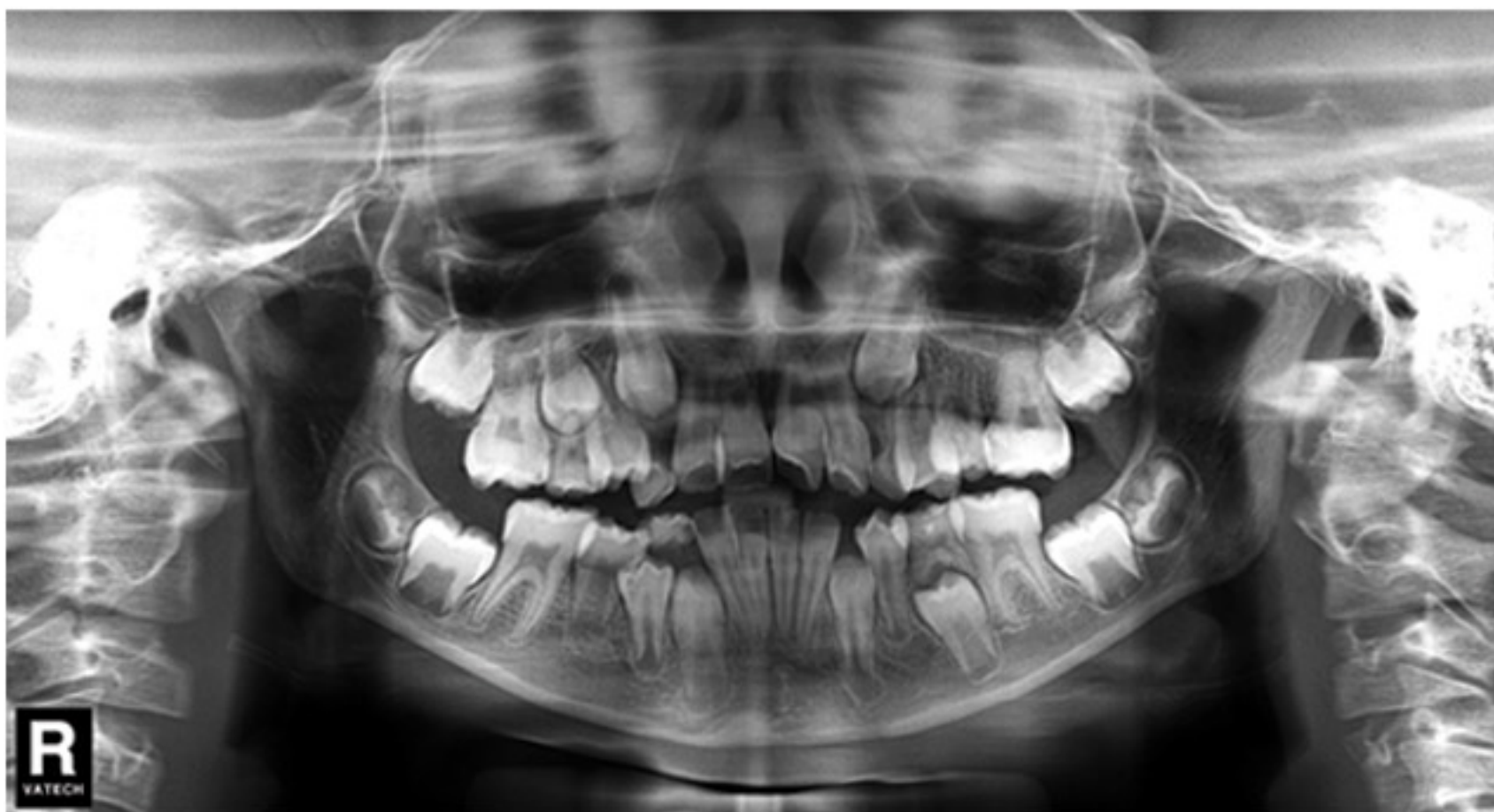
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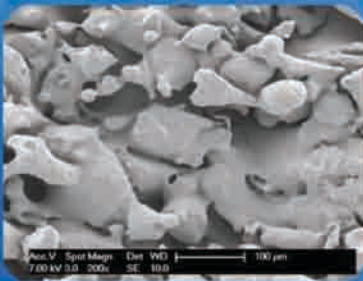
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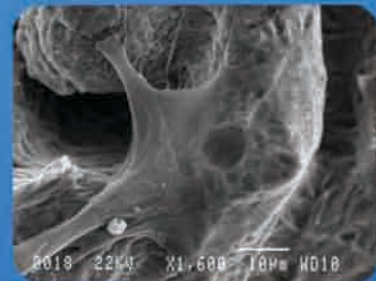
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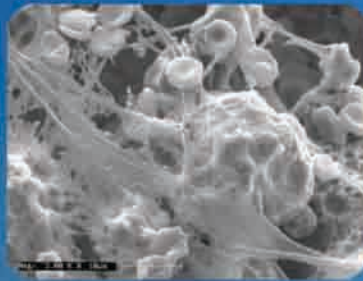
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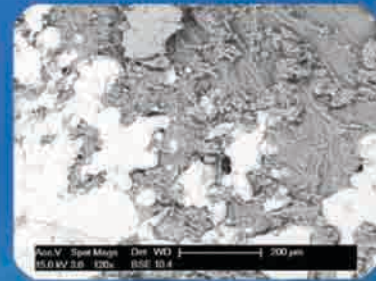
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cells activity



Immediate 3D organization  
of fibrin network



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inside the surface (clear)



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# *Advances in Operative Dentistry*

## Volume 1: Contemporary Clinical Practice

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Quintessence Publishing Co, Inc  
Chicago, Berlin, London, Tokyo, Paris, Barcelona,  
Sao Paulo, Moscow, Prague, Warsaw, and Istanbul



## Library of Congress Cataloging-in-Publication Data

**Advances** in operative dentistry : contemporary clinical practice /  
edited by Jean-Francois Roulet, Nairn H.F. Wilson, Massimo Fuzzi.

p. ; err

Includes bibliographical references and index.

ISBN 0-86715-402-0 (hardcover)

1. Dentistry, Operative.

[DNLM: 1. Dentistry, Operative. WU 300 A2445 2001 1. Roulet,  
Jean-Francois. 11. Wilson, Nairn H.F. 111. Fuzzi, Massimo.

RK501 .A36 2001

617.6'05--dc21

2001001460



© 2001 Quintessence Publishing Co, Inc

Quintessence Publishing Co, Inc

551 Kimberly Drive

Carol Stream, Illinois 60188

[www.quintpub.com](http://www.quintpub.com)

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Lithography: S & T Scan, Berlin

Printing and Binding: DBC Druckhaus Berlin-Centrum

Printed in Germany

ISBN 0-86715-402-0



# Contents

<b>Contributors</b>	<b>7</b>
<b>Preface</b>	<b>11</b>
<b>Introduction</b> <i>E. Steven Duke</i>	<b>13</b>
<i>Chapter 1</i> <b>Protection of Dentin and Pulp</b> <i>Carlo Prati</i>	<b>17</b>
<i>Chapter 2</i> <b>Protection of the Pulp-Dentin Complex with Adhesive Resins</b> <i>Serge Bouillaguet and Bernard Ciucchi</i>	<b>27</b>
<i>Chapter 3</i> <b>Moisture Management with Rubber Dam in Operative Dentistry</b> <i>Karl-Heinz Kunzelmann</i>	<b>35</b>
<i>Chapter 4</i> <b>Tissue and Moisture Management in Operative Dentistry</b> <i>Stefano Patroni</i>	<b>49</b>
<i>Chapter 5</i> <b>Esthetic Anterior Restorations</b> <i>Jean-Francois Roulet and Roberto Spreafico</i>	<b>57</b>
<i>Chapter 6</i> <b>Direct Posterior Restorations-Techniques for Effective Placement</b> <i>Guido Goracci</i>	<b>73</b>
<i>Chapter 7</i> <b>The "Composite-up" Technique: A Simple Approach to Direct Posterior Restorations</b> <i>Gilles F. Koubi, Stefan Koubi, and Jean-Louis Brouillet</i>	<b>87</b>
<i>Chapter 8</i> <b>Materials and Luting Cements for Indirect Restorations</b> <i>Marco Ferrari, Alessandro Vichi, and Albert J. Feilzer</i>	<b>95</b>



<i>Chapter 9</i>	
<b>Indirect Restorations for Anterior Teeth</b>	
<b>Space-The Eternal Problem</b>	<b>109</b>
<i>Richard Ibbetson</i>	
<i>Chapter 10</i>	
<b>The Control and Maintenance of Dentoperiodontal Relationships</b>	
<b>in Indirect Anterior Restorations</b>	<b>119</b>
<i>Samuele Valerio</i>	
<i>Chapter 11</i>	
<b>Advances in Bonded Ceramic Restorations for the Anterior Dentition</b>	<b>135</b>
<i>Pascal Magne</i>	
<i>Chapter 12</i>	
<b>Computer Veneers with the Cerec 3</b>	<b>153</b>
<i>Andreas Bindl, Wibke Apholt, and Werner H. Mormann</i>	
<i>Chapter 13</i>	
<b>Esthetic Posterior Indirect Restorations</b>	<b>165</b>
<i>Jean-Francois Roulet and Roberto Spreafico</i>	
<i>Chapter 14</i>	
<b>Bonded Partial Restorations for Endodontically Treated Teeth</b>	<b>191</b>
<i>Jean, Jacques Lasfargues, Frederic Bukiet, Gil Tirlet, and Frank Decup</i>	
<i>Chapter 15</i>	
<b>The Oral and Dental Effects of Aging</b>	<b>211</b>
<i>Angus W. G. Walls and Michael J. Noack</i>	
<i>Chapter 16</i>	
<b>Operative Treatment for Elderly People</b>	<b>223</b>
<i>Michael J. Noack, Michael Wicht, and Angus W. G. Walls</i>	
<i>Chapter 17</i>	
<b>Adhesive Techniques for the Management of Fractured and</b>	
<b>Worn Teeth in Elderly Patients</b>	<b>229</b>
<i>Angus W.G. Walls</i>	
<i>Chapter 18</i>	
<b>Conservative Dentistry: Educational Patterns in Europe</b>	<b>241</b>
<i>Alphons J.M. Plasschaert and Sandro Rengo</i>	
<b>Index</b>	<b>257</b>



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# Preface

A career in dentistry is not an easy option; in fact, quite the contrary is true. Why? The answer, which also explains what makes dentistry such a great profession, says it all: Dentistry is ever-changing and requires extreme versatility. A dentist must have excellent manual skills; good three-dimensional perception; knowledge of all aspects of dental science, including dental technology and materials; and, at one and the same time, be a good physician with the ability to successfully manage patients. Together with this special blend of attributes, dental practitioners in most parts of the world where dentistry is a liberal profession must also be entrepreneurial business managers.

At the inaugural ConsEuro meeting in Bologna, Italy, May 2000, European international experts reviewed the state of the art and science of operative dentistry. Sound knowledge and understanding is crucial, but, in a practical discipline such as dentistry, this foundation must be matched by high levels of technical skills. By way of an analogy: One can understand the principles of skiing and have detailed knowledge of the musculoskeletal structures and mechanisms necessary to traverse a piste, but still be unable to ski down a slope. Competence, which is a marriage of knowledge and skill, is the key.

Given that clinical competence is as important as scientific knowledge, many of the ConsEuro keynote speakers presented seminars on practical aspects of contemporary operative dentistry. This book captures the essence of these semi-

nars, spanning all aspects of the practice of state-of-the-art operative dentistry. Everyday procedures and the challenges they pose are illustrated with a multitude of figures, emphasizing the scientific basis of the restoration and esthetics of teeth. While the topics of the chapters range from the preservation of tooth tissues and the maintenance of tooth vitality to the placement of direct and indirect restorations in anterior and posterior teeth, they have in common an underlying theme of high-quality clinical outcome.

To complete the clinical elements of this book, there is consideration of operative dentistry for the aging population. The rate of change in operative dentistry for patients of all ages is increasing, and educational systems must move with the times. It is therefore appropriate that this book concludes with an overview of existing and future educational programs in operative dentistry.

Each and every practicing dentist, teacher of operative dentistry, and dental student will discover much new information to mine from this ground-breaking book.

Developing and editing this book on behalf of ConsEuro has been a privilege and an honor. It is our hope that all those who read and study this book will be encouraged to contribute to the further advancement and excellence in the practice of operative dentistry.

J.F. Roulet, N.H.F. Wilson, and M. Fuzzi  
Berlin, Manchester, and Bologna



# Introduction

E. Steven Duke

Historically, textbooks on operative dentistry have been directed toward dental students, who have a very limited knowledge and scope of the discipline. Further, the dental student's experience with the practice of operative dentistry is at an entry level, void of significant competence. As such, earlier texts have been very narrow in their approach to instruction and relied heavily upon tradition and simplified techniques taught almost in a "cookbook" fashion, with very little critical thought expected from the students. Rather than a critical review by the authors, approaches to operative dentistry were presented as interpretations of the correct way of doing procedures. This was usually followed by a list of suggested readings from various publications and other texts. However, it is important to note that scientific peer reviews that provided the foundation for the conclusions made in these earlier texts were absent. Further, the texts addressed only the regions of the world where they were drafted, and most recently many originated in North America.<sup>3,8</sup>

As an introduction to operative dentistry, most textbooks would provide some basic principles, procedures, or techniques, and were often said to address the "science" or "art" of operative dentistry. While there was usually plenty of art, the science was minimal in most textbooks. Often scientific references were not provided; instead, only suggested readings were presented for further pursuit of knowledge and validation.

*Advances in Operative Dentistry* differs greatly along these lines. First, the text is not an introduction to operative dentistry. The text is directed to the practicing clinician or advanced graduate student. Second, the chapters are a compilation of scientific papers with numerous references cited to substantiate the material presented and set the stage for critical thought. Third, a number of the chapters deal with technologies that are innovative and peripheral to many established procedures of operative dentistry presented in other texts. Yet, the reader may argue that adequate evidence is or is not presented. This is one unique feature of this text—it provokes thought from the reader and may even spark further reading on the part of readers who wish to more fully understand a procedure or technique. This concept of an "interactive" text, which does not provide all the answers but only opens the door for new knowledge, is a novel educational approach that is being used more often in other disciplines.

Another unique feature of *Advances in Operative Dentistry* is its acknowledgment of the constant presence of patients in dental practice. The chapters discuss numerous factors that influence treatment options. For example, risk assessment is always important when considering treatment options. Risk factors such as oral hygiene, demographics, socioeconomic status, and nutrition are all critical elements when one considers an operative

intervention.<sup>1,2,4</sup> Therefore, an operative intervention should include measures to reduce a patient's risk, such as a proper nutritional profile, an alteration in systemic medications, or an intervention that is followed and reassessed at a later date. This again is in sharp contrast to the mind-set of most operative dentistry textbooks, which revolve around cutting tooth structure in a "proper" fashion. While proper preparation of a tooth is necessary, there may be more appropriate alternatives to consider. One would have to go to great lengths to find this concept in traditional operative dentistry textbooks. For example, the possibility that a repaired restoration is just as definitive as a replacement restoration should be considered. In fact, the repaired restoration may be the better choice when it conserves tooth structure and is based upon a philosophy of preservation of good oral health and tooth structures for a lifetime.<sup>5</sup>

Issues that are seldom discussed in operative dentistry textbooks relate to patient demographics and economics. Such parameters are just as important as the most precise techniques that may be discussed in the text. Regional issues regarding the general oral health, educational background on oral health issues, and economic conditions of a population will have a direct impact on the nature of care rendered. In most developed populations of the world, edentulism is on the decline.<sup>6,10</sup> Increasing is the number of partially or fully dentate patients. Parallel to this is an aging population that is retaining teeth well into the later years of life.<sup>9</sup> In many instances populations are outliving their natural dentition, requiring extensive restorative reconstructions. Such restorative procedures are costly and require greater

skill from the clinician. This will ultimately lead to manpower issues, ie, there will not be enough dentists to meet the oral health demands of most populations. The expanded use of dental auxiliaries and the promotion of more effective preventive therapies will be necessary measures to counter the anticipated shortage.

The introduction of new technologies—such as CAD/CAM to enhance the cost efficiency of dental care and air abrasion and the chemical removal of caries to encourage conservative cavity preparation—and of new procedures, such as conservative preventive restorations, are discussed. The acceptance of newly developed technologies varies greatly in different regions of the world. However, knowledge about innovation carries little cost and should be shared by all scientists and educators. The final integration into a regional practice will result after a comprehensive review and assessment by individual regions and professionals. Presumptions about what is an appropriate global view of operative dentistry are without logic or scientific foundation.

In summary, *Advances in Operative Dentistry* is a comprehensive presentation of the multifactorial relationships that influence and govern the nature of operative dentistry. Numerous questions remain, as they should, because of the scientific foundation of the manuscripts compiled. As our populations evolve, so should the guidelines of practicing operative dentistry. As new knowledge is gained, it should be incorporated into practice as soon as possible to best suit the challenges facing clinicians around the world. Science has no geographic boundaries, and the world collectively can contribute much to advancing the practice of operative dentistry.



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# Protection of Dentin and Pulp

Carlo Prati

## Introduction

The use of adhesive techniques in recent years has expanded to the extent that it is questionable, if not anachronistic, to deal with the problems of dentinal and pulpal protection under conventional amalgam restorations. Hence, only the problems of pulpal-dentinal protection in modern adhesive dentistry are examined.

Dentin is a permeable substrate that covers but does not fully protect pulpal tissue. However, because enamel covers dentin, whenever enamel is altered or removed (as in caries, fractures, etc) both dentinal and pulpal tissues are in danger. For these reasons, it is difficult to limit present considerations to dentinal and pulpal protection. The preservation of sound enamel is probably the best solution for complete protection of dentin and pulp. Despite such apparently simple considerations, we must answer the following questions:

1. What causes of dentinal and pulpal damage are involved in failures in modern adhesive dentistry?
2. How can one protect dentin and pulpal tissues during the life of a restoration? Is the protection of dentin and pulp really necessary with modern materials?

3. Does the protection of restoration margins also protect the pulp-dentin complex?

The aims of this chapter are to examine critical aspects of restorative techniques and restoration performance that require the protection of dentin and enamel.

## Causes of Dentinal Damage

The causes of dentinal damage are related to the penetration and growth of bacteria inside dentinal tubules and in the dentinal smear layer. During the preparation of a cavity, a large number of bacteria may be introduced into the cavity and contaminate the smear layer. For these reasons, a range of disinfectant solutions were previously proposed<sup>2</sup> to reduce the number of bacteria in the surface of prepared dentin.<sup>3</sup> The materials proposed to disinfect dentin and enamel after cavity preparation are set out in Table 1-1. Today, with the use of etching solutions and self-etching primers, it is unlikely that the dentinal surface will remain contaminated prior to the application of composite materials. In fact, acid solutions (pH 0.8-2.0) probably remove all bacteria present on the floor and walls of a cavity.



Table 1-1 Materials used to reduce damage to tooth tissues

Materials	Methods	Action	Tissues
Dentin-enamel bonding systems	Hybrid layer formation	Reduced gap	Enamel and dentin
Calcium hydroxide	Antibacterial liner	Reduced bacteria growth New reparative dentin	Dentin and pulp
Liners and bases	Sealers	Reduction of dentinal permeability	Dentin and pulp

While it is possible to reduce the number of bacteria immediately prior to restoration placement, it remains a great problem to reduce bacterial growth in gaps between restoration and dentin (and restoration and enamel) during the life of the restoration. The biofilms and associated bacteria that completely cover restoration surfaces and infiltrate marginal gaps are the most important etiologic factors in secondary caries, associated enamel disintegration, pulpal damage, and pulpitis. In other words, bacteria and their toxic products are the major source of pathologic damage to dentin and pulp subsequent to bacterial infection. For these reasons, the protection of the pulp-dentin complex requires the protection of restoration margins. Unfortunately, bacteria and their fermentation products may alter enamel and dentin along the margins of a restoration, especially if the margin of the restoration has a porous, demineralized, and permeable structure.<sup>1,5,11</sup> The greater the permeability of affected dentin, the more postoperative pain and sensitivity can be expected.<sup>12</sup> It is well-known that pain is related to the rate of permeability. If dentin is well sealed, there is no fluid flow outward from the pulp and dentin permeability is

very low or absent. For these reasons, post-operative sensitivity might represent an index of the sealing capacity of restoration margins.

Mechanisms of Dentinal Damage

When a gap is present along the margin of the restoration, there is a wide open "window" for bacteria to gain access to the pulp. The more the window is open, the greater the bacterial penetration of the dentinal tubules will be. Greater dentinal permeability means higher risk of dentinal and pulpal damage. Complete absence of permeability means good protection and perfect prevention. Probably all restorations have at some time one or more open windows destined to open ever wider; failure is therefore only a question of time!

Bacterial progression toward pulp does not, however, mean early pulpal damage (and pain). If the gap is limited, the outward fluid flow can wash away many bacteria and may limit pathologic alterations. However, reduced pulpal vitality with a reduced pulpal gradient and pressure is unlikely to produce a flow rate sufficient to

Table 1-2 Materials used to achieve external protection of restoration margins

<b>Materials</b>	<b>Methods</b>	<b>Action</b>	<b>Tissues</b>
Glass-ionomer cements	Fluoride releasing	Reduction in caries activity	Enamel and dentin
Compomers	Fluoride releasing	Supposed reduction in caries activity	Enamel and dentin
Sealers	Sealing of damaged margins	Repair of enamel chips and gaps	Enamel
Toothpastes	Fluoride-releasing detergents	Reduction in caries activity Removal of plaque Removal of bacterial biofilms	Enamel
Mouthwashes	Chlorhexidine releasing Xylitol releasing	Reduction of bacterial growth Removal of plaque	Enamel and dentin

oppose bacterial progression.<sup>12</sup> It is also important to remember that outward fluid flow around a filling does not prevent a chemical gradient directed pulpally.<sup>2</sup> The fluid flow rate around new restorations placed in mesio-occlusodistal Class II cavities using a total-etch/bonding system, a conventional bonding agent, or a glass-ionomer cement base has been investigated.<sup>18</sup> The outward fluid flow may be detected immediately following the application of the restorative materials and only partially correlates with the findings of microleakage tests.<sup>18</sup> This work demonstrated that fluid flow persists for a relatively long time (about 3 months) and may influence the adhesion of bonding agents and marginal integrity.<sup>14,16,17</sup> In another preliminary clinical study, the postoperative pain and sensitivity level following the provision of ceramic crowns to restore molars and premolars was monitored. Different types of adhesive systems were compared. The complete hybridization of the dentinal surface eliminated pain and sensitivity during

impression procedures and prevented any significant sensitivity during the first year of evaluation. Other clinical studies have confirmed the excellent biocompatibility of modern dentin-enamel bonding systems.<sup>7</sup>

### Concept of "Internal" and "External" Protection of Restorations

It is clear that it is extremely important to minimize the marginal gap around a restoration (the open window) and to reinforce all the mechanisms that can keep this "window" closed. Methods for the so-called "external protection" of restorations are listed in Table 1-2. External protection includes all the systems able to prevent marginal alterations and degradation, reduce secondary caries, and maintain the interface between restoration and remaining tooth tissues.

Methods for the "internal protection" restorations are listed in Table 1-3. These

Table 1-3 Materials used to achieve internal protection of restoration margins

Materials	Methods	Action	Tissues
Glass-ionomer cements	Fluoride release	Antibacterial activity	Enamel and dentin
Dentin-enamel bonding systems	Hybrid layer formation	Dentinal sealing Reduction of dentinal permeability	Dentin

Table 1-4 Dentinal marginal microleakage observed in three groups of materials after immersion in either saline or a cariogenic solution for 1 week"

Dentin Bonding Agent/Composite-Compomer	Dentinal Marginal Microleakage (mean±SD)	
	Saline solution	Cariogenic solution
Clearfil Liner Bond 2/ Clearfil PhotoPosterior	19.0 ± 16.6 <sup>b</sup>	78.3 ± 18.9 <sup>a</sup>
Prime & Bond 2.1/Dyract AP	26.3 ± 29.6 <sup>b</sup>	66.9 ± 24.6 <sup>a</sup>
Syntac Sprint/Compoglass F	74.6 ± 25.6 <sup>c</sup>	66.2 ± 28.5 <sup>a</sup>

\*Storage in the acidic enviroment caused demineralization in the region of margins with an increase in microleakage. (Groups with the same superscripted letter are statistically equal.)

methods play an important role only when external protection has failed. Internal protection of dentin means control of permeability and better control of fluid flow rate. 12-14,16-18

Of course, an outstanding question is why windows open, or rather, why may the margins of a restoration develop many channels, gaps, and fractures, creating access for bacteria? The causes of marginal alterations in new restorations (composite shrinkage, lack of adhesion, etc) are well-known and better described elsewhere in this book. The causes of acquired marginal alterations include: occlusal loading, cuspal flexure, chemical degradation, and most importantly incomplete hybrid layer

formation and altered hybrid layer morphology. 6,7,19-21

Chemical degradation of the marginal integrity of restorations (enamel and dentin) is probably the most important cause of microleakage and bacterial invasion. 19 In a laboratory study, it has been demonstrated that microleakage may be minimized by using appropriate dentinal and enamel bonding systems. Alterations of tooth tissues (demineralization and secondary caries) around the margins (or the marginal hybrid layer) of restorations dramatically increase microleakage, as shown in Table 1-4. Tissues around the restoration provide the foundation for marginal integrity throughout the life of

the restoration. Scanning electron micrographs illustrate the typical alterations in enamel and dentin around different types of restorations after storage in an artificial cariogenic solution. Alterations to the marginal tissues create many porosities and voids, allowing large numbers of bacteria to "run" into deeper parts of the dentin and possibly the pulp. Porosity of enamel and, in particular, dentin is an important cause of pulpal-dentinal alterations. In other words, secondary caries increase, porosities, and the resulting channels between the oral environment and the pulp-dentin complex invite pulp disease. The area immediately adjacent to the margin of the restoration must be kept intact (ie, free of caries) to prevent any type of subjacent damage.

## Methods to Prevent Marginal Alteration

The mechanisms to prevent early marginal alterations, such as the control of composite shrinkage and the limitation of initial occlusal loading are discussed elsewhere. The issue in the present review is how to prevent marginal alterations during the life of the restoration and maintain the health of the pulp.

Several years ago glass-ionomer cements were promoted as fluoride-releasing materials. All the fluoride-releasing materials now present on the market (resin-reinforced glass-ionomer cements, compomers, ionomers, etc) may protect enamel margins. Several laboratory investigations have demonstrated such an effect<sup>5,10,21</sup> Recent scanning electron microscopic (SEM) analyses failed to demonstrate any important effects of fluoride-re-

leasing materials in preventing enamel marginal alterations after storage in cariogenic solutions (lactic acid, pH 4.6) for 1 week and 1 month (Figs 1-1 to 1-6). The author's initial enthusiasm for fluoride-releasing materials has been partially eroded by the lack of robust clinical evidence. However, further studies are required before discontinuing investigations of these materials in the author's laboratories. Several new formulations may be found to protect the enamel prisms close to the tooth-restoration interface. Others may be found to reduce the amount of bacteria in plaque and oral biofilms and thereby contribute to a reduction in secondary caries.

It is acknowledged, however, that many studies have demonstrated significantly higher levels of remineralization in tooth tissues adjacent to glass-ionomer-filled cavities compared with amalgam-filled cavities.<sup>5</sup> In another recent study, Hsu et al<sup>6</sup> demonstrated that fluoride-containing amalgam and glass-ionomer cements can elicit a significant preventive effect on secondary root caries in an in vitro bacterial model system. In an interesting laboratory study, Dijkman and Arends<sup>6</sup> investigated the effect of a fluoride-releasing composite on enamel demineralization along the interface gap found around restorations. Their results indicate that fluoride-releasing composites may play a role in the future prevention of secondary caries because they can prevent the "intragap" demineralization of enamel.<sup>6</sup> This finding suggests that enamel in a gap may be protected by acid demineralization and thereby help preserve-albeit partially-the restoration. Future studies must produce more information on the role of fluoride in preventing secondary caries and marginal demineralization.



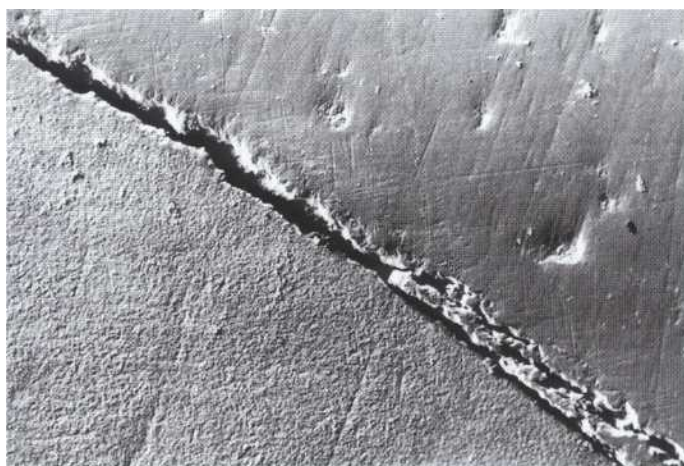


Fig 1-1 Marginal hybrid layer with gaps, fractures, and voids. These fractures represent the "window" for bacterial penetration toward the pulp.

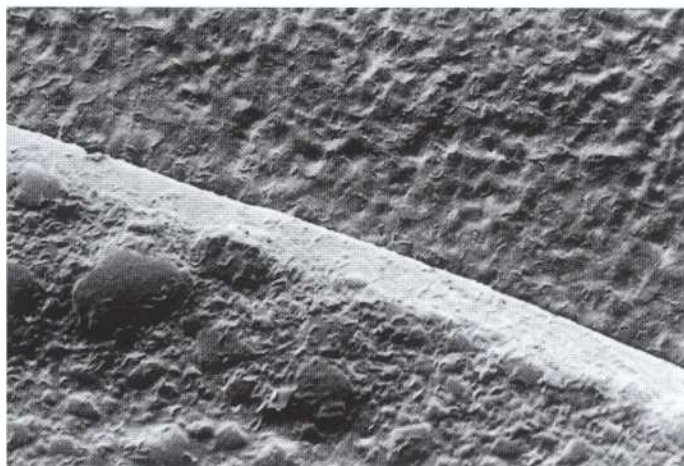


Fig 1-2 Perfect marginal adaptation. The characteristic morphology of composite resin is apparent. The thickness of the bonding agent is approximately 10  $\mu\text{m}$ . This is the typical morphology of the marginal hybrid layer.



Fig 1-3 Marginal hybrid layer of a restoration stored in saline solution. Compomer (left) and the enamel margin are clearly visible. Porosity of the enamel around the margin of the restoration is evident.

**Fig 1-4** Marginal hybrid layer. The erosion and demineralization of dentin are clearly visible along the margin. This alteration may contribute to an increase in the marginal gap and to the formation of microchannels within the dentin-hybrid layer interface. Permeability of dentin is extremely high close to the margin of a restoration.



**Fig 1-5** Marginal hybrid layer with gaps and voids. The thickness of the hybrid layer is approximately 3  $\mu\text{m}$ . Dentine tubules have been opened during immersion in a demineralizing solution. The removal of collagen has exposed many dentinal tubules and channels.



**Fig 1-6** Typical enamel lesion (enamel demineralization) observed along the margin of a restoration. The integrity of the enamel surface was lost during immersion in cariogenic solution for 1 week to simulate in vivo alterations. The use of compomers did not significantly improve the protection of enamel.

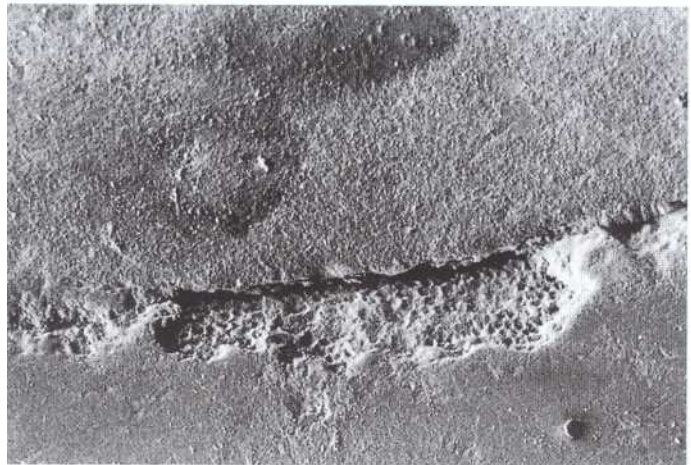






Fig 1-7 Maxillary molar with secondary caries in a 21-year-old patient with no pulpal symptoms, notably pain and thermal sensitivity.



Fig 1-8 Appearance of the maxillary molar following removal of the old restoration. The pulp is exposed, as confirmed by the presence of blood.



Fig 1-9 The application of a glass-ionomer cement may reduce the risk of further pulpal problems.

## Methods of Preventing Pulpal-Dentinal Alterations

The available literature, which is relatively limited, confirms that the use of modern total-etching and self-etching systems does not increase the incidence of pulpal pathology.<sup>4</sup> This means that current clinical procedures and materials are safe and do not cause serious pulpal damage. In the author's clinical studies, no attempt has been made to investigate problems related to the use of bonding systems. The

author used a bonding system for direct pulpal capping without any serious difficulties (Figs 1-7 to 1-9). It therefore may be suggested that in most cavities pulpal damage (with pain and sensitivity reported by patients) is unlikely. Other information continues to be published pertaining to direct pulpal capping with bonding agents and composite resins.<sup>9</sup>

The use of calcium-hydroxide cements may have a rationale; however, there are no robust studies able to demonstrate the safety and hazards, if any, of such materials. Resin-reinforced glass-ionomers have

a well-documented antibacterial activity<sup>15</sup> and good adhesion to dentin, and may thus be an alternative to calcium-hydroxide cements in very deep cavities.

Several studies have recently demonstrated that the use of dentin-enamel bonding systems is both safe and free of adverse pulpal effects. The formation of a thin but impermeable hybrid layer best prevents any pulpal damage by sealing dentin through the closure of dentinal tubules. In other words, a hybrid layer protects dentin and pulp. All methods able to produce a complete hybrid layer may be included in the methods used to prevent pulpitis and secondary caries.

## Conclusions

Pulpitis, pulpal damage, dentinal alterations, and caries are caused by bacteria and their products moving inward toward the pulp. Using the materials able to seal the external margins and the inner aspects

of cavity walls is the correct method to protect pulp and dentin. The reduction of dentinal permeability is a goal in preventive dentistry.

Demineralization of dentin around restoration margins opens a fine network of dentinal channels and lateral anastomoses, which are the site of the microleakage that occurs around margins. SEM evaluations have confirmed the presence of gaps and debris around the margins of restorations. Many porosities have been observed 50 to 100  $\mu\text{m}$  from the dentinal surface. In several samples, fractures and chips along the margins of composites were observed. These observations suggest that such materials are not able to resist acid attack and may be demineralized by acid biofilms.

The prevention of marginal alterations (external protection) and the hybridization of dentin (internal protection) are the most modern and effective methods to prevent dentinal and pulpal damage.



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# Protection of the Pulp-Dentin Complex with Adhesive Resins

Serge Bouillaguet and Bernard Ciucchi

## Introduction

The demand for esthetic restorations and worries about the toxicity of mercury have driven the replacement of dental amalgam by adhesive resins. While efficient bonding to dental tissues appears to be guaranteed under laboratory conditions, such reliability is not always encountered in clinical use. This observation is to an extent supported by the low but constant incidence of pulpal sensitivity problems reported following the placement of adhesive restorations. Fortunately, most of these reactions are minor and reversible; some, however, are more pronounced. The intensity of the pulpal response to bonding and restorative procedures is modulated by different factors. The first of these is undoubtedly related to the protective effect afforded by dentin and the pulp. The ability of resins to wet dentin surfaces, resist polymerization stresses, and seal the restoration are all further factors that affect the pulpal response. This chapter briefly reviews the function of the pulp-dentin complex and attempts to define the risks of adverse pulpal reactions during restorative procedures. Clinical recommendations are discussed in an attempt to optimize bonding to dentin and to

limit the incidence of adverse pulpal reactions.

## Anatomy of the Dentin and Pulp

Pulp and dentin form a common organ. The pulp's primary function is the production of mineralized tissues, and the mineralized dentin plays a protective role for the pulpal tissues. When exposed to pathologic processes (caries, attrition, and abrasion) or to restorative procedures (cavity preparation), various interactions between dentin and pulp may be found to occur. However, the respective contributions of these reactions to the control and regulation of noxious stimuli are somewhat different. In dentin, the presence of dentinal tubules makes the dentin permeable, and it is apparent that noxious substances can readily move across it by diffusion. Fortunately, there is also evidence of an interaction between dentin and certain molecules that can be trapped or bound inside the dentinal tubules.<sup>14</sup> As a result, the concentrations of noxious substances at the pulpal openings of the dentinal tubules are reduced. However, this permeability is

not uniform throughout the crown of the tooth.<sup>17</sup> Close to the pulp, the permeability is ten times that measured at the periphery, with dentinal permeability varying from one region of the crown to another. Differences in dentinal permeability have been observed between young and aged dentin and may be attributed to various amounts of materials deposited within the tubules (sclerosis).<sup>17</sup> It is generally accepted that deep dentin is a poor barrier to bacterial, chemical, and physical stimuli. Such stimuli are usually accompanied by pain and related pulpal reactions.

The dental pulp has a complex vascular and nervous supply that permits, amongst other functions, inflammatory reactions, the control of the steric balance of interstitial fluids, and maintenance of a constant tissue pressure.<sup>18</sup> As soon as dentinal tubules are opened, the positive pulpal tissue pressure tends to flush dentinal fluid through the dentin.<sup>7</sup> This outward convective fluid movement reduces the concentration of noxious substances in the diffusates. Also, pulpal blood flow contributes to the removal of toxic dentin-diffused materials from the pulp.<sup>19</sup>

Sensory nerve fibers respond to cavity preparation by releasing neuropeptides responsible for neurogenic inflammation.<sup>6</sup> These mediators activate the release from blood vessels of plasma proteins that migrate into dentinal tubules and cause a decrease in dentinal permeability. When deep cavities are prepared, there is a severe pulpal reaction, given disruption to the odontoblast cell layer. Cell damage will trigger increased inflammatory reactions, mostly oriented toward the production of reparative dentin at the site of injury.

These observations support the concept that deep dentin is more vulnerable

than superficial dentin to cavity preparation. Anything that can diminish convective pulpal fluid movements and diffusion transport processes across dentin should reduce the incidence of adverse pulpal reactions.

## Protection of the Pulp-Dentin Complex

Theoretically, dentin hybridization should provide strong and durable micromechanical retention of resins and complete sealing of the restoration without the risk of pulpal toxicity.<sup>16</sup> When such conditions are obtained clinically, the risk of pulpal irritation by adhesive restorations is prevented. However, recent reports have identified factors that may affect the quality of bonding, especially to dentin. As reported by Erickson, dentin is a heterogeneous substrate that significantly influences the bonding properties of current adhesive systems.<sup>10</sup> The type of dentin (young or sclerotic), its variations in composition (high water content versus high mineral content) and permeability (high versus low permeability), and the ability of a resin to wet such surfaces are all factors that will affect adhesion. The handling of adhesive systems also may have profound repercussions on the quality of bonding. With total-etch/wet-bonding systems, excessive etching of the dentin can produce poor bonding when collagen fibers at the base of the demineralized dentin are not completely impregnated with resin (Figs 2-1 a to 2-1 d).<sup>19</sup> Furthermore, there is a risk of collagen collapse after etching. Moisture control has been shown to be critical under such clinical conditions.<sup>22</sup> Other studies have reported that combining primer and

adhesive resins to allow a single application step may reduce the effectiveness of hybridization.<sup>23</sup> One approach to prevent the risk of defective dentin hybridization is the use of self-etching adhesive systems (Figs 2-2a to 2-2c). With these systems, etching and priming of the dentin can occur simultaneously by infiltration of the smear-covered dentin with acidic resins (Figs 2-2a to 2-2c). Therefore, critical procedures such as rinsing after etching and then drying of the dentin are eliminated. Furthermore, the risk of incomplete impregnation of the demineralized dentin by the resin is avoided. Recently, it has been demonstrated that self-etching adhesives can exhibit bonding characteristics equivalent to those of most current adhesive systems.<sup>3</sup>

Another factor that may influence the quality of bonding is the configuration of the cavity.<sup>11</sup> This has been confirmed in a recent study that showed that the adhesive characteristics of a bonding agent to the walls of a Class 11 cavity were significantly reduced compared to those obtained on flat dentinal surfaces.<sup>8</sup> It is speculated, however, that the placement of thick adhesive layers can counteract the stresses generated during the polymerization of the restorative material.<sup>9</sup>

Despite the mechanical resistance of the adhesive interface, it is essential to counter polymerization stresses, especially given the increasing evidence that perfect sealing of the restoration is required to prevent bacterial leakage.<sup>1</sup> It is interesting to note that even in the presence of strong adhesion, incompletely infiltrated hybrid layers can still permit leakage through sub-microscopic porosities within the hybrid zone.<sup>21</sup> Surprisingly, most adhesive systems cannot eliminate the passage of fluid

across bonded interfaces because of defective hybridization. Notwithstanding a 90% reduction in dentin permeability after bonding, persistent permeation of fluid after bonding may be observed with some materials.<sup>2</sup> This result has been attributed to the incomplete evaporation of the solvent in the primer system (overwet phenomenon) or to the incomplete polymerization of the resin (excessive thinning of the adhesive layer). It is generally accepted that persistent permeation of fluids will increase the risk of postoperative sensitivity and can accelerate the degradation of the adhesive resin in clinical service.

The final point to be considered when evaluating the quality of bonding is the absence of pulpal toxicity. Despite biocompatibility studies that report that bacterial leakage is more likely to cause adverse effects to the dental pulp than components from restorative materials, other reports have indicated that resin molecules are toxic at micromolar concentrations.<sup>1,13,20</sup> The risk of toxic effects is further increased by the potential for adhesive materials to leach into the pulpal tissues given the tubular structure of the dentin. During bonding procedures, the risk of chemical irritation is present. Such irritation could undoubtedly trigger an immediate pulpal response. Fortunately, the concentrations of leached components from resin composites do not appear to cause acute toxicity to odontoblasts and therefore most reactions observed are minor and reversible.<sup>4,12</sup> More interesting are the long-term subtoxic effects on pulpal cells resulting from the progressive degradation of poorly polymerized adhesive resins diffusing down to the pulp. Recent studies indicate that very low concentrations of resin monomers, which are known to pass through dentin



Figs 2-1a to 2-1d Bonding to dentin with conventional (three-step) adhesive systems.



Fig 2-1a Dentinal substrate after acid etching. The smear layer has been removed and both the peritubular and intertubular dentin are demineralized. The collagen fibers are exposed and bathed in water. This substrate is highly hydrophilic and particularly sensitive to dehydration. The blue coloration represents the water content of the structures illustrated.



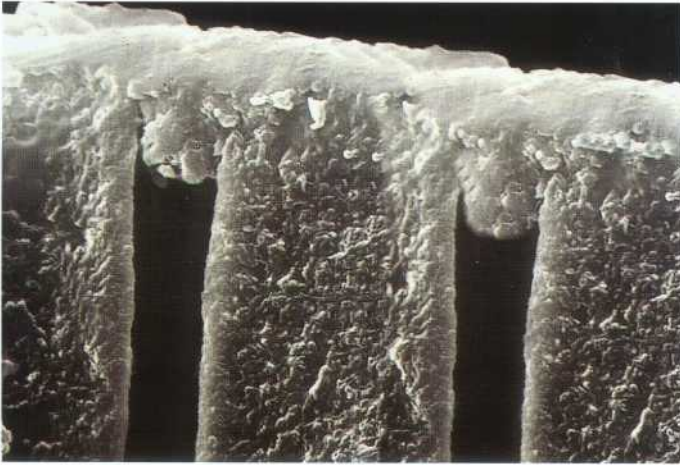
Fig 2-1b Dentinal substrate after priming. The water has been replaced by hydrophilic resins (primers) that have impregnated the collagen fibers. The solvent of the primer can be organic (alcohol or acetone) or inorganic (water). Priming with water-based primers is a relatively slow process, while organic solvents will displace water more rapidly (convective movement). Evaporation of the solvent will leave the collagen fibers coated and stiffened by the resins. The substrate has changed from hydrophilic to hydrophobic. The red coloration represents the extent of primed dentin.



Fig 2-11c Dentinal substrate after adhesive resin application. The hydrophobic resin diffuses slowly into the dentinal tubules and impregnates the intertubular dentin. If resin penetration is not complete, it will leave noninfiltrated areas of demineralized dentin and nonadherent resin plugs. These defects are responsible for poor sealing of the dentin and rapid degradation of the adhesive interface.



Fig 2-1d Dentinal substrate after polymerization of the adhesive resin. The polymerized resin has completely infiltrated the demineralized dentin and offers effective protection to the pulp-dentin complex.



Figs 2-2a to 2-2c Bonding to dentin with a self-etching adhesive system.

Fig 2-2a Dentinal substrate after preparation. Smear layer is covering the dentin and smear plugs are occluding the dentinal tubules. These structures contribute greatly to a reduction in dentinal permeability.

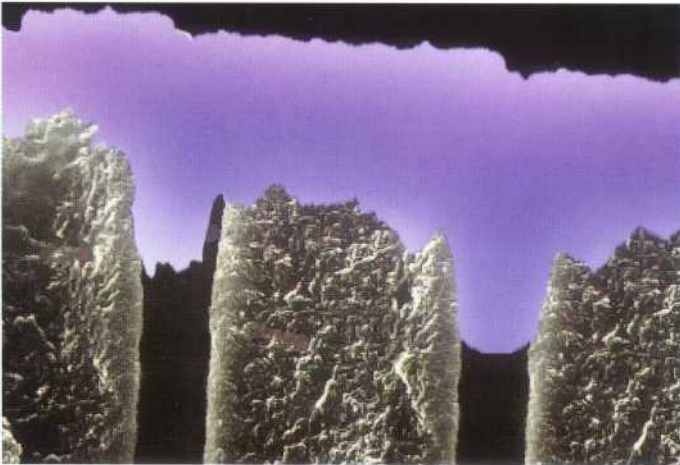


Fig 2-2b Dentinal substrate after application of acidic resins. The resins have dissolved and impregnated the smear layer as well as some intertubular dentin. The resins have also penetrated the dentinal tubules.



Fig 2-2c Dentinal substrate after application of the adhesive resin. The resin has simply coated the primed surfaces without any risk of incomplete penetration. This bonding procedure is very effective in deep dentin.

by diffusion, can have significant effects on the proliferation and activity of human monocyte-macrophages.<sup>5,15</sup> Consequently, the potential for bacterial injury to the dental pulp may be enhanced since its resistance to infectious agents is decreased. This problem is likely to become more acute when bacterial leakage occurs with the progressive biodegradation of the adhesive resins in long-term clinical service.

## Clinical Recommendations

To optimize bonding, one should evaluate the potential of each adhesive system under specific clinical conditions. Shallow cavities located in superficial or sclerotic dentin can be treated using a low-viscosity self-priming adhesive system (one-bottle adhesives) that will simultaneously bond to enamel and dentin. Successive increments of filling material should be applied and properly photo polymerized. When deeper cavities are prepared, one should consider using a conventional (three-step) adhesive system, given that such systems facilitate control of the thickness of the adhesive layer. A thick adhesive layer will give some elasticity to an adhesive interface to compensate for the volumetric shrinkage of the composite material. Thicker adhesive layers also may be obtained with filled adhesive resins or by using low-viscosity

composite liners after bonding. Deep cavities in young patients require a different approach to avoid adverse reactions to bonding. In such situations, the dentin is highly permeable and the volume of composite material is particularly important. The use of a self-etching adhesive system provides a uniform hybridization of the dentin without the risk of imperfect impregnation of the dentinal surface that is encountered with total-etch systems. With these systems, bonding to enamel margins can be optimized using a separate 37% phosphoric acid etchant to provide maximum sealing at the periphery of the restoration. Thus, optimum sealing of both dentin and enamel margins can be realized.

## Conclusions

There is increasing evidence that the pulp-dentin complex can react positively to adhesive restorations, given the use of appropriate operative techniques. Adhesive systems have the potential to seal restorations and, as a consequence, to offer effective protection of the pulp-dentin complex. This potential is, however, challenged by the complexity of bonding procedures and the limitations of bonding systems relative to the microdiversity of the dentinal substrate.

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# Moisture Management with Rubber Dam in Operative Dentistry

Karl-Heinz Kunzelmann

## Introduction

The technology to isolate teeth under rubber dam and thereby eliminate adverse effects of mouth humidity was first applied in 1864 by the New York dentist S.C. Barnum. Subsequently, the use of rubber dam has made a substantial contribution to facilitating operative techniques and quality assurance, notably in endodontics and adhesive restorative procedures. However, the gap between recommendations and reality in the use of rubber dam is wider than with any other technology in dentistry.<sup>4</sup> While universities stoically teach the use of rubber dam, colleagues in practice typically reject this technique. The most frequently quoted arguments for not using rubber dam relate to the time taken to apply it and patient objection.

The rapid development of modern dentinal bonding and composite materials and the widespread use of such systems as an alternative to amalgam have brought rubber dam back to the center of interest in recent years. The introduction of the compomer Dyract (Dentsply, Konstanz, Germany), revived discussions about rubber dam, given that Dyract is the first resin-based material that does not require the

use of rubber dam in its application. This feature of Dyract was a substantial reason for the high initial acceptance of compomers in the Federal Republic of Germany. In addition, this feature resulted in renewed consideration of the view that rubber dam is a condition sine qua non in relation to adhesive dentistry.

While the adherence to tooth substrates of early forms of adhesive restorative systems may have been adversely affected by exhaled air humidity, this is difficult to comprehend when considering modern hydrophilic dentin bonding systems. The compomer matrix may be slightly more hydrophilic than the matrix of hybrid composites given the availability of carboxylate groups in the compomer matrix. Compomers, however, are used together with dentinal bonding agents almost identical to those used with composites. Accordingly, it could be argued that all composites may be placed without the use of rubber dam. Eliminating the dogma that rubber dam is a requirement for adhesive dentistry has stimulated debate regarding the future role of rubber dam. However, considering the advantages of rubber dam (Table 3-1), it may be concluded that it greatly facilitates adhesive procedures by

**Table 3-1** Main arguments for the use of rubber dam

- Protection of the patient from aspirating or swallowing debris and small instruments
- Dry, clear operating field
- Protection of the soft tissues
- Infection control for patient, dentist, and chairside assistant
- Possibilities for disinfecting the field of operation

**Table 3-2** Thickness of rubber (latex) dam membranes

Thin	0.13–0.18 mm
Medium	0.18–0.23 mm
Heavy	0.23–0.29 mm
Extra heavy	0.29–0.35 mm

keeping the operating field dry throughout operative procedures.

When working to a systematic scheme, rubber dam can be applied within 2 to 3 minutes. Notwithstanding ergonomic advantages, cost benefits may accrue from the use of rubber dam. A prerequisite for the efficient, effective use of rubber dam is knowledge and experience of the relevant techniques, linked to the ability to select the instruments, materials, and procedure for placement best suited to particular situations.<sup>1-3,5,6</sup>

**Material and Instruments**

**Rubber Dam**

Rubber dam membranes of different materials are available in various thicknesses (Table 3-2), sizes, and colors.

Regarding which thickness of rubber dam to use, the guide is: the thicker the material, the better the isolation. However, thick rubberdam membranes place a high stress on the retainers for the dam, ie, the rubber dam clamp. This is particularly apparent when isolating a molar tooth under rubber dam. Therefore, thin rubber dam membranes are recommended for the isolation of posterior teeth, reserving thicker membranes for use in the isolation of anterior teeth. Alternatively, as has been the author's preference for many years, rubber dam membranes of "medium" thickness may be used throughout the mouth. When undertaking the chairside bleaching of teeth, however, "heavy" rubber dam is recommended to best protect the gingival tissues from the bleaching solution. Rubber dam is available in rolls (eg, 150 mm x 550 mm) or ready cut (eg, 150 mm x 150 mm). Since rubber dam is primarily used in combination with a rigid frame, ready-cut dam offers advantages.

The colors in which rubber dam is supplied include beige, gray, green, and blue. Beige rubber dam tends to be recommended for endodontics because it is somewhat transparent, allowing tooth position and axis to be assessed during treatment. Green and blue rubber dam tends to

be used in adhesive dentistry procedures, given the color contrast with teeth. When using such intensely colored rubber dam, however, it is important to record tooth shade prior to isolation. Currently, there is a trend toward individually characterized restorations that are built up in increments of differently shaded composite materials. When applying this approach, the use of gray rubber dam is indicated. Given the different colors of rubber dam, it is possible to work ergonomically by, for example, linking color to the weight of dam (eg, green for medium, blue for heavy). In this way, one can quickly select rubber dam of appropriate thickness.

With the increasing use of rubber products in medicine, there has been an increasing incidence of adverse reactions to latex. Manufacturers of rubber dam have given consideration to this problem. Adverse reactions can be caused by the latex or by materials used in the manufacturing process. The powder used to separate sheets of rubber dam during production and storage contributes to the incidence of adverse reactions. Powder-free rubber dam has therefore been developed (Kentzer Kaschner Dental, Ellwangen/ Jagst, Germany). The powder is removed by repeated washing. A further development is silicone-based, nonlatex rubber dam (Roeko, Langenau, Germany). A modified rubber dam punch that forms larger holes than the usual punch should be used to compensate for the reduced elasticity of the silicone membrane.

## Rubber Dam Frame

The rubber dam membrane is stretched with the help of a rubber dam frame. Different rubber dam frames are available

(Figs 3-1a to 3-1d). Rubber dam frames may be metal or plastic. Plastic frames are radiolucent and are therefore suitable for use in endodontic procedures involving radiographic examinations. However, the prongs of plastic frames are thicker than those of metal frames and, as a consequence, it may be relatively difficult to secure rubber dam to a plastic frame.

U-shaped frames have the advantage of fitting around the nose of the patient. It is incomprehensible that the manufacturers of oval-shaped rubber dam frames do not direct the prongs of the frame away from the nose of the patient, given the occasional reference in the literature to trauma from such prongs, which, in any case, tend to complicate rather than facilitate the adjustment of the dam. One can solve this problem by removing prongs that may traumatize the nose and inserting dentinal pins into the frame lateral to the nose.

Its light weight, shape, and good dam retention favor the routine use of the Young frame in cases in which radiographs are not required. In cases in which the use of radiographs is anticipated, the Sauveur frame is recommended.

## Rubber Dam Punch

The rubber dam punch is used to perforate the dental dam. Two different types of punch are available. In the Ainsworth punch (Fig 3-2a), the hinge is behind the tine and the rotating metal table. In the Ivory punch (Fig 3-2b), the hinge is toward the front. Having the hinge in front of the cutting table results in a circular, evenly cut perforation of the dam, thereby reducing the risk of the dam tearing in use.

When using a rubber dam punch, it is important to ensure that the tine fits accu-

Figs 3-1a to 3-1d Rubber dam frames.



Fig 3-1a Universal, U-shaped rubber dam frame.

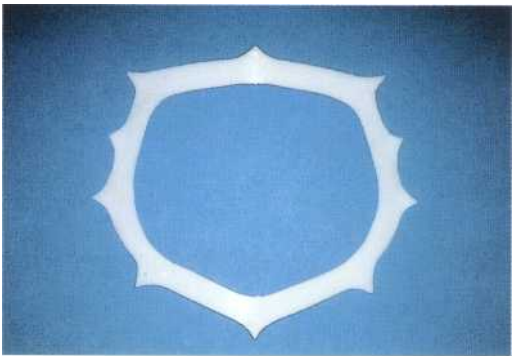


Fig 3-1 b Nygaard-Ostby rubber dam frame.

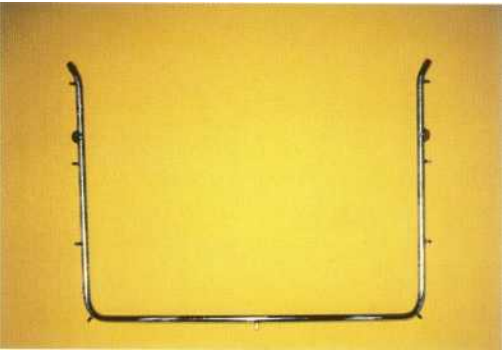


Fig 3-1c Young U-shaped rubber dam frame.

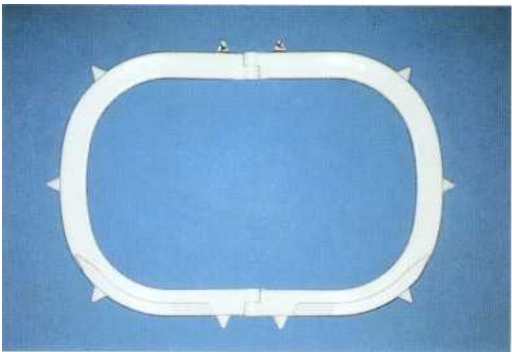


Fig 3-1d Sauveur oval rubber dam frame.

Figs 3-2a and 3-2b Rubber dam punches.



Fig 3-2a The Ainsworth punch.

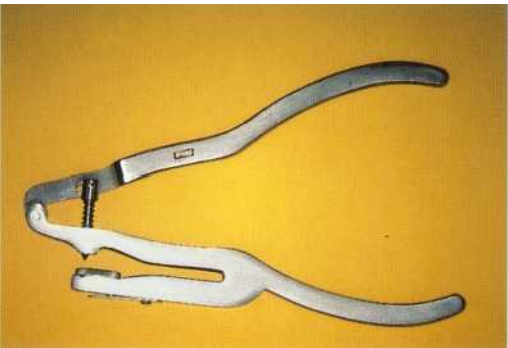


Fig 3-2b The Ivory punch.

Figs 3-3a and 3-3b The tine should be centered in the selected hole of the cutting table.

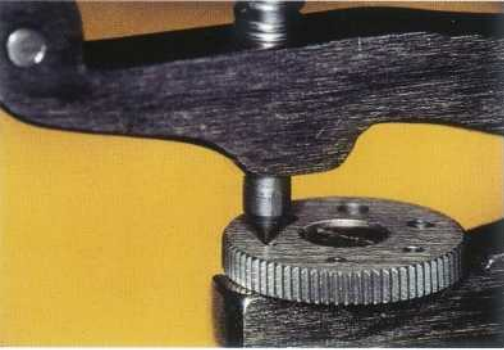


Fig 3-3a Incorrect centering.

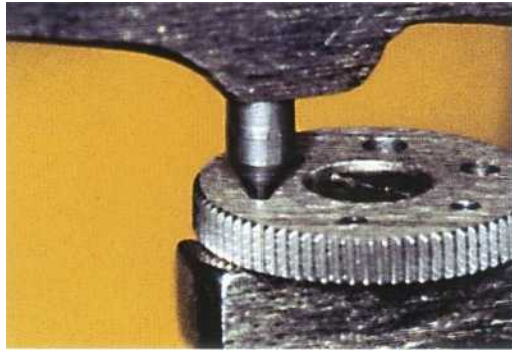
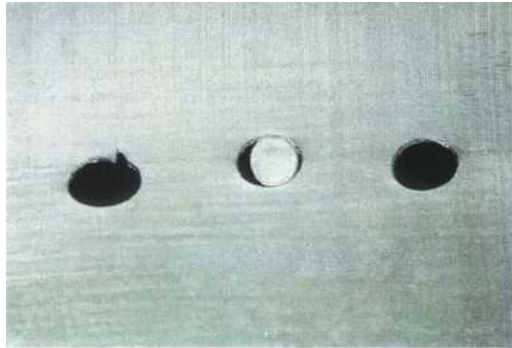


Fig 3-3b Correct centering.

Fig 3-4 Clean-cut hole (right), incomplete cut with residual tag of dam (center), and irregular hole following removal of residual tag (left).



rately into the selected hole in the cutting table (Figs 3-3a and 3-3b). If the tine does not fit accurately into the hole of the cut table, the cutting edge of the hole can be damaged, making a clean cut impossible. When the cut is incomplete and the residual tag of rubber is torn off, the dam may unexpectedly tear during placement (Fig 3-4).

## Rubber Dam Clamp Forceps

Rubber dam clamp forceps differ in the design of their distal tips (Fig 3-5). Forceps with a stop machined into the distal tips (eg, Ivory) are distinct from forceps with plane distal tips (eg, Martin, Aeskulap). Distal tip stops have two advantages: They prevent the tips penetrating too deeply into the rubber dam clamp and allow more controlled positioning of the clamp during





Fig 3-5 View of the distal tip of Ivory forceps. The stop facilitates manipulation and placement of the clamp while minimizing trauma to the gingivae.

Table 3-3 Distinguishing features of rubber dam clamp types

<ul style="list-style-type: none"><li>• Winged or wingless</li><li>• Distance of the clamp bow to the distal surface of the tooth</li><li>• Length of the clamp jaw (eg, premolar vs molar clamps)</li><li>• Contact zone buccal = lingual or buccal &lt; lingual (eg, maxillary vs. mandibular molar clamps)</li><li>• Clamp jaw with or without extra curvature in apical direction</li></ul>
---

placement. Forceps without distal tip stops may cause damage to gingivae if allowed to penetrate the clamp too deeply. All rubber dam clamp forceps have a locking handle to allow the forceps to be locked in an open position, facilitating clamp placement. Forceps are best locked with the minimum necessary opening. The locking handle should be held upwards so that gravity works in the clinician's favor on release.

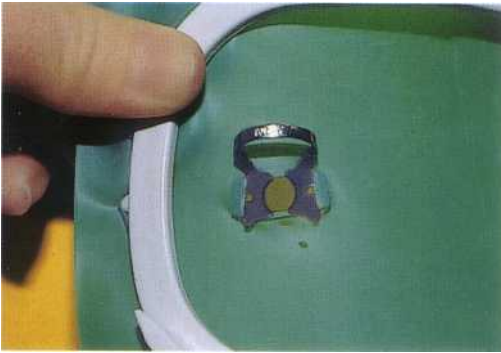
Rubber Dam Clamps

Rubber dam clamps retain the rubber dam. Clamps engage below the maximum convexity of the tooth and thereby hold the rubber dam in position. For stability, it is im-

portant for most clamps that they have optimum contact with the tooth. If a clamp has two prong contacts on one side, but only one contact on the opposite side, it will tend to rotate or be displaced when the dam is tensioned.

While a small number of clamps can deal with most clinical situations, there is an almost incomprehensible range of clamps available commercially. Clamps may, however, be simply classified (Table 3-3).

The decision to select winged or wingless clamps depends on the application technique and the location of the tooth. Clamps without wings need less space, which, for example, can be favorable for maxillary molars, especially if the ascend-



**Figs 3-6a and 3-6b** Extraoral placement of a clamp (winged) in the dam. This technique allows placement of the rubber dam frame, membrane and clamp at the same time. It is especially helpful when isolating a small number of teeth.

ing part of the mandible interferes with the clamp. Winged clamps, on the other hand, provide extra retraction of the dam. Winged clamps are necessary if the dam is to be applied as illustrated in Figs 3-6a to 3-6b.

The distance of the clamp bow to the distal surface of the tooth is particularly important when isolating the last tooth in an arch. Long clamps give better access but may interfere with anatomic structures (eg, the ramus of the mandible). Long clamps therefore tend to be selected if single teeth are to be isolated. For example, long clamps are indicated when using the intraoral camera of a Cerec system.

Clamp shape is dictated by tooth shape. The spacing between the prongs of the clamp jaws (contact zone) must be larger for molar teeth than for premolars (Figs 3-7a to 3-7f). Because of the symmetrical shape of clamp jaws, the same clamp can be used in either the left or the right side of the jaw. Maxillary molars frequently have a tapered shape, necessitating the selection of a clamp with jaws of dif-

ferent contact zone length. This, however, requires different clamps for left-and right-side use, as well as different-sized teeth.

Rubber dam clamps gain retention by being positioned below the maximum convexity of the tooth. Problems may therefore arise when isolating teeth that are broken down or only partially erupted. In such situations, rubber dam clamps with apically directed prongs are selected to gain retention subgingivally (Fig 3-8).

Rubberdam clamps may be obtained in sets (eg, Ivory Nos. 7, 8, 8A, 14A for molars; Nos. 0, 1, 2 for premolars; and No. 212 for anterior teeth), which are best stored in a clamp organizer (Fig 3-9).

## Rubber Dam Application

### Preparation

Standardization of procedures is a prerequisite to the efficient, effective use of rubber dam. Preoperative preparation can simplify various steps in the process. The necessary instruments (rubber dam

Figs 3-7a to 3-7f Rubber dam clamps.

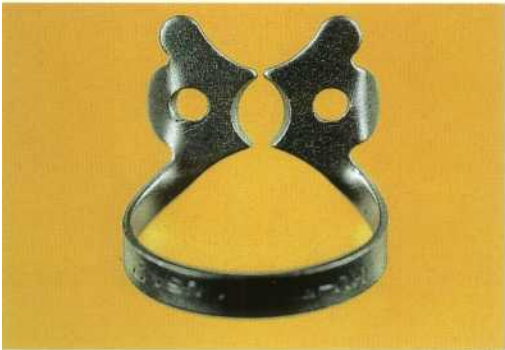


Fig 3-7a Rubber dam clamp No. 2 (with wings). This clamp is used for premolar teeth.



Fig 3-7b Wingless rubber dam clamp No. 2.



Fig 3-7c Rubber dam clamp No. 7. This clamp is designed for molar teeth.



Fig 3-7d Clamp No. 14A. The prongs are directed gingivally, which is helpful, for example, with partially erupted teeth.



**Figs 3-7e and 3-7f** Clamp Nos. 12A and 13B. The size of the buccal clamp jaw is larger than the lingual jaw. This facilitates placement on tapered teeth, for example, maxillary first molars.

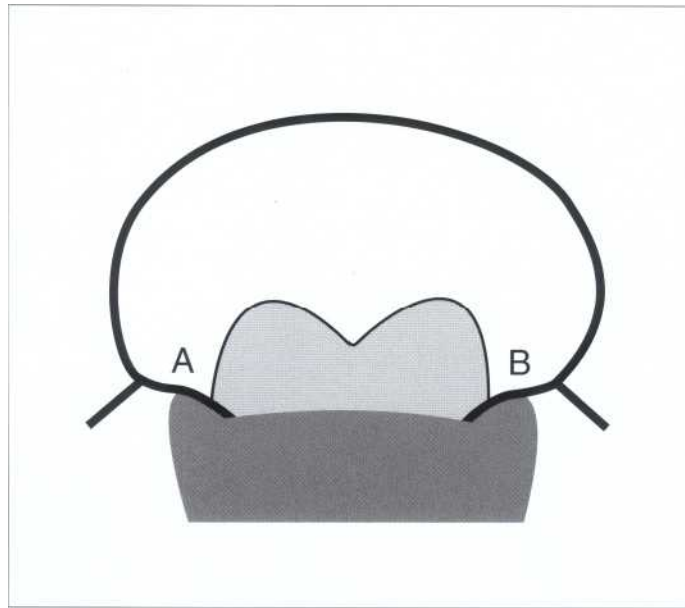


Fig 3-8 Rubber dam clamps for broken down and partially erupted teeth have an additional curvature (A and B) to create apically directed prongs. The prongs are placed between the gingival tissues and the tooth.



Fig 3-9 Rubber dam clamp organizer (Kentzer Kaschner Dental, Ellwangen/Jagst, Germany).

frame, rubber dam clamp forceps, rubber dam clamps, and rubber dam punch) should be at hand.

The rubber dam, together with associated items, including tooth ligatures, rubber dam napkins, and lubricant (glycerin gel), can be selected and prepared in advance, as can tooth ligatures of dental floss (30 to 40 cm in length) stored rolled up on cotton-wool rolls. The rubber dam can be prepared for different situations. Positions for perforations can be marked on the dam preoperatively using a template and a water-resistant felt-tipped pen. Perforations may be cut for the three most frequent situations, ie, the isolation of all anterior teeth, a quadrant of posterior teeth, and a single tooth.

For the isolation of anterior teeth, eight perforations should be cut in a semilunar arc according to the template for 14 to 24. Contrary to traditional teaching to include only the tooth to be treated together with the two adjacent teeth, current practice is to isolate a segment of teeth. When treating anterior teeth, the reason for this is that rubber dam can be reliably anchored with the help of the rubber dam clamps on premolar teeth. In such situations, all eight perforations should be formed using the second smallest hole of the Ivory punch.

For posterior teeth, the rubber dam clamp is best placed on the tooth distal to the tooth to be treated. For premolars the second smallest hole and for molars the next larger hole of the Ivory punch should be selected. If additional perforations are necessary, they are included at the chairside. Perforations need only be prepared for one quadrant because the dam maybe oriented for all four quadrants. The small difference between the curvature of maxillary and mandibular jaws is

compensated for by the elasticity of the dam.

In endodontics, usually only one perforation is necessary for the isolation of asingle tooth.

## Application Technique

Many different application techniques are described and taught, with selection depending on personal preference. It is possible to work successfully with one of a number of techniques, which differ according to the timing of the placement of clamp and frame. The clamp may be placed first and the dam stretched over the clamp and then attached. Alternatively, the clamp can be placed in the dam and then placed around the tooth priorto stretching the dam around the frame (Fig 3-9). The author prefers a further variation in which the membrane is stretched overthe rubber dam frame and then over the tooth prior to placing the clamp.

Irrespective of the application technique, the following may be of assistance: Before rubber dam is placed, it should be determined whether dental floss can pass through the proximal contact. If it is not possible to pass dental floss through a proximal contact, rubber dam will not pass through the contact. If this occurs, it may be necessary to renew a filling or separate the teeth with a wooden wedge. Alternatively, it may be decided to exclude the contact in the isolation. It is also prudent to check the retention of the rubber dam clamp prior to placing the rubber dam.

Rubber dam passes through proximal contacts more easily if it is lubricated. The lubricant should not contaminate cavities and must therefore be water soluble.



Figs 3-10a to 3-10p Placement of rubber dam.



Fig 3-10a Dental floss is passed through the proximal contacts to identify potential problems prior to placing the rubber dam membrane.



Fig 3-10b The rubber dam is punched and fixed to the frame. The membrane is lubricated around the holes on the oral surface.

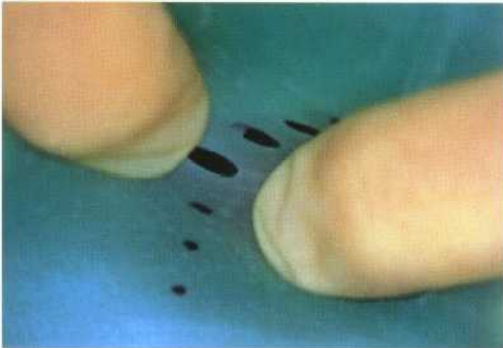


Fig 3-10c The rubber dam membrane is stretched with the index fingers to see the tooth on to which the dam will first be placed.

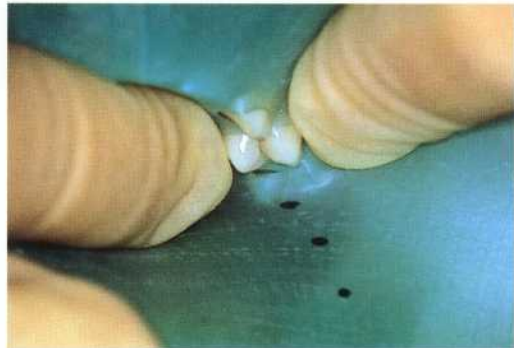


Fig 3-10d The rubber dam membrane is slid over the tooth.

Petroleum jelly, which is occasionally recommended, should not be used. An example of an appropriate water-soluble lubricant is glycerin gel (Air block, Dentsply, Konstanz, Germany).

The lower lip frequently gives rise to difficulties when applying rubber dam because it may be pressed against the mandibular anterior teeth when the mouth

is opened. Inserting a cotton roll into the mandibular anterior sulcus can create space to accommodate the rubber dam between lip and teeth. The cotton roll is left in the sulcus during treatment.

The step-by-step application and removal of rubber dam is illustrated in Figs 3-10a to 3-10p.

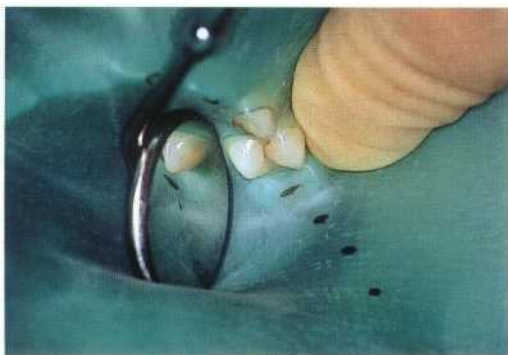


Fig 3-10e The index finger of the leading hand is replaced by a dental mirror.



Fig 3-10f The clamp is placed with the rubber dam forceps. The palatal jaw of the clamp is positioned first and kept in constant contact with the tooth. The buccal jaw of the clamp is then positioned.



Fig 3-10g Alternatively, rubber dam is held in position on the arch with the index and middle fingers of the nonleading hand if the operator has to work without assistance.



Fig 3-10h The second retainer is placed. Note that the middle finger stabilizes the palatal jaw of the clamp that is positioned first.



Fig 3-10i The dam is secured with the clamps. Now the membrane is passed through the contact points.

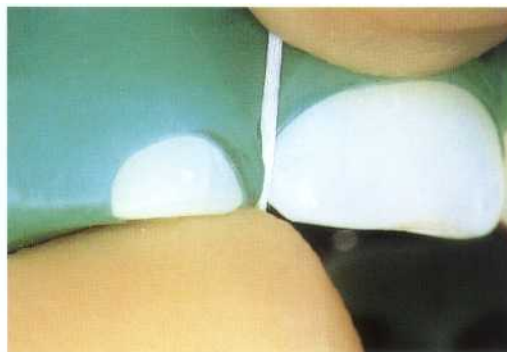


Fig 3-10j Dental floss can be used to pass the membrane through tight contacts points. It is important to start on one side and work around, pulling the dam apically.



Fig 3-10k As the membrane is pulled, it gets thinner and follows the dental floss. The floss is then removed buccally.



Fig 3-10l This procedure is repeated, passing the dam through consecutive contacts.



Fig 3-10m Rubber dam is inverted to complete the seal around the tooth. This is best accomplished interproximally with dental floss and buccally and lingually with a blunt instrument, eq, a beaver-tail bur-



Fig 3-10n Dental floss ligatures help to keep the rubber dam close to the gingival tissues.

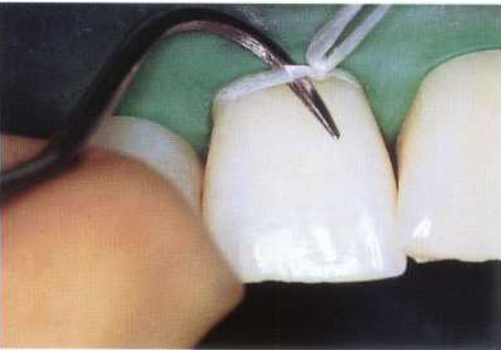


Fig 3-10o For the rubber dam to be removed, first the ligatures have to be cut. Using a scaler helps to avoid injuring the gingival tissues because it is usually difficult to cut a tight ligature with scissors.



Fig 3-10p The dam septa are cut with scissors while the rubber dam is pulled away from the gingival tissues and the tooth. Use dental floss to remove any rubber dam remnants.

## Summary

Rubber dam **facilitates the efficient, effective completion of operative** procedures. The application of rubber dam should not take more than 3 to 4 minutes. If circumstances preclude the placement of rubber dam in such a short period of time, one should

consider other forms of isolation, including cotton rolls, cellulose pads, or retraction cords combined with high-volume suction or saliva ejectors. The benefits to the operator and patient of using rubber dam include the opportunity to undertake treatment in a controlled, relaxed manner.

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## Tissue and Moisture Management in Operative Dentistry

Stefano Patroni

In the last 20 years, biological aspects of restorative dentistry have received a great deal of attention. This attention emanated from the experimental work of the Scandinavian periodontal research community.

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some therapeutic dogmas, including the principle of "extension for prevention" promoted by G.V. Black,<sup>4</sup> which dominated restorative dentistry for almost a century. Subsequently, many reviews have stressed the necessity for more biological thinking and the need for the revision of old-fashioned, mechanistic approaches to oral health care.

Achieving periodontal health sometimes seems diametrically opposed to the requirements of restorative dentistry. The mechanical prerequisites of occlusal reduction and length of preparation are more predictably managed when the margin of the restoration can be placed supragingivally. However, interocclusal space limitations, previous hard tissue destruction, esthetic considerations, exposed margins, and "black triangles" can create a great challenge for the restorative dentist.<sup>14</sup>

It is well-known that periodontal damage may occur during the restorative

phase of treatment (Figs 4-1 to 4-3). Atraumatic manipulation of the periodontal tissues during retraction, tooth preparation, provisionalization, and the recording of final impressions are the keys to predictable tissue control and biologic integrity (Figs 4-4 to 4-7).

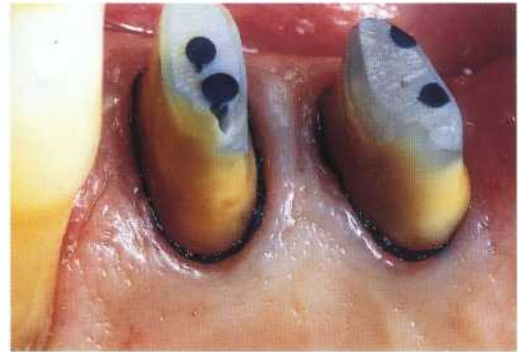
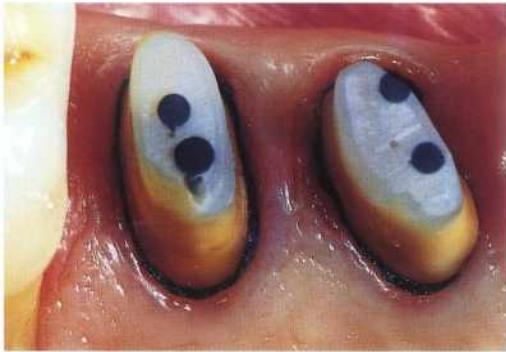
It is important to be aware that the position of the crown margin in relation to the gingiva can significantly affect the Gingival Index value as well as the gingival sulcus depth.<sup>2,23,26,27,32</sup> Subgingivally positioned crown margins are associated with the highest Gingival Index values, whereas supragingivally located crown margins are associated with the lowest values.<sup>23</sup>

In their studies, Renggli and Mormann<sup>20,24</sup> concluded that during cavity or crown preparation margins should be placed supragingivally whenever possible and restoration margins that have been placed subgingivally should be exposed. Valderhaug<sup>30,31,33,34</sup> showed that loss of the periodontal supporting apparatus was greater around teeth restored with subgingivally located crown margins than it was around those with crown margins located supragingivally. Other authors<sup>13,15,25</sup> claim, however, that a precise marginal crown fit





Figs 4-1 to 4-3 Following the "hygienic phase" of treatment, it is possible to prepare the tooth without damaging the periodontal tissues.



seems to be the prerequisite for the stability of the periodontal tissues around abutment teeth.

Valderhaug and Heloe<sup>34</sup> found that the incidence of caries is increased when restoration margins are located subgingivally. Lang et al<sup>16</sup> documented that, following the placement of restorations with overhanging margins, a subgingival flora that closely resembles that of chronic periodontitis may be detected. Thus, it is possible to conclude that there is no biologic reason to locate restoration margins subgingivally, only esthetic reasons.

Whenever restoration margins invade the periodontal attachment they violate

the biologic width<sup>7,19,29</sup> and cause damage to the periodontium, which results in loss of attachment.

Therefore, each time that it is necessary to restore a tooth that presents deep subgingival caries (Figs 4-8 and 4-9); a root fracture; root resorption or perforation; preexistent deep, subgingivally located preparation margins; or a short clinical crown, consideration should be given to surgical crown lengthening and/or forced orthodontic eruption<sup>9,10,28</sup> to avoid any impingement upon the biologic width.

Surgical crown lengthening has been described as a procedure similar to an apically repositioned flap with concomitant



**Figs 4-4 and 4-5** A further example of atraumatic manipulation of the periodontal tissues. No bleeding is present following retraction and tooth preparation.



**Figs 4-6 and 4-7** After 4 weeks, at the time of the try-in of the casting, it is possible to observe the preservation of tissue health.



**Figs 4-8 and 4-9** Radiographic examination reveals a deeply located lesion of caries in the distal aspect of 36. It is evident that it will only be possible to restore the tooth after a surgical crown-lengthening procedure.

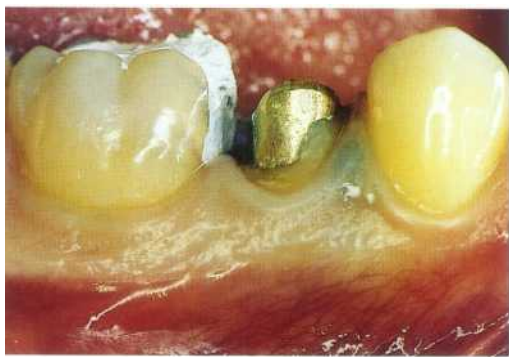


Fig 4-10 Tooth 45 presents a short clinical crown. Tooth 46 includes a deep cavity invading the periodontal attachment.

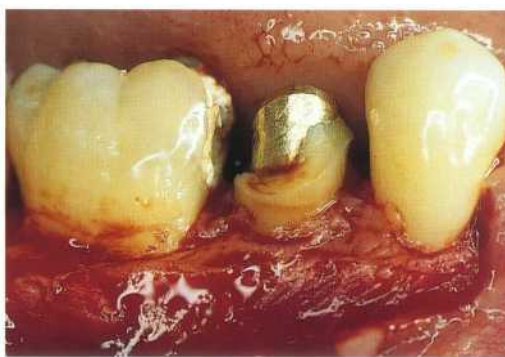


Fig 4-11 Flap design: a partial-thickness flap is elevated.

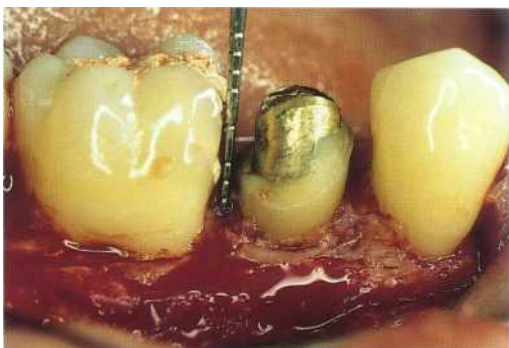


Fig 4-12 Measurement of the distance between gingival margin and the bony crest.

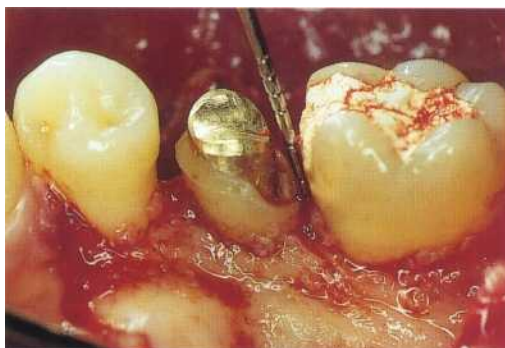
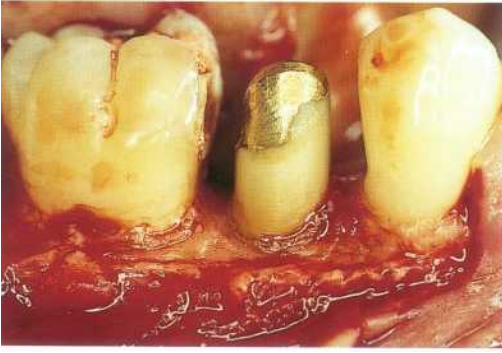


Fig 4-13 The root form and an exostosis are evident lingually.

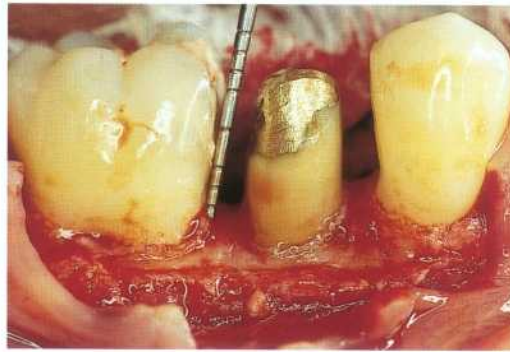
ostectomy and osteoplasty.<sup>1,6,11,12,22</sup> Proper flap design is an essential element of the surgical procedure (Figs 4-10 to 4-13), which generally involves a partial-thickness flap that can be extended to a partial-thickness flap.<sup>8</sup> The flap is scalloped and the newly created papillae are thinned to a thickness of approximately 1.5 mm. Following bony contouring, the flap is repositioned at the level of the bone margin or more apically through the use of periosteal vertical or horizontal mattress sutures (Figs 4-14 to 4-17).

Healing following osseous crown-lengthening surgery results in a junctional epithelium that extends to the apical level of the root planing.<sup>21</sup> Postsurgical resorption of the osseous crest creates space for supracrestal connective tissue.<sup>21</sup> A reduced apically relocated biologic width is reestablished following crown-lengthening surgery as reported by Caton and Nyman.<sup>5</sup> After a period of 3 to 6 months of tissue maturation, it is possible to perform the planned restorative procedures without violation of the biologic width (Figs 4-18 to 4-21, 4-22 and 4-23).





**Fig 4-14** The bony architecture after osteotomy and osteoplasty.



**Fig 4-15** The surgical measurement of the distance between the cavity margin and the bone level after osteotomy.



**Fig 4-16** The lingual aspect of the surgical field after osteotomy and osteoplasty. The root of 45 was prepared distally to create more space between 45 and 46.



**Fig 4-17** The flap is positioned adjacent to the bone level using vertical periosteal mattress sutures.



**Fig 4-18** The buccal aspect 5 months after surgery.



**Fig 4-19** The lingual aspect 5 months after surgery.



Figs 4-20 and 4-21 The integrity of the periodontium has not been violated by the careful placement of the margin of the metal ceramic crown on 45.



Fig 4-22 Bioesthetic, intracrevicular metal ceramic crowns on maxillary central incisors. The adjacent periodontal tissues are preserved despite the intracrevicular placement of the crown margins.



Fig 423 The biologic width has not been violated by the placement of the metal ceramic crowns.



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## Esthetic Anterior Restorations

Jean-Francois Roulet and Roberto Spreafico

### Introduction

The rate of development of materials and application techniques in the last 15 years has enabled the dentist to fulfill the highest esthetic requirements of our patients, ie, to place "invisible" or imperceptible restorations. Dentists can produce natural-looking restorations that comply with Garber's maxim: "The game is to make the artificial look natural" (Garber DA, personal communication, 1989). The result of these developments is that the dentist can restore teeth following the principle of minimal invasiveness, ie, maintaining as much sound tooth tissue as possible. A few examples demonstrate the possibilities:

Patient 1 (Figs 5-1a to 5-1d): This patient was bothered with diastemata, which developed following periodontal treatment. Using enamel bonding techniques, the shape of the teeth was changed to make them larger and to close the diastema (treated by Dr. S. Herder).

Patient 2 (Figs 5-2a to 5-2f): This 11-year-old girl fell from her bicycle and fractured the incisal edge of tooth 11. The parents

brought along one fragment; the pulp was exposed. After direct pulpal capping, the fragment was bonded to the remaining tooth and the missing fragment reconstructed with composite (treated by Prof. M. Degrange).

Patient 3 (Figs 5-3a to 5-3e): Following trauma, the incisal edge of tooth 21 was reconstructed with composite in 1991. Nine years later a second blow displaced the tooth approximately 1 mm palatally, and pulp necrosis and discoloration followed. Root canal treatment failed despite a satisfactory initial outcome; therefore, an apicectomy was performed. After the restoration was appropriately placed, it reflected the color shift of the tooth (Fig 5-3d). After bleaching, the tooth had the same color as the adjacent teeth. In addition, the restoration had undergone a chameleon-type color shift.

### Progress in Materials Development

With the introduction of light-curing technology,<sup>2,6</sup> the color of composites became very stable because the initiator system no

Figs 5-1a to 5-1d Patient 1 (courtesy of Dr. S. Herder).



Fig 5-1a Diastema after periodontal treatment (right side).



Fig 5-1b Diastema after periodontal treatment (left side).



Fig 5-1c After reconstruction with composite and adhesive technique. Note that the teeth were not veneered; composite was added only to the proximal surfaces.



Fig 5-1d Side view.

**Figs 5-2a to 5-2f Patient 2** (courtesy of Prof. M. Degrange).



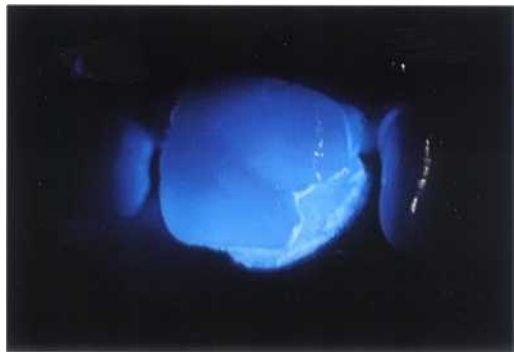
**Fig 5-2a Eleven-year-old girl after bicycle accident.** Incisal edge of tooth 11 is severely fractured.



**Fig 5-2b** Isolation of the operative field with rubber dam.



**Fig 5-2c** Direct pulp capping with calcium hydroxide cement.



**Fig 5-2d** A fragment was bonded to the remaining tooth tissues. The remaining defect was reconstructed with composite.



**Fig 5-2e** Postoperative view.



**Fig 5-2f** After 1.5 years.



Figs 5-3a to 5-3e Patient 3.



Fig 5-3a Patient in 1991 following reconstruction.



Fig 5-3b Close-up view of reconstruction. The finishing line is just visible.



Fig 5-3c Root canal treatment after palatal dislocation of the tooth, which was followed by pulp necrosis (2000).



Fig 5-3d Situation after apicectomy. The tooth is discolored. Note that the restoration is indistinguishable.



Fig 5-3e Same tooth after bleaching. Note that it is almost the same color as the adjacent teeth and that the restoration is still indistinguishable.

longer decomposed into colored (brown or yellow) compounds.<sup>9</sup> Furthermore, once chairside mixing was eliminated, the materials were almost free of voids,<sup>10</sup> which minimized pigment trapping in the material's surface. Light curing substantially reduced the polymerization time, which opened the way for the layering technique to become a cornerstone in the provision of esthetic restorations. In the late 1980s, manufacturers had started to produce composites in both different colors and different opacities (Herculite, Kerr; Tetric Ceram, Vivadent, Schaan, Liechtenstein; Enamel Plus HFO, Micerium srl, Italy; Esthet!X, Dentsply, Konstanz, Germany), which made the esthetic qualities of a restoration more predictable. In the last 20 years, the filler technology for composites has been greatly improved. Modern small-particle hybrid composites show stable optical surface characteristics that are close to those of enamel.<sup>11</sup>

## Progress in Adhesive Technology

Following the introduction of the enamel etching technique by Buonocore,<sup>1</sup> it was many years until well-defined application procedures and principles were determined and then widely applied in daily dental practice.<sup>3,8</sup> Based on this research, it was apparent that to obtain optimal marginal morphology, bevels had to be placed in enamel margins. Furthermore, it became clear that enamel unsupported by dentin did not have to be removed, as is the case with classical, nonadhesive restorative techniques. This opened the way for the preservation of buccal enamel

in proximal proportions, thereby minimizing the visible portion of the restoration and improving esthetic outcomes.

In the early 1980s, manufacturers began to market dentin adhesives. However, only once the basic principles were thoroughly understood<sup>5</sup> was reliability achieved. With today's dental adhesives it is possible to obtain a micromechanical retention in dentin with various application techniques.

## Basic Principles for the Provision of Esthetic Anterior Restorations

A natural tooth shows many different features (Fig 5-4), that should be mimicked in a natural-looking restoration. In natural teeth, the color comes from within, not from the surface (Figs 5-5, 5-6a, and 5-6b). It is therefore necessary to replace dentin with an opaque "dentin-composite" and enamel with a more transparent/translucent "enamel-composite." Special effects can be obtained in the incisal area using transparent composites. This approach forms the basis of the layering concept for anterior restorations (Figs 5-7a to 5-7h). There is a simple way to understand the opacities of different composite materials and their use in creating natural-looking restorations. Take an impression of the palatal aspect of an extracted incisor. Use this form to produce a composite tooth using the layering technique (Figs 5-8a to 5-8f).

An enamel bevel with no definite finishing line is very important to achieve optimal esthetics (Fig 5-9). It creates a continuous transition from the tooth color into the composite color, which never matches the



Fig 5-4 Natural incisor. Note the optical features: Cervically the color is darker and more brownish/orange than in the body portion. In the incisal area the enamel appears bluish because of the dark background of the oral cavity shining through. The incisal edge is shiny yellow because of light reflections in the almost transparent enamel. Also visible are the mamelons, which are dentinal protuberances that taper toward the incisal edge, shining through the enamel. This tooth has some white stria in its body and a white spot in the incisal (courtesy of Dr. G. Losche).

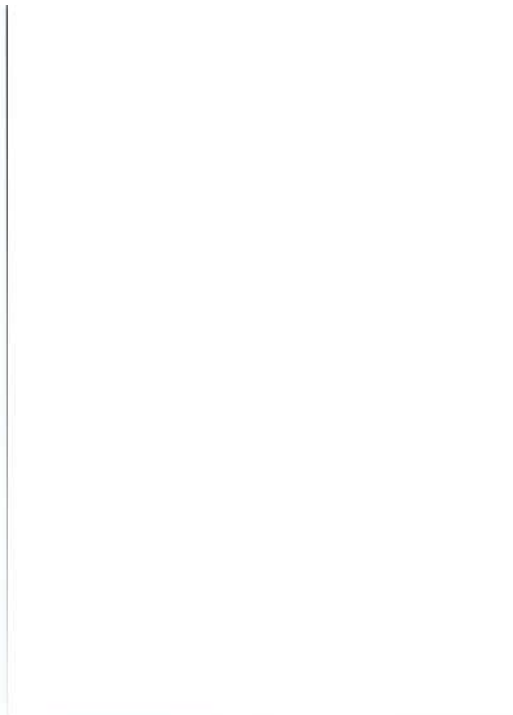


Fig 5-5 Cross section of an anterior tooth illuminated by a laser beam. Note that the light penetrates the enamel layer and is then dispersed in the dentin, immediately under the transparent limiting dentinal layer and next to the dentinoenamel junction. Therefore, the color of the natural tooth comes more from the dentin than from the enamel (surface) (courtesy of Dr. G. Losche).

Figs 5-6a and 5-6b Incisor with all the palatal enamel and a large amount of the dentin removed.

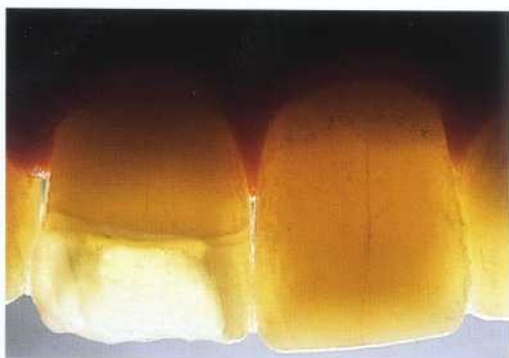


Fig 5-6a In transmitted light the tooth appears too light because the dentin, which contributes most to the tooth color, is missing.



Fig 5-6b In reflected light the tooth seems to be too dark because of the dark background of the oral cavity.

tooth color exactly. Therefore, the eye is deceived because it is best suited to perceive discrete changes (eg, a black line on a white background). If color changes are gradual, the eye has difficulty detecting them.

Finally, there is a phenomenon that may occur if a simple mistake is committed. Usually bonding agents are very transparent because they are unfilled. If such a bonding agent is applied in a thick layer (Fig 5-10), it may create a gray hue along the margin of an otherwise perfect restoration, which will then be visible (Fig 5-11). A means of preventing this phenomenon is to use a filled, tooth-colored bonding agent.

The human eye is also good at discerning structures. Therefore, one must include in the restoration the macro and micro surface features of natural teeth if the restoration is to blend into the surrounding tooth tissues. Such structures are created with diamond burs. Final polishing is then

accomplished with the Occlubrush (Hawe Neos, Switzerland).

A clinical case is illustrated in Figs 5-12a to 5-12i to demonstrate in detail the sequence of placing anterior restorations.

This 55-year-old female patient wished to have the appearance of her upper anterior teeth improved. The best option to fulfill the patient's esthetic expectations would be the provision of six ceramic veneers or crowns extending from canine to canine. Unfortunately, the patient could not afford such treatment and she decided to have the existing composite restorations in the central and lateral incisors and in the canines replaced. In this way, imperceptible restorations may be placed in anterior teeth. The challenge is to integrate the restorations with the remaining dental tissues. The difficulty lies (especially with the lateral incisor) in replicating the different colors evident in the remaining tooth tissues.

Figs 5-7a to 5-7g Layering technique for anterior restorations.



Fig 5-7a Preoperative view of a central incisor including an unesthetic white spot. To be as conservative as possible, careful removal of the white spot and a direct composite restoration was planned.



Fig 5-7b Two layers of composite, one enamel and the other transparent, were layered on the spatula to check the color matching.



Fig 5-7c The cavity is prepared. Because the preparation is contained in enamel, an enamel-colored and transparent composite will be required.

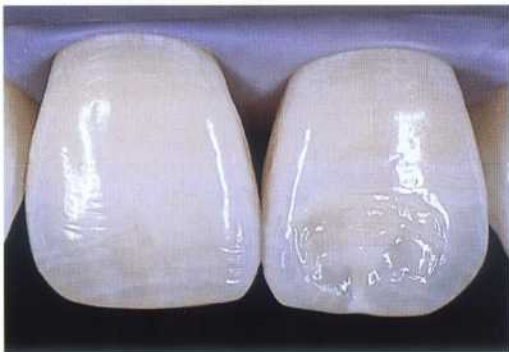


Fig 5-7d The initial increment of composite is placed and contained prior to light curing.





Fig 5-7e Some white stain is placed in the contours of the initial increment and polymerized to replicate the white lines present in the adjacent tooth.

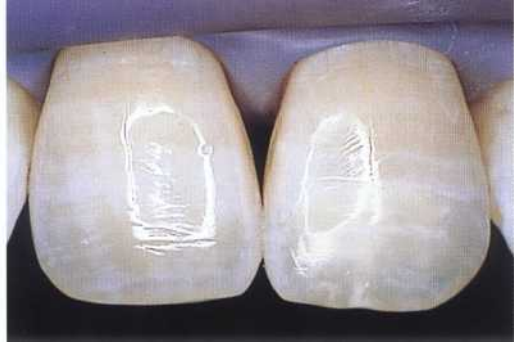


Fig 5-7f The restoration is completed with a layer of transparent composite, contouring, and finishing.



Figs 5-7g and 5-7h The restored tooth 2 weeks later. Note the good esthetic integration of the restoration with the surrounding tissues, the adjacent tooth, and the oral environment.



Figs 5-8a to 5-8f An exercise in the application of the layering technique: the step by step production of a composite tooth.

Fig 5-8a A good exercise in learning how to layer composite is to produce a composite tooth. A silicon mold is obtained from a natural tooth. An initial thin layer of a translucent composite is placed in the palatal aspect of the silicon mold and light cured.



Fig 5-8b The composite shell is removed from the silicon mold.



Fig 5-8c An opaque dentin composite is layered in the transparent shell; mamelons are created as found in an intact tooth.

Fig 5-8d It is very important to layer the dentin composite with a varying thickness. In the intact tooth, dentin is thickest in the cervical region, relatively thin in the middle of the tooth, and absent in the incisal region.



Fig 5-8e A layer of enamel composite is applied over the dentin, leaving the incisal portion and limiting layer to be formed of translucent composite.



Figs-8f Afterfinishing, microfeatu-  
res are created in the surface us-  
ing a diamond bur. The tooth is  
completed by polishing.



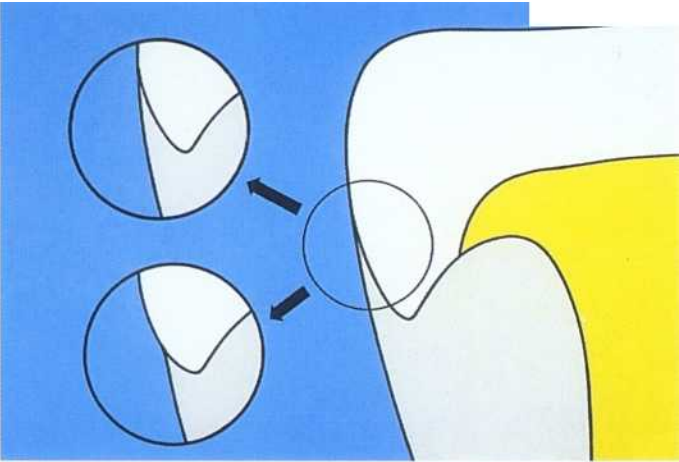


Fig 5-9 The importance of a bevel for esthetics. A bevel creates a gradual transition between the color of the tooth and the color of the composite, which never exactly match. In this way the eye is deceived to perceive good esthetics.

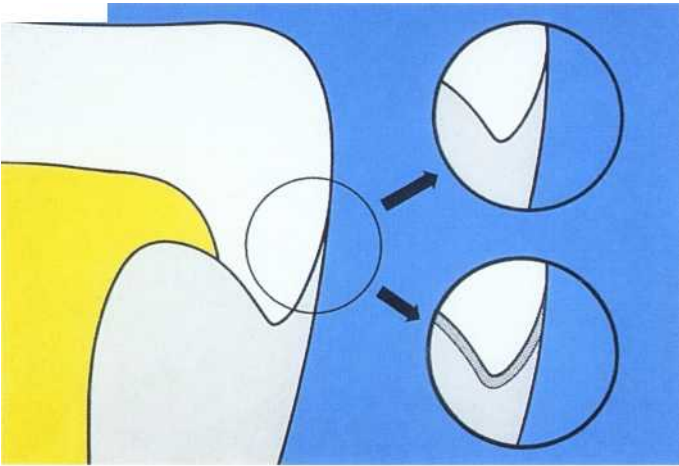


Fig 5-10 If a clear, transparent bonding resin is used, it must be applied in a thin layer, otherwise the restoration will have a gray hue to the finishing line.



Fig 5-11 Two Class III restorations in tooth 22. The mesial restoration is visible despite perfect morphology. This is caused by a thick layer of bonding resin creating a gray hue along the finishing line. The distal restoration blends in perfectly with the color of the tooth.

Figs 5-12a to 5-1211 Step-by-step illustration of a clinical case.



Fig 5-12a Preoperative view of teeth 21,22, and 23 requiring replacement composite restorations as a consequence of secondary caries and poor esthetics. Because the shape of 22 was judged to be acceptable, a silicon guide was obtained to facilitate the restoration of this tooth.



Fig 5-12b Following cavity preparation and prior to rubber dam placement, composite shades are tested on the tooth to confirm the color matching. An enamel composite is layered over a more opaque dentinal shade to confirm shade selection.



Fig 5-12c Following the application of rubber dam, cavity preparation is completed.



Fig 5-12d The previously prepared silicon guide is applied palatally. The guide seems to restore the form of the tooth. An initial layer of enamel composite (shade A3) is applied to the silicon stent and the margins of the preparations. Following light curing of the initial increment of composite, the stent is removed.



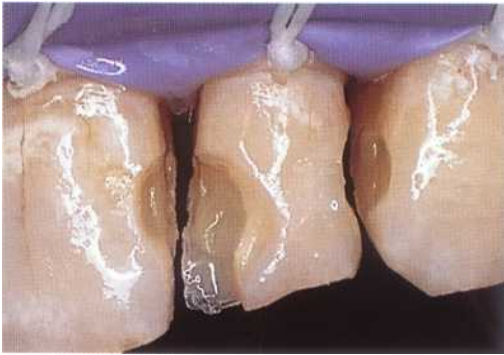


Fig 5-12e A dentin composite (shade A 3.5) is layered in the cervical area of the tooth (22) and in the other Class III preparations.

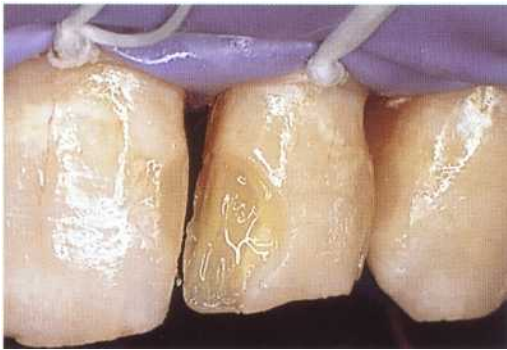


Fig 5-12f The Class III restorations are completed with a layer of enamel composite (shade A3). Further incremental layers of dentinal composite (shades A3 cervically and A2 incisally) are placed in tooth 22.

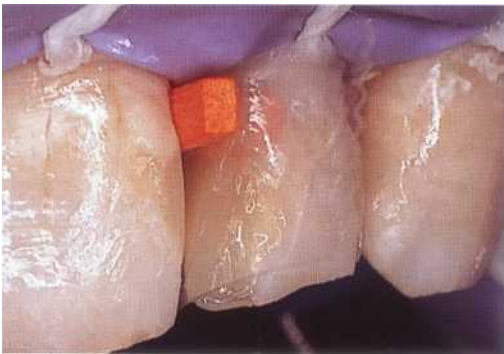


Fig 5-12g The clear matrix band is applied and secured with a wooden wedge to build up the proximal surface. Two increments of enamel composite (shade A3 cervically and A2 coronally) are applied.



Fig 5-12h The restored teeth after finishing and polishing. The restorations appear darker because of the dehydration of the remaining tooth tissues. With dehydration enamel becomes more opaque and lighter.



Fig 5-12i The restored teeth 1 month later. The restorations are fully integrated with the surrounding dental tissues.

## Conclusions

With modern composites and the application of the techniques described in this chapter, it is possible to place imperceptible restorations that satisfy the most demanding esthetic requirements and patient expectations. Furthermore, existing literature indicates that such restorations may have excellent longevity.<sup>4</sup> However,

the provision of imperceptible, long-lasting restorations demands a high degree of skill and considerable time and effort, with significant cost consequences in relation to the fees for the treatment. In the absence of suitable remuneration, as is common in nationally funded schemes in many countries in Europe, it is impossible to provide restoration of the type described to every patient.

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## Direct Posterior Restorations- Techniques for Effective Placement

Guido Goracci

### Introduction

Silver amalgam has for many years been the restorative material of primary importance in conservative dentistry. In addition to favorable clinical properties and ease of use, dental amalgam is versatile and economical in use. However, the introduction of esthetic restorative materials with enhanced properties, together with recent controversies concerning the toxicity of mercury, have resulted in a reevaluation of the role of amalgam in everyday clinical practice. This reevaluation has resulted in current composite resins being viewed as substitutes for amalgam in the provision of direct restorations in posterior teeth.<sup>20,23</sup>

### Advances in Composite Restorations

Restorations composed of early forms of composite resins had two principal problems: poor wear resistance limiting their use to anterior locations in non-load-bearing situations (Fig 6-1) and lack of adhesion to dental structures.<sup>1,2,4</sup> In addition, marked polymerization shrinkage resulted in marginal gap formation and bacterial leakage (Figs 6-2

and 6-3) with a high risk of recurrent caries.<sup>14</sup>

Contemporary hybrid composites with high levels of filler loading have, in contrast, good wear resistance and excellent mechanical properties.<sup>3</sup> Problems related to the excessive occlusal wear of composite restorations under occlusal loading have been largely eliminated. To overcome problems of marginal gap formation and microleakage associated with the polymerization contraction of composite resins,<sup>14</sup> new bonding systems with high bond strengths to dentin have been developed. These systems allow for the simultaneous etching of dentin and enamel (Figs 6-4 and 6-5) with the removal of the smear layer ("total etching") (Figs 6-6 to 6-8), creating opportunity for micromechanical bonding to enamel and chemical micromechanical bonding to dentin (Figs 6-9 to 6-15).<sup>18</sup> The chemical bond to dentin is mediated by the bifunctional molecules of the substrate primer. The micromechanical bond to dentin is formed by the penetration of the resin into the tubules, creating tags and a resin-dentin inter-diffusing area called the "hybrid layer" (see Fig 6-12).<sup>24</sup> The features of a hybrid layer, formed by the penetration of liquid resin into the limiting layer of the etched dentin,



Fig 6-1 Occlusal wear in a composite restoration in a posterior tooth.

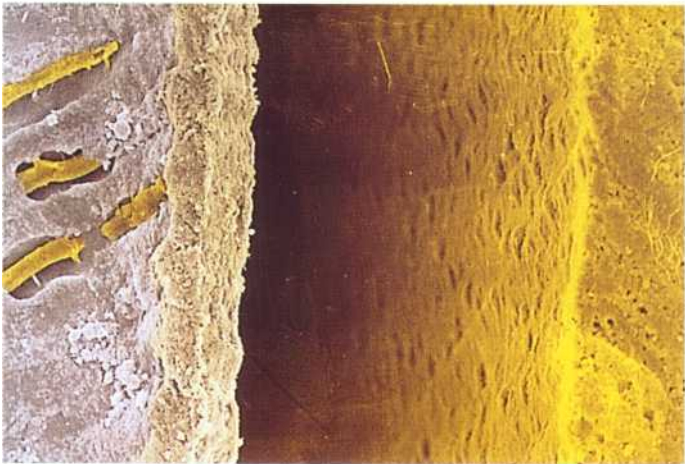


Fig 6-2 Evidence of microleakage between composite and dentin (original magnification X 1,000).



Fig 6-3 A dentinal tubule containing bacteria (original magnification X 13,000).



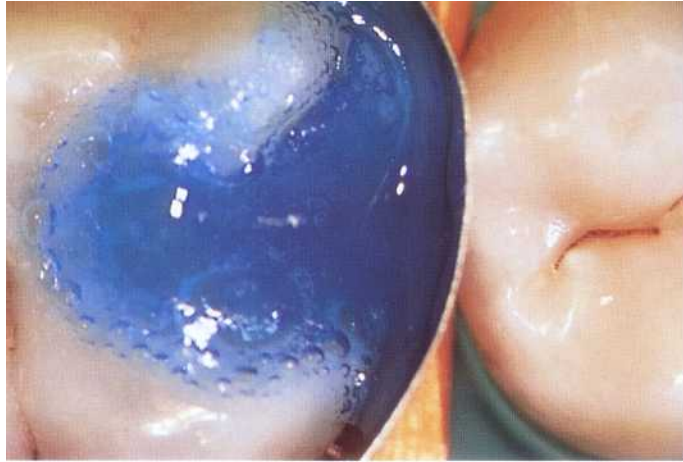


Fig 6-4 Simultaneous etching of enamel and dentin.

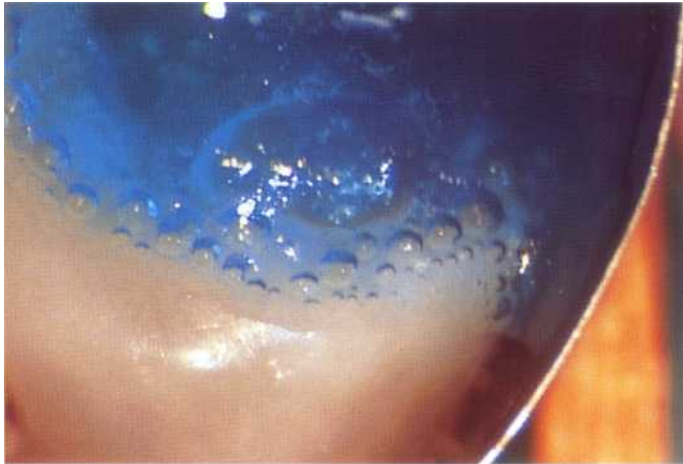


Fig 6-5 Details of the etching of enamel.

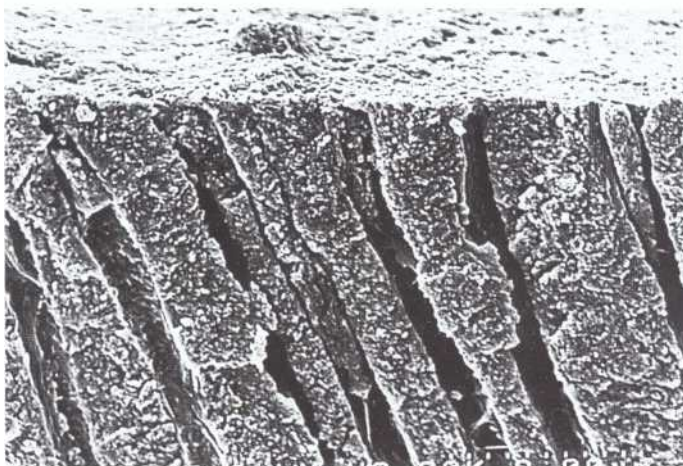


Fig 6-6 Fractured dentinal surface. Note the smear plugs in the dentinal tubules (original magnification x 2,000).

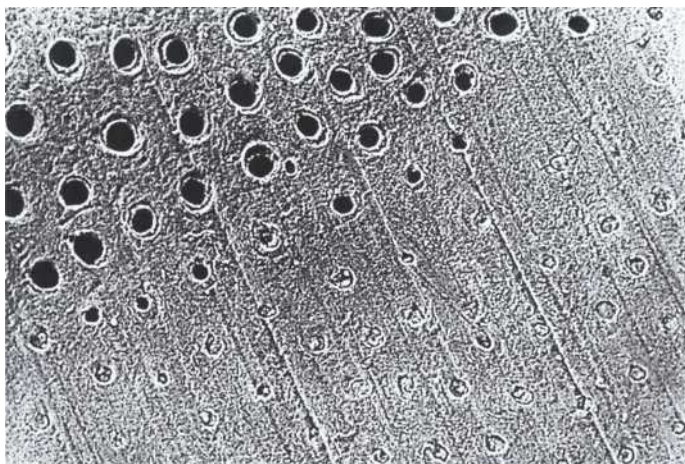


Fig 6-7 The dentin in the upper part of the illustration was etched with 37% phosphoric acid for 15 seconds. Note the removal of the smear layer (original magnification X 1,000).

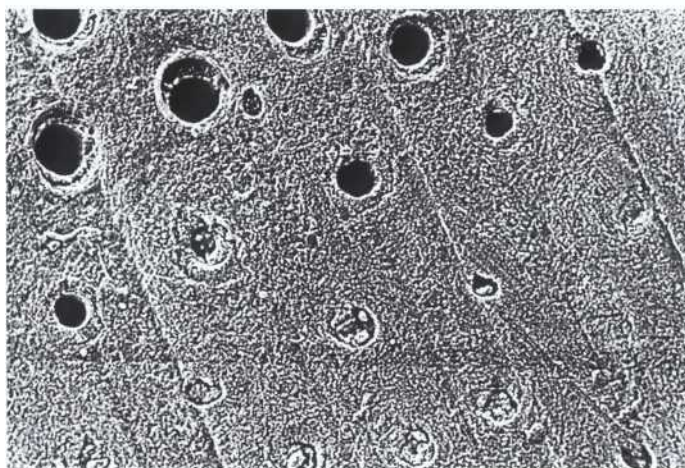


Fig 6-8 Detail of Fig 6-7 (original magnification X 2,000).

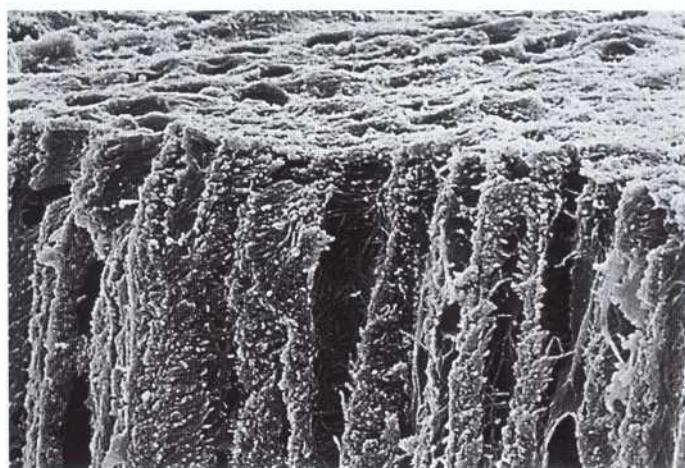
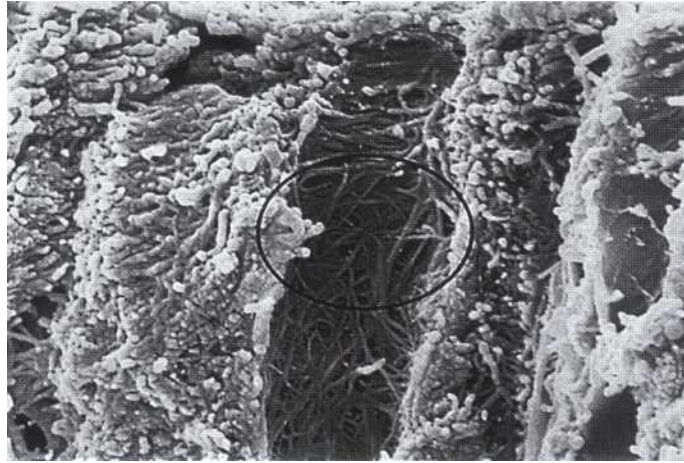


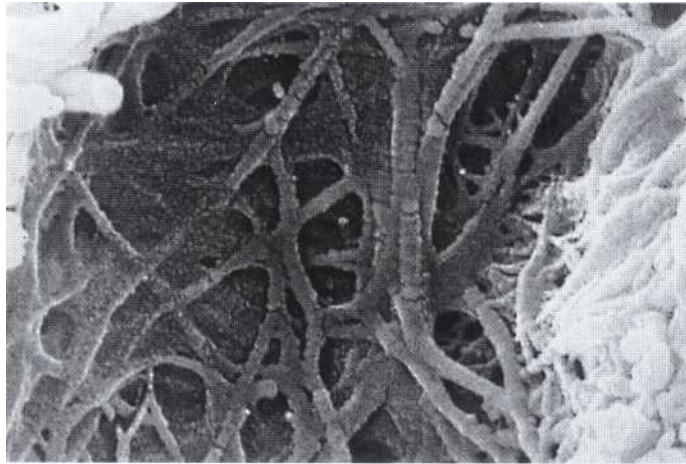
Fig 6-9 Etched dentin fractured longitudinally in the direction of the dentinal tubules. The exposure of collagen fibers is evident (original magnification X 2,000).



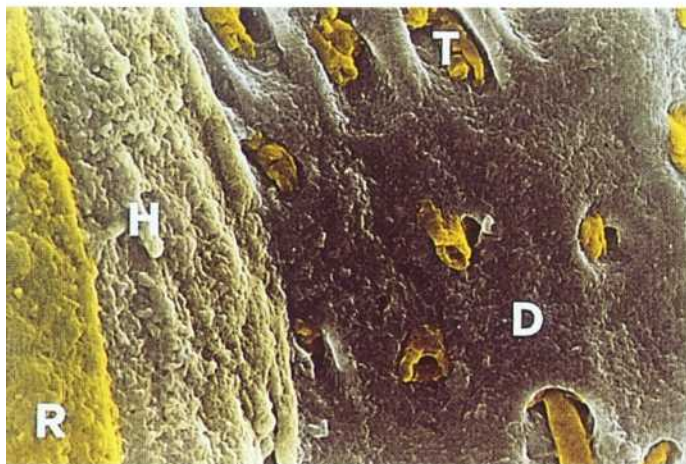
**Fig 6-10** Fractured dentin. Note the removal of the peritubular dentin and the exposure of the collagen fibers of the intertubular dentin (original magnification x 5,000).



**Fig 6-11** Details of the collagen fiber network (original magnification X 20,000).



**Fig 6-12** A replica of a resin-composite interface (original magnification X 2,000) (T, resin tags; H, hybrid layer; D, dentin; R, resin).



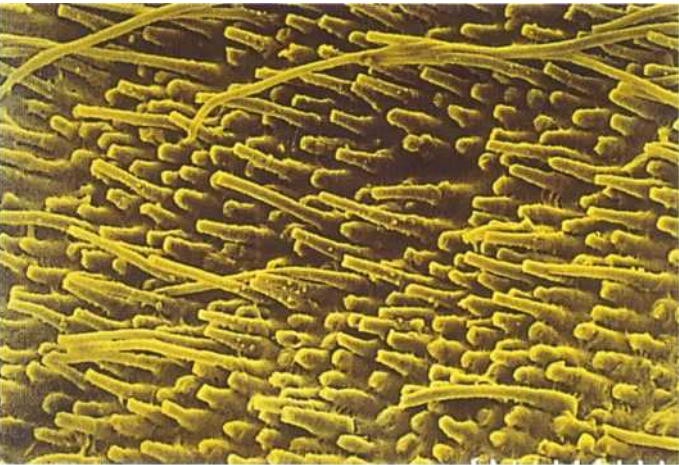


Fig 6-13 Composite resin tags  
(original magnification x 500).

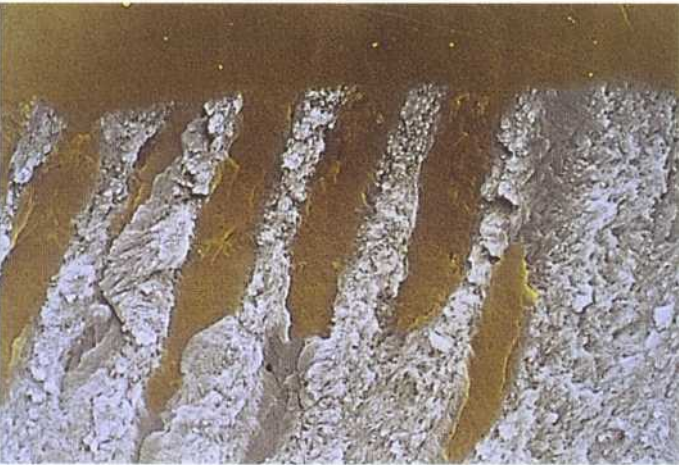


Fig 6-14 Fractured dentinal surface. Note the resin penetration into the dentinal tubules (original magnification x 2,000).



Fig 6-16 Composite-dentin inter-  
face (original magnification x  
2,000).

depend on the relationship between the depth of action of the etching acid and the capacity of the resin to penetrate the conditioned dentin.<sup>26</sup> An excellent tooth-restoration interface is created by the matching action of these two mechanisms.<sup>30</sup> Resin tags significantly increase the bonding area (see Figs 6-13 and 6-14), and the hybrid layer may provide an "elastic" layer between the restorative material and the underlying dental tissues (Fig 6-15).<sup>15,17,25,29</sup>

## Placement of Composite Restorations

With the use of appropriate adhesive systems, it is possible to place composite restorations without marginal gap formation.<sup>12</sup> Such developments have realized new horizons in conservative dentistry,<sup>11</sup> with clinical and laboratory research being directed towards the use of new forms of adhesive biomaterials for the provision of esthetic restorations in posterior teeth.<sup>16</sup> Numerous studies have demonstrated that composite resins are nontoxic and, when applied near the pulp, do not cause an adverse reaction<sup>6,11,17</sup>; most reactions under composite restorations are related to the presence of bacteria. The dental pulp is not adversely affected by the etching of dentin prior to the placement of a restoration (Figs 6-16 and 6-17).<sup>15</sup>

The use of a dental adhesive allows the preservation of remaining tooth tissues because it limits the need for retentive features within a preparation.<sup>5</sup> It remains important, however, to remove all frank carious dentin (Fig 6-18). This may be facilitated by the use of caries detectors (Figs 6-19 to 6-22).<sup>13</sup>

To optimize the bond between resin and dentin, it is important to use proprietary etchants of sufficient strength. The use of low-concentration etchants that are incompatible with the adhesive system may not eliminate the peritubular dentin and result in resin tags, which are not adherent to the dentin.

After etching, the cavity must be thoroughly washed. Following washing, it is important to avoid excessive drying of the dentinal surfaces. Such drying results in the collapse of the collagen network exposed by etching and may give rise to nanoleakage between resin and dentin in clinical service.<sup>21</sup> Appropriate drying of the dentin is achieved using Kanca's so-called "gentle dry" for 3 seconds.<sup>22</sup>

For the placement of composite material in a Class II preparation, it is considered best to use a metal matrix and plastic wedges to facilitate the restoration of the proximal anatomy and contact area. Subject to confirmation of the findings of the recent study by Versluis et al<sup>32</sup> which indicate that the direction of the application of the curing light does not influence the direction of polymerisation shrinkage, it may prove possible to dispense with plastic matrices, reflecting wedges, and the requirements to have multidirectional applications of the curing light.<sup>27,28</sup>

According to the work of Davidson et al,<sup>8</sup> an increment of composite should not exceed 2 mm in depth. In another important study, Versluis et al explain that the degree of polymerization tends to be uniform following appropriate illumination and that the thickness of an increment depends on the intensity of the activating unit.<sup>31</sup> A recent study by Goracci et al indicates that the depth of cure that can be achieved with a light output intensity of





Fig 6-16 Histological section of an extracted tooth 30 days after cavity preparation, etching of the preparation with phosphoric acid (15 seconds), and restoration using Bisico One Step Adhesive. No pulpal inflammation is apparent. Reparative dentin is present subjacent to the dentinal tubules cut during cavity preparation.



Fig 6-17 Details of the reparative dentin.

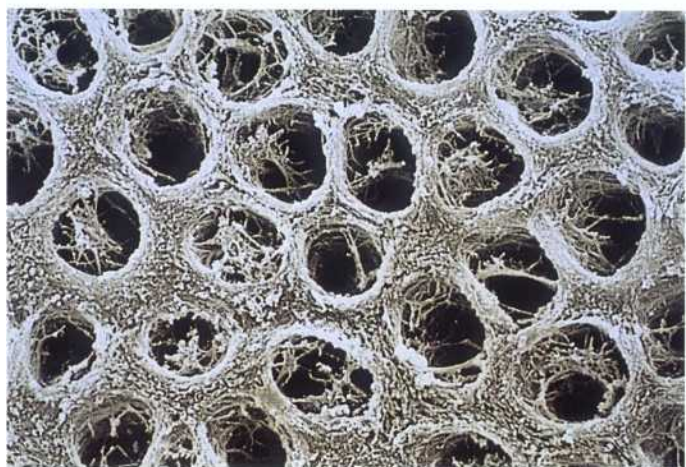


Fig 6-18 Demineralized carious dentin (original magnification X 1,000).



Fig 6-19 Cavex caries detector.

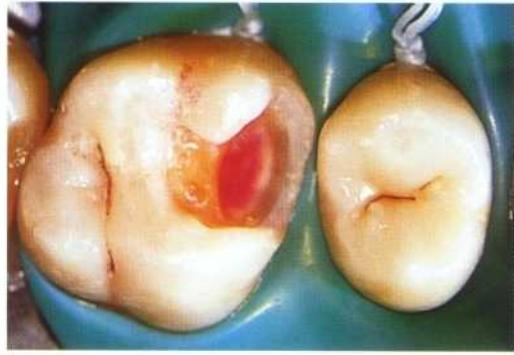


Fig 6-20 The caries detector discloses caries in dentin and increases the likelihood of conservative cavity preparation.



Fig 6-21 Detail of caries in dentin identified with caries detector.



Fig 6-22 Detail of the preparation following caries removal.

500/600 mW/cm<sup>2</sup> is 4 mm (unpublished data).

Regarding the nature of the polymerization process, curing light intensity may influence the marginal integrity and seal of composite resin restorations.<sup>19</sup> The use of a light-curing technique involving a gradually increasing exposure to the polymerizing light has advantages in terms of enhancing the adaptation of the composite to the preparation (Fig 6-23).<sup>7,8</sup> Such findings may be confirmed by scanning electron microscopic examinations of replicas

of tooth-restoration interfaces (Figs 6-24 and 6-25).

On the basis of these findings, new light-curing units have been produced to allow the polymerization of restorations of composite resins with light of increasing intensity.<sup>9,10,25</sup> The use of these lights helps to minimize stresses associated with polymerization.

The restoration of a permanent mandibular first molar using the techniques described for preparation, etching, wet bonding, and polymerization is illus-





Fig 6-23 Modified lamp with provision to regulate the intensity of the light emitted.

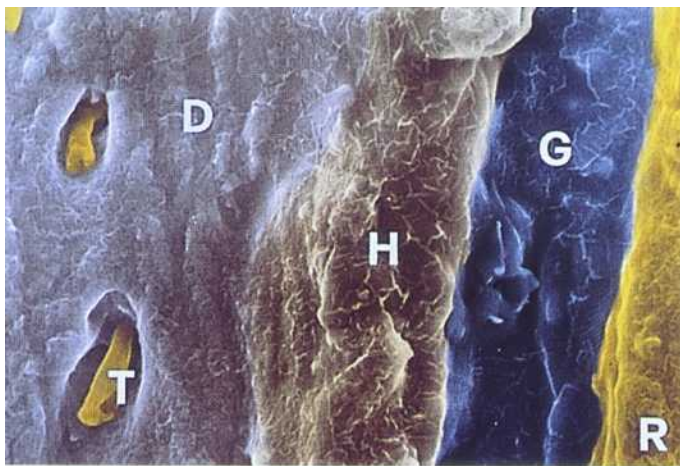


Fig 6-24 A replica of a restoration polymerized using a conventional technique ( $400 \text{ mW/cm}^2$  for 40 seconds). The polymerization contraction has produced a  $10\text{-}\mu\text{m}$  microgap between dentin and resin (original magnification  $\times 2,500$ ) (T, resin tags; H, hybrid layer; G, microgap; D, dentin; R, resin).



Fig 6-25 A replica of a restoration polymerized with progressive increase of light intensity ( $0\text{-}400 \text{ mW/cm}^2$  for 30 seconds, then  $400 \text{ mW/cm}^2$  for 20 seconds). The resin composite is perfectly adapted to the dentinal surface (original magnification  $\times 2,000$ ).

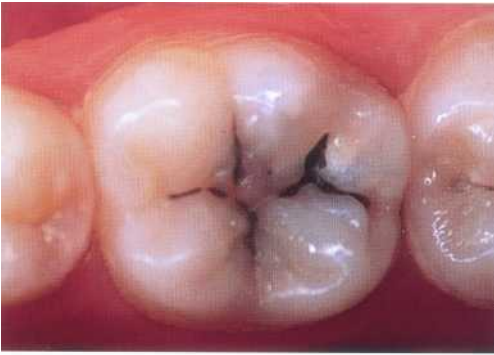


Fig 6-26 Caries in a permanent mandibular first molar.

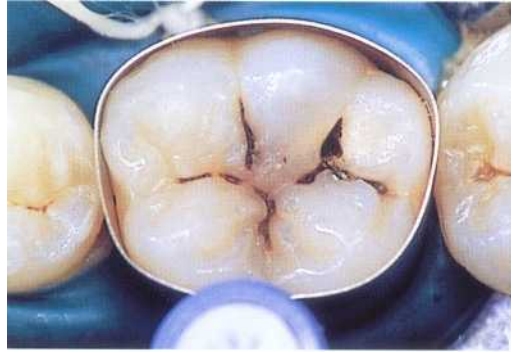


Fig 6-27 Isolation with rubber dam.



Fig 6-28 Reproduction of occlusal morphology using an occlusal index of transparent silicone impression material.



Fig 6-29 Occlusal index removed.

trated in Figs 6-26 to 6-35. The anatomic form of such a composite resin restoration may be readily reproduced using an occlusal index formed prior to cavity preparation (Figs 6-28 and 6-29) and repositioned on the tooth after placement of the composite material (Fig 6-33). The effectiveness of this technique is illustrated in Figs 6-34 and 6-35. Any cusp or marginal ridge lost or damaged must be reconstructed in wax prior to forming the index.

The technique is efficient and effective and may contribute to improving the quality and the subsequent clinical performance of posterior composite restorations.

The use of composites in posterior teeth continues to be a challenge to many clinicians. Ease and the speed of placement of posterior composite and the subsequent in-service performance of such restorations may be enhanced with the application of the techniques described.

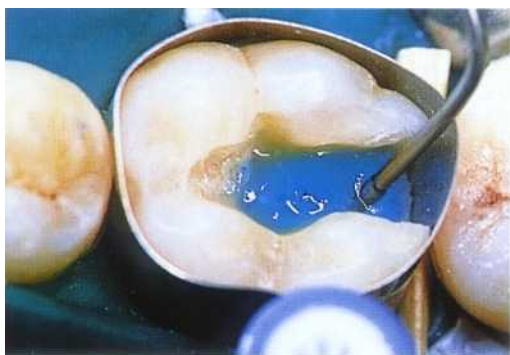


Fig 6-30 Application of etchant to the completed preparation.



Fig 6-31 Etching for 15 seconds.



Fig 6-32 Excess water removed with a brief blast of air, leaving the dentin slightly moist.

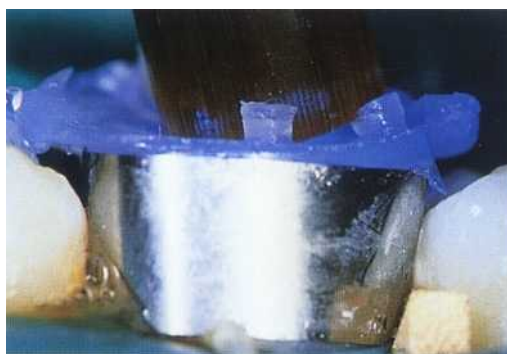


Fig 6-33 Polymerization of the final increment of composite through the transparent matrix.



Fig 6-34 Restoration after matrix removal.



Fig 6-35 Finished restoration. The anatomy of the occlusal surface has been reproduced.



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# The "Composite-up" Technique: A Simple Approach to Direct Posterior Restorations

Gilles F. Koubi, Stefan Koubi, and Jean-Louis Brouillet

## Introduction

The purpose of this chapter is to report a novel technique for the placement of esthetic composite resin restorations in posterior teeth. The advantages of direct composite restorations in posterior teeth include the preservation of remaining, sound tooth tissues. The indications for direct composites in posterior teeth include Class I and II restorations in premolars and Class I and small to moderate Class II restorations in permanent molar teeth. All posterior composite restorations should be placed under rubber dam, with the provision of such restorations involving four phases of treatment:

1. Cavity preparation and hybridization of the dentin to effectively protect the pulp-dentin complex.
2. Prewedging and the placement of a thin sectional, precontoured metal matrix to facilitate the formation of proximal contact points.
3. Placement of a chemically self-cured flowable composite in the base of the cavity to speed up the restorative procedure and limit stresses associated with polymerization shrinkage.

4. Restoration of the occlusal portion using the "composite-up" technique. The composite-up technique involves a multi-increment approach in which each increment is light cured for 3 seconds. With the occlusal portion placed, the surface of the restoration is finished by applying and light curing (40 seconds) a thin layer of resin sealant to reduce microcracks.

The reluctance of patients to accept metallic restorations increases day by day, with a growing diffidence toward the continuing use of amalgam, which is suspected by some of being toxic. Fortunately, such developments are matched by refinement in the field of composite resins and adhesive bonding systems, providing substitutes for traditional restorative materials. Although modern composite resin systems are reliable, many general dental practitioners remain uncertain as to the applications and clinical procedures for the successful use of such materials in posterior teeth. This chapter describes a clinical protocol for the routine use of composite and related systems in the placement of Class II restorations.

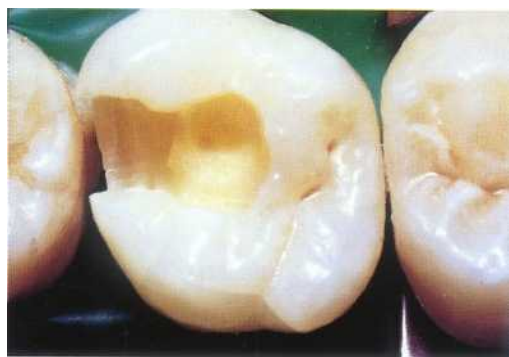


Fig 7-1 Occlusoproximal cavity in a maxillary first permanent molar.

## Indications

The indications for the use of composites in posterior teeth are limited to Class I restorations, Class II restorations in premolars and small- to moderate-sized Class II restorations in permanent molars. When restoring large complex Class II preparations, an indirect approach should be adopted. While composites can be placed on a deeply located cervical margin, assuming the margin is accessible, it is preferable to limit the application of composites to margins of enamel.

## Cavity Preparation

Cavity preparation should be linked to the removal of caries and finishing of the cavosurface margins. The preparations should be free of bevels with the cavosurface margins having a well-finished 90-degree configuration (Fig 7-1). The traditional principles of extension for prevention and creation of retention form, which were very costly of sound tooth tissues, have

been abandoned, given the efficacy of adhesive bonding systems that can ensure the bonding and sealing of composite materials to enamel-dentin substrates.<sup>11</sup>

## The Operative Procedure

Following the successful completion of cavity preparation, preceded by cleaning of the tooth with a slurry of pumice and water and the application of rubber dam, the operative procedure may be considered to comprise four stages:

1. Adhesion and biocompatibility measures
2. Reconstruction of the proximal surface(s) according to anatomic and physiologic requirements, including an appropriately located and formed contact point
3. Filling of the apical two thirds of the preparation
4. Restoration of the occlusal surface to ensure esthetics and function

## Adhesion and Biocompatibility Measures

Modern adhesive materials make it possible to bond to and seal dentin<sup>12,15</sup> and to create a hybrid layer,<sup>22,23</sup> which protects the pulp from bacterial, chemical, and physical insults that may give rise to pulpitis<sup>5,20</sup> and postoperative pain.<sup>7</sup>

Adhesive procedures involving the removal of the smear layer<sup>4,17</sup> are to be preferred given their superior performance and protection of the pulp. Such procedures involve (for a material such as All Bond II [Bisco Inc]): total etching (15 seconds),<sup>24</sup> thorough rinsing (20 seconds), a



Fig 7-2 Following the application of the adhesive, the placement of a metal matrix and wedges facilitates the restoration of the contact point.

15-second application of a biocompatible primer to moist dentin (wet bonding),<sup>10,13</sup> and application of the adhesive and subsequent light curing (30 seconds).

### Reconstruction of the Proximal Surfaces

Given their flexibility, transparent polyester matrices are difficult to position and control in the reconstruction of proximal surfaces. Metal matrix, which can be contoured, if not precontoured, can be accurately applied and adapted to cervical margins with wedges. Plastic wedges, given their greater hardness, should be preferred over wooden wedges. The wedges, if appropriately applied, also cause separation of the teeth and facilitate the formation of an appropriate contact point (Fig 7-2).



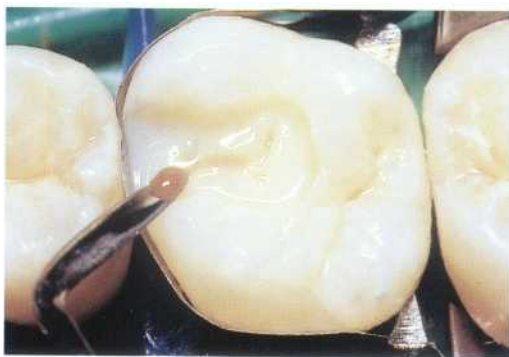
Fig 7-3 Injection of self-curing, flowable composite to fill the apical two thirds of the preparation.

### Filling of the Apical Two Thirds of the Preparation

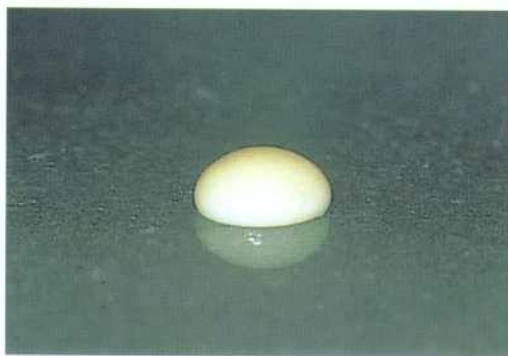
Composites shrink on polymerization, which is a principal limitation of such materials. Polymerization shrinkage gives rise to microleakage and the possibility of post-operative sensitivity and secondary caries.

The polymerization shrinkage of composite resins is mass-dependent, necessitating an incremental approach to the placement of light-cured composites.<sup>25</sup> The time and attention required to place a Class II composite restoration may be limited by a single application of a chemically self-curing composite resin in the base of the preparation, according to the technique of Bertolotti.<sup>2</sup> Using a flowable composite (eg, Bisfil 213, Bisco Inc) with a paste-paste presentation, the single application of self-curing composite may be made using an injection technique, filling the preparation to the level of the occlusal dentinoenamel junction<sup>21</sup> (Fig 7-3). Polymerization of the self-curing composite occurs within 2 minutes, leaving an oxygen-inhibited layer on the surface of the material. This layer contributes to the bond





**Fig 7-4** Use of tints to accentuate occlusal features in the restoration.



**Fig 7-5** Rounded contour of a small increment of composite.



**Fig 7-6** The viscous nature of the light-cured composite facilitates the creation of occlusal form.



**Fig 7-7** Spot light curing ( $>100\text{mW/cm}^2$ ) of the initial increment (3 seconds).



**Fig 7-8** Application of the second increment of light-curing composite.



**Fig 7-9** The development of the occlusal anatomy.



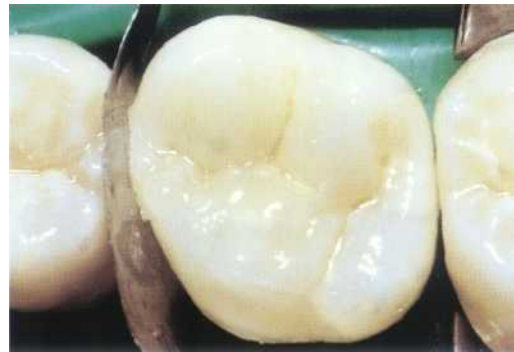
**Fig 7-10** The occlusal grooves and pits are highlighted with tints.



**Fig 7-11** Application of a thin layer of sealant to finish the surface of the restoration.



**Fig 7-12** Light curing ( $> 400\text{mW/cm}^2$ ) of the newly placed restoration (40 seconds).



**Fig 7-13** Following removal of the matrix, "fine finishing" may be required.



**Fig 7-14** Finishing of the restoration.



**Fig 7-15** The completed restoration.

between the self-curing material and subsequent increments of light-cured material applied to restore the occlusal portion of the restoration. Although self-curing composites suffer polymerization shrinkage, this shrinkage is less than that which occurs with light-cured composites<sup>4,15</sup> which may shrink to the extent that cervical debonding occurs. The activation of self-curing composites occurs relatively slowly, commencing where the material comes into contact with the relatively warm walls of the preparation. Shrinkage in association with these walls is, as a result, partially eliminated.<sup>8</sup> In addition, according to Garberoglio<sup>9</sup> and Alsten,<sup>1</sup> the numerous air inclusions in self-curing composites act as "absorbers" of shrinkage stresses, giving further advantages to self-curing materials.

## Restoration of the Occlusal Surface

Once the appropriate shades and color modifiers (Fig 7-4) for the light-curing composite have been selected, the occlusal section is restored incrementally. The viscous nature of light-cured composites helps give the necessary rounded form to cuspal features (Figs 7-5 and 7-6). After each application of a small increment of material, using, for example, a Hollenback carver, the composite is contoured and spot cured for 3 seconds, using a light with an intensity greater than 100mW/cm<sup>2</sup>, according to the "pulse delay technique" (Fig 7-7) as advocated for a material such as VIP (Bisco Inc).<sup>18,19</sup> Incremental buildup (Fig 7-8) gives control of cuspal form and allows the creation of pits and fissures (Fig 7-9), while facilitating good color match (Fig 7-10) To strengthen the surface of the

restoration and to reduce microcracks and other microscopic defects, a thin layer of a sealant (eg, Fortify, Bisco Inc) is applied (Fig 7-11) and the restoration is then light cured for 40 seconds with a light intensity greater than 400mW/cm<sup>2</sup> (Fig 7-12).

The composite-up technique is considered to reduce residual stresses in the restoration, in particular at the margins and along the walls of the preparation. The "C factor," as described by Feilzer et al,<sup>6</sup> is minimized (0.5 versus 5 for conventional techniques), limiting the formation of cracks in adjacent enamel. In addition, the controlled "soft polymerization" of the composite is considered to be advantageous.<sup>16</sup>

## Finishing

Finishing of the restoration is accomplished by removal of the wedges, matrix, and rubber dam and completion of any necessary occlusal refinements, cleaning, and polishing (Figs 7-13 to 7-15).

## Conclusions

The composite-up technique provides an effective state-of-the-art approach to the placement of Class II composite restorations, with consistent biologic, esthetic, and functional qualities.

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# Materials and Luting Cements for Indirect Restorations

Marco Ferrari, Alessandro Vichi, and Albert J. Feilzer

## Introduction

An important aim in restorative dentistry is to restore decayed and damaged teeth in such a way that the anatomy and function is reestablished and exposed dental tissues are protected against the infiltration of harmful fluids.<sup>2</sup> A further aim is a durable restoration. To realize this aim, the dentist can generally choose between a direct or indirect restorative technique. Traditionally, indirect gold restorations have been considered the most durable restorations. Today, direct adhesive restorations are in many cases a viable alternative; however, they are not without their shortcomings. When there is no adhesive bond between the restoration and the dental hard tissues, marginal gap formation will result from polymerization shrinkage. As a consequence, marginal leakage may occur with the inherent risk of secondary caries and postoperative sensitivity.<sup>22</sup> When a bond between the restorative material and tooth tissues is present, severe shrinkage stresses may develop in the restored tooth,<sup>9</sup> which puts the adhesion of the restoration to the cavity walls at risk. Postoperative sensitivity, cuspal flex-

ure, and crack formation in the enamel may be the first signs and symptoms of shrinkage stresses in the restored tooth unit. By using indirect techniques, many of these shortcomings may be avoided. Moreover, new dental materials and techniques have recently been introduced to facilitate the provision of indirect esthetic restorations with appropriate strength, biocompatibility, resistance to wear, and fit. Esthetic concerns have led to the introduction of a number of all-ceramic systems (eg, Dicor, Dentsply, York, PA; Vita Hi-Ceram, Vident, Baldwin Park, CA; Optec, Jeneric, Wallingford, CT; IPS Empress and Empress, Ivoclar, Schaan, Liechtenstein).

The aim of this paper is to provide an overview of esthetic materials for indirect restorative techniques.

## Esthetic Materials for Indirect Techniques

### Ceramics, Glasses, and Porcelains

Porcelain is an esthetic material that has been used as a dental restorative material for more than 150 years. Historically, the

use of porcelain as a restorative material was limited because of its brittleness and lack of elasticity. The development of new production techniques and adhesive cements have, however, resulted in dental porcelains enjoying a successful revival.

A ceramic is a material that consists of a compound of a metal with a nonmetal, often an oxide, that exists in a crystalline phase in an amorphous glass matrix. A porcelain is an opaque, nonfusing combination of silica and potash, while glass is a translucent, fusing combination of silica and potash. A glass can have the same composition as a ceramic, but it lacks the crystalline phase. Glasses can be cast using a method that is similar to that used for metal alloys. After casting, restorations of glasses undergo a "ceramming" procedure in an oven during which a crystalline phase develops. The manufacturers add some impurities to the glasses to facilitate the ceramming process.

Currently dentists can choose one of several materials for the production of an indirect ceramic restoration. To ensure a strong and durable porcelain restoration, it is necessary to make provision for a minimum restoration thickness of 1.0 to 1.5 mm. Prior to the availability of adhesive cements, the strength of the crown depended solely on the material itself. With the use of adhesive cements, a strong adhesive bond can be formed between tooth tissues and the ceramic restoration, strengthening and supporting the restoration, while also limiting the need to sacrifice sound tooth tissue at the time of preparation. New developments in ceramics are based on different construction techniques and on stronger base materials (eg, In-Ceram and Procera or Zirconiumoxide).

## **Resin Composites**

Great efforts have been made to improve the mechanical properties of direct tooth-colored restoratives. As a result, the mechanical qualities of composite resins have reached a level comparable to that of amalgam. Large restorations of composite resins are not, however, easy to place and contour. Furthermore, the lack of dimensional stability of these materials during curing can require an increased use of indirect techniques employing one of a number of systems (eg, Targis Vectris, Ivoclar AG). An interesting new approach is the use of fiber-containing systems.

## **Human Tooth Tissue: "The Natural Inlay"**

In 1998, Moscovich and Creugers<sup>18</sup> introduced a method to use extracted teeth in the provision of indirect restorations—the "natural inlay." The inlay is formed from a wax pattern using a copy-milling device (Celay, Microna, Switzerland). Although it is a very creative idea, it is questionable as to whether this technique has any future. This is the first form of dental restoration in which caries may develop.

## **Materials for Cementing Indirect Restorations**

### **Adhesive Cements**

Many systems are now available for the adhesive cementing of ceramic and indirect composite resin restorations (Table 8-1). A choice can be made from a spectrum of materials, ranging from purely composite resin cements combined with an adhesive bonding system to traditional glass-ionomer cements, which bond to tooth tis-

Table 8-1 Adhesive cements: Classification and properties

<b>Classification</b>	<b>Bond strength to tooth tissues*</b>	<b>Bond strength to ceramics*</b>	<b>Advantages</b>	<b>Disadvantages</b>
Composite resins	++++	++++	Dual (light) cure, many colors available, high wear resistance, low solubility	Shrinkage
Compomers	++	++	Slight fluoride release	Less knowledge available, shrinkage and slight water swelling
Resin-modified glass ionomers	+++	++	Fast cure, low solubility, slight fluoride release	Low wear resistance, water swelling
Glass ionomers	++	+	Proven preventive effect, long setting time, moderate fluoride release	Solubility, brittleness

\*+, limited; ++, good; +++, very good; +++++, excellent.

sues without the need of adhesives. Resin-modified glass-ionomer cements and compomer cements may be of particular interest in the future because of their ease of use.

Resin luting cements are primarily indicated for the luting of porcelain restorations. The esthetic qualities and fracture strength of restorations are markedly increased by adhesive luting. 15 Marginal accuracy and seal remain crucial factors in the clinical performance of indirect restorations. The type of finishing line used can affect the quality of the marginal seal. 13 Porcelain restorations require a shoulder- or chamfer-type tooth prepara-

tion with a rounded angle. 5,13,15,26 Reports in the literature confirm that it is possible to produce restorations using routine laboratory techniques with a degree of "loose" fit, which results in a cement film thickness of approximately 50  $\mu\text{m}$ .1,11,13

Seating of restorations with a resin luting cement has several advantages. The solubility of the exposed resin luting cement is negligible in the oral environment, and a film thickness of 20 to 30  $\mu\text{m}$  may be ob-

Table 8-2 Nonadhesive cements: Classification and properties

Classification	Advantages	Disadvantages
Zinc-phosphate cements	Proven reputation	Solubility
Polycarboxylate cements	Slightly adhesive properties to tooth tissues	Handling properties (stickiness)
Zinc oxide-eugenol cements		Low strength, inhibiting effect on resin composites

Nonadhesive Cements

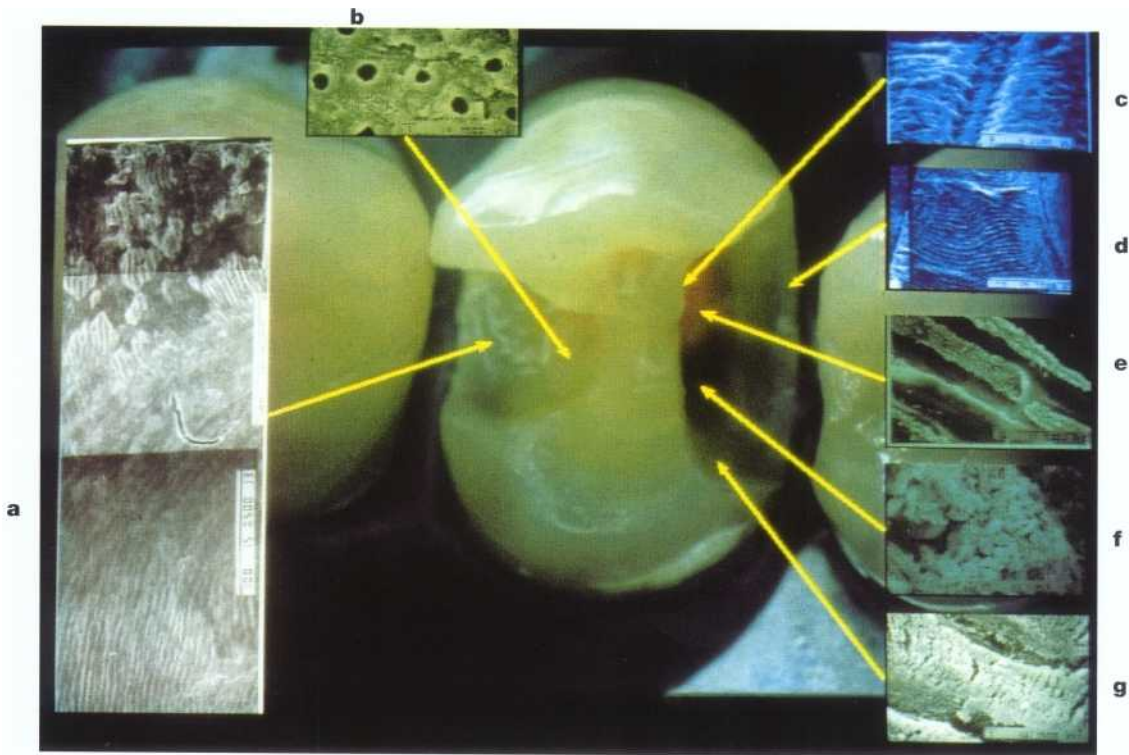
Nonadhesive cements (Table 8-2) for the cementing of ceramic and indirect composite resin restorations require preparations to be retentive and the restorations to have sufficient inherent strength. This applies even for full crowns of very strong ceramics (eg, In-Ceram). It is, therefore, questionable as to whether it is appropriate to use nonadhesive cements for such purposes.

Bonding to Dental Tissues

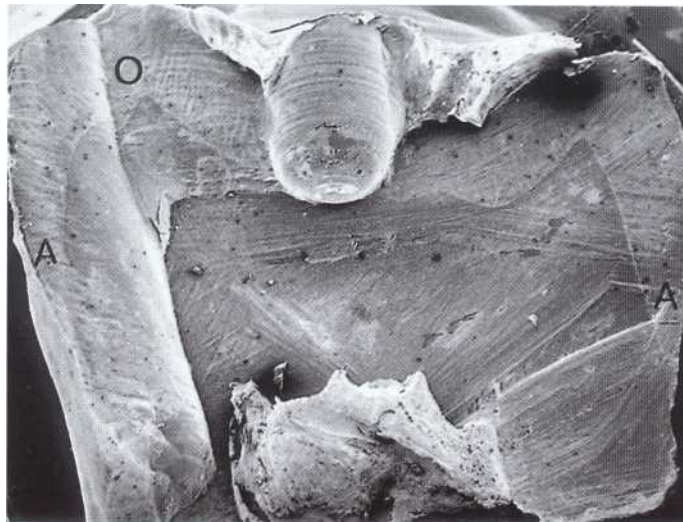
Three dental substrates are involved in the bonding of indirect esthetic restorations: enamel, dentin, and cementum (Fig 8-1).

Enamel predominates along the occlusal and axial margins of Class II cavity preparations.<sup>23,24</sup> At the occlusal margins, a very thick layer of enamel forms the substrate for a durable bond with adhesive luting materials, while along the axial walls the enamel is much thinner (Fig 8-2).

In any one cavity, the dentinal substrate shows different morphology according to the area observed.<sup>4,12</sup> Moving from the outer cavity margins toward the pulp, tubule density and size increase. Also, the dentinal substrate may comprise different types of dentin, including sclerotic, young, deep, superficial, and carious dentin (see Fig 8-1). Although hybridization of margins of dentin and cementum has been demonstrated<sup>12</sup> (Fig 8-3), the absence of resin tags in the limiting 200 to 300  $\mu\text{m}$  of the cervical margin indicates no peritubular dentin demineralization and therefore, a limited increase of intertubular surface area after conditioning (Fig 8-4).<sup>4,12</sup> This may be responsible for a relatively low bond strength and, as a consequence, low durability of the bond to the cavity margin. In fact, the cervical margin is the least reliable section of a Class II preparation for sealing. The presence of an outer layer, partially formed by cementum 150 to 400  $\mu\text{m}$  thick, may affect the quality of bonding when the margin is located below the cemento-enamel junction (CEJ)<sup>4,12</sup> (Fig 8-5).



**Fig 8-1 Different dental substrates present in the same cavity after etching** (a, enamel margin; b, deep dentin; c, occlusal enamel; d, thin enamel cervical margin; e, sclerotic dentin; f, carious dentin; g, intertubular dentin).



**Fig 8-2** Thick enamel is present along the occlusal margins of a Class II cavity. Along the axial walls of a Class II cavity, only thin enamel is present (O, occlusal enamel; A, axial enamel) (original magnification X 10).



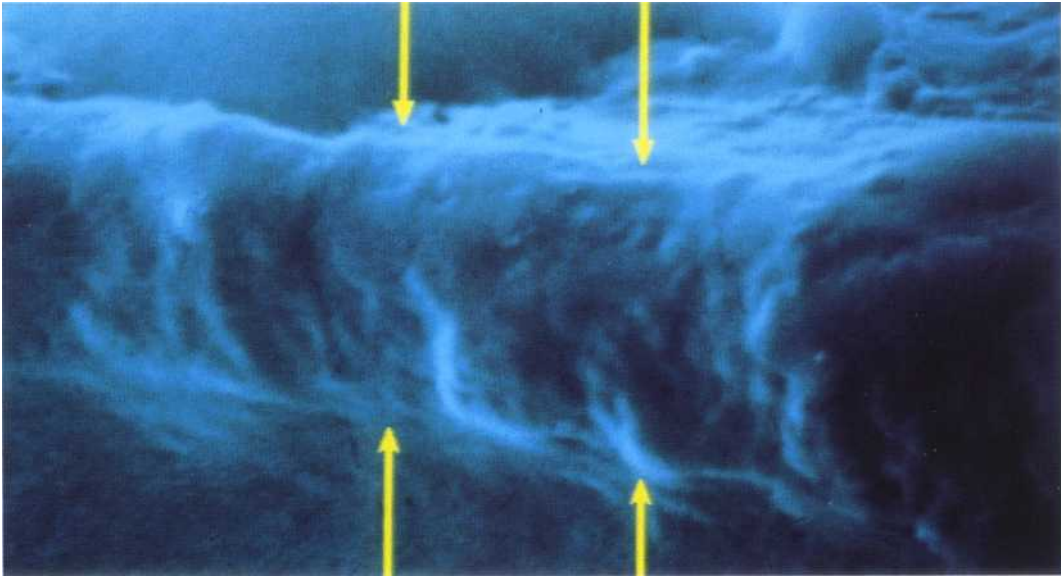


Fig 8-3 Hybridization of a cementodentinal margin in a vital tooth (original magnification x 7,500).

When the cervical margin is located above the CEJ, the thickness of the enamel is important. When the enamel margin is 0.3 to 0.8 mm, it cannot provide the substrate for a perfect seal of the restoration (Fig 8-6).<sup>10,19</sup> This may be caused by the fact that in thin cervical enamel the prisms run predominantly parallel and, as a consequence, a relatively low bond strength is developed.<sup>10,19,23,24</sup>

The bonding mechanism to dental substrates is based on resin tags, with lateral branching and hybrid layer formation.<sup>20,21</sup> For this to occur with new adhesives, a prerequisite is the correct acidic treatment of the substrate. More heavily mineralized substrates, such as enamel and sclerotic dentin, must be etched for longer than less demineralized structures such as nonsclerotic dentin and cementum.

## Techniques for the Construction of Indirect Restorations

### Bench-Made Restorations

Given the opportunities afforded by layering techniques and the use of materials with different translucencies and colors, bench-made indirect restorations are the most esthetic form of indirect restoration. The final quality of the restoration depends to a large extent on the dental technician. For this reason, the quality of restorations made by this technique is not as predictable as that of restorations made by other means.

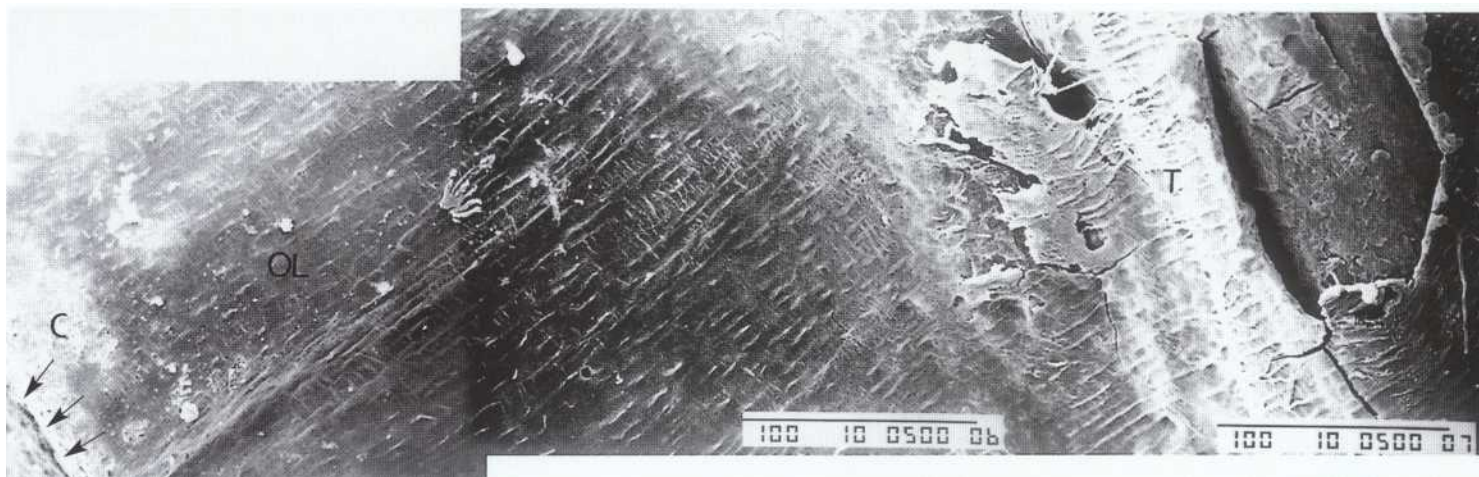
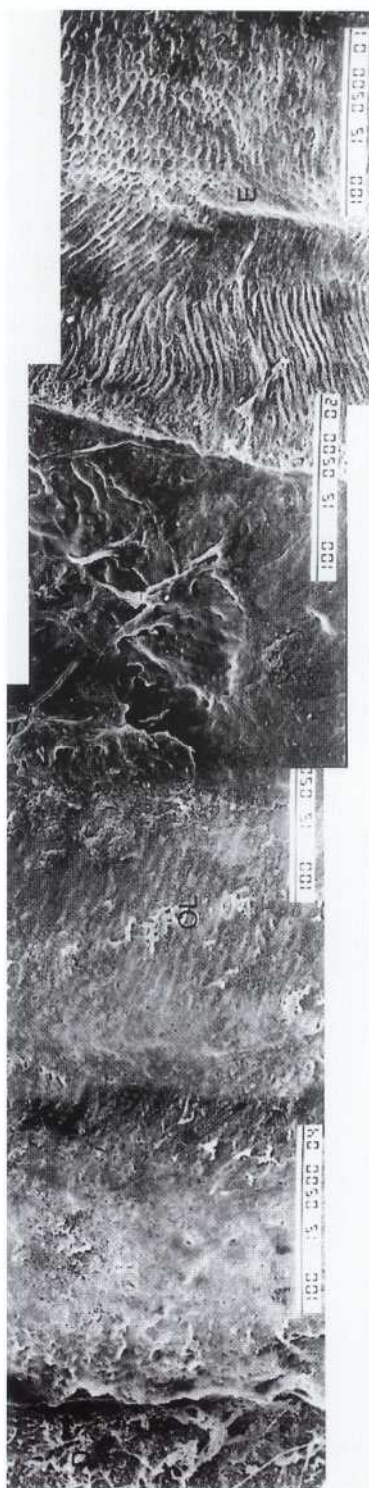


Fig 8-4 Resin replica of a cervical margin placed below the CEJ. No resin tags are evident in the first 200 to 400  $\mu\text{m}$  from the cervical margin (arrows, C, cementum; OL, outer layer; T, resin tags) (original magnification  $\times 500$ ).



Fig 8-5 View of a cervical margin placed below the CEJ. An outer dentinal layer is evident (D, dentin; OL, outer layer; C, cementum) (original magnification  $\times 1,000$ ).



**Fig 8-6** Direct view of a cervical margin placed above the CEJ. A very thin enamel margin is present (E, enamel margin; OL, outer layer; T, resin tags) (original magnification  $\times 500$ ).

## Casting

The casting technique is a generally available and relatively inexpensive method that invariably gives a predictable fit to the final restoration. The material used for the casting of ceramic restorations is typically a glass that, when melted, has a fluidity that facilitates complete casting. After casting in glass, a restoration must be cerammed. This lengthy procedure results in the glass becoming a composite that includes a crystalline phase. The strength of this type of restoration tends to be insufficient in stress-bearing locations.

Another approach to the casting of ceramic restorations is the pressing technique (eg, the Empress product range). With this technique porcelains can be used instead of glass, which results in stronger restorations that can be used in stress-bearing regions. The esthetic quality of such restorations is relatively poor given that the restoration is one color, although surface stains may be added.

## Milling

Ceramic materials are very strong. When using ceramics in dentistry it is possible to provide restorations with high intrinsic strength. However, impurities and voids in ceramics have a weakening effect. For this reason, ceramic blanks manufactured under controlled conditions are stronger than specimens of ceramic produced by a technician at the bench. Through the milling of preformed ceramic blanks using a CAD/CAM system or copy milling device, it is therefore possible to produce restorations of high strength. However, such restorations suffer the disadvantage of being monochromatic. To overcome this problem, two-color blanks may be used

and the final restoration may be characterized by external staining. The Cicero CAD/CAM system relies on the milling of a block of porcelain that has been baked on an investment die.

## Quality of Indirect Restorations

Until there have been further developments in bonding<sup>14,17,20</sup> with improvements in marginal seal and the clinical performance of esthetic restorations,<sup>27,28</sup> problems of adaptation and leakage will continue to occur at the gingival margins of indirect restorations.<sup>7,16</sup> Robinson et al<sup>15</sup> and Dietschi et al<sup>16</sup> noted that the marginal adaptation of indirect restorations was better than that of direct restorations in Class II cavities. Dietschi et al<sup>16</sup> also pointed out that when residual enamel is less than 1 mm in height or 0.5 mm in thickness, indirect rather than direct restorations have superior marginal qualities. Less leakage may be found with indirect Class II restorations (inlays) compared to direct esthetic restorations. This is probably because inlays do not suffer polymerization shrinkage during placement, except for the small amount associated with the thin layer of composite resin luting cement,<sup>8</sup> and therefore suffer limited variations in clinical procedures. Leakage at the margins of Class II restorations is correlated with the type of dental substrate forming at the margins, the etching procedures used, and the type of bonding system selected.<sup>3</sup> However, Hilton et al<sup>16</sup> and Ferrari et al<sup>12</sup> have reported an extensive leakage along the facial and lingual enamel walls of Class II direct and indirect esthetic restorations.

## Application Technique

A case is demonstrated in Figs 8-7 to 8-18 to further explain the application of the adhesive technique using luting restorations. Since adhesion is crucial to the success of bonded ceramic restorations, great care must be taken in the conditioning of the surfaces. If the patient has had provisional restorations, it is important to remove all remnants of the provisional cement without damaging the surface. Surfaces may be cleaned prior to etching/conditioning by sandblasting. The ceramic surface should be conditioned (etched with hydrofluoric acid and silanated) in the dental office immediately prior to insertion of the restoration to guarantee an optimal composite-ceramic bond.





Fig 8-7 Maxillary first premolar with a large defect. Esthetic considerations and shape of the lesion indicate an indirect porcelain restoration.

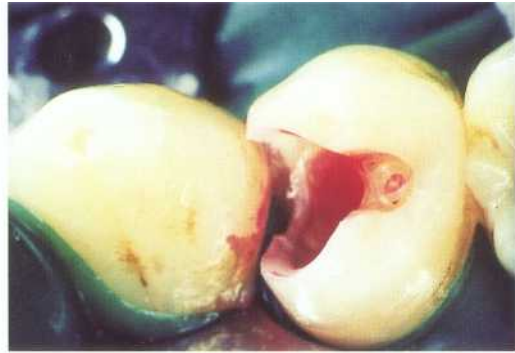


Fig 8-8 To completely remove the caries, the cavity is stained with a caries detector.

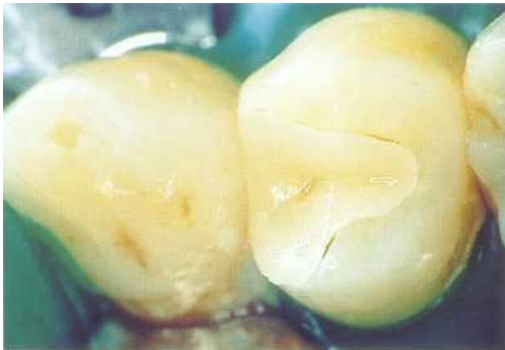


Fig 8-9 Try-in of the porcelain inlay.



Fig 8-10 A microsandblaster is used to clean the preparation.



Fig 8-11 Phosphoric acid is applied to the enamel margins for 15 seconds.



Fig 8-12 Phosphoric acid is applied to the entire preparation for 15 seconds.





Fig 8-13 The cavity is rinsed and gently air dried.



Fig 8-14 A primer adhesive solution is applied and then light cured for 20 seconds.



Fig 8-15 The etched and silanated inlay is ready to be luted into the cavity.



Fig 8-16 During the initial setting of the resin cement, excess cement is removed with a probe.



Fig 8-17 Excess resin is removed from the interproximal area with floss.



Fig 8-18 Occlusal view of the completed restoration.

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# Indirect Restorations for Anterior Teeth Space-The Eternal Problem

Richard Ibbetson

## Introduction

The range of esthetic restorations for anterior teeth has continued to broaden over the last 25 years. The ability to bond porcelain to tooth structure has increased the options available to the modern restorative dentist. Developments in ceramics have allowed increased use of all-ceramic restorations in some areas of the mouth where perhaps they would previously have been contraindicated. However, longer term evaluation of some of these newer ceramic systems is still needed.

Successful results with ceramic and metal-ceramic restorations in the anterior part of the mouth require that appropriate space is made available for the technician to create an effective esthetic illusion. More space is required for ceramic restorations of thickness sufficient to realize optimal physical properties. This requires controlled tooth reduction, and the responsibility for this rests with the dentist. If reduction is excessive, pulpal damage may result. Precise tooth preparation is necessary to create resistance and retention form for traditional cemented restorations and to facilitate the use of resin luting materials in modern, adhesively bonded

restorations. If tooth preparation fails to create sufficient space for an adequate thickness of restorative material, the result could be a thin restoration that is prone to fracture. However, more often such inadequacies result in restorations that have poor contour and poor esthetic results.

Unfortunately, dentists frequently make errors in tooth preparation. These are not solely the province of dentists with lower levels of ability, but are common throughout the profession. Therefore, although such errors could be interpreted as a sign of underperformance, they are more correctly seen as evidence that accurate tooth preparation is difficult.

## Common Errors in Anterior Tooth Preparation

The position of the facial margin in an anterior indirect preparation is critical both to the final esthetic result and also to the health of the gingival tissues. It is well-known that if subgingival margin placement is necessary for esthetic purposes, the preparation should intrude minimally into the gingival crevice. However, dentists frequently fail to control the relationship of their preparation to the crevice, particularly

failing to appreciate how far coronally the interdental papilla may lie on an anterior tooth (Fig 9-1). Consequently, errors in margin placement are often associated with gingival inflammation (Fig 9-2).

A further error in margin placement occurs in the area of the proximolabial line angles. Anatomically, the tooth "waists in" quite markedly in these areas. When cutting a full crown preparation and trying to establish a labial shoulder or heavy chamfer facially, the dentist commonly establishes the finish line slightly coronal to the required position and then gradually moves it further apically. In the area of the proximolabial line angles, such a technique frequently results in loss of the width of the finishing line as the tooth suddenly becomes narrower as the tip of the bur moves apically. Attempts to reestablish the full width of the finish line frequently places the margin significantly below the gingival margin.

Both of the above errors could be avoided if dentists better understood the anatomy and form of teeth.

## **Taper of Preparations**

Dentists have always been taught to try to produce low values for the taper of the axial walls of crown preparations. In traditional cemented crowns, low values of taper are important in minimizing the stress applied to the cement lute during function. Most dentists have been trained to assess taper by viewing the preparation axially in a mirror with one eye from a distance of 30 to 40 cm.<sup>7</sup> They have been told that if they had produced less than 10 degrees of taper, the opposing walls of the preparation would be just visible; however,

this is not true. A preparation with a taper of less than 10 degrees will, when viewed by this method, appear to be undercut. Better methods exist for assessing taper in preparations. Many of these are based on the use of the bur in the handpiece as a surveying rod to assess alignment and relative parallelism of the axial walls. This serves to illustrate the fallibility of the human eye in assessing geometric form, a factor of significant importance if we are to produce preparations of high quality.

Most dentists are familiar with the fact that the facial aspects of teeth are curved. The extent of the curvature is dependent on the length of the clinical crown of the tooth. How is it then that we see preparations such as that illustrated in Fig 9-3? This is the die of a preparation of a maxillary incisor. The facial aspect of the preparation is in one plane. There has been no attempt to recreate the natural curvature of the facial aspect of this tooth. How does this come about? It is not necessarily the sign of a careless dentist; rather, it indicates that tooth preparation is difficult and that assessment of preparations is not best carried out using the naked eye alone.

## **Methods of Assessing Tooth Reduction**

Many techniques have been suggested for aiding the dentist in assessing tooth reduction for indirect anterior restorations. Great emphasis has always been placed on the benefits of having the experienced eye of the mature practitioner. Illustrations such as those discussed earlier indicate the fallibility of the human eye in assessing the quantity and quality of tooth reduction. Some way of monitoring or measuring





**Fig 9-1** The interdental papilla lies significantly coronal to the labial margin.



**Fig 9-2** Anterior crown with the gingiva showing inflammation as a result of the subgingival margin placement.



**Fig 9-3** Die of an anterior crown preparation showing only one plane of facial reduction.



Fig 9-4 Depth cuts are used to aid tooth reduction.



Fig 9-5 Sectioned matrix is used to assess tooth reduction.

tooth reduction would surely be beneficial. Following are a number of recommendations.

### Depth Cuts

Many dentists have been taught to use depth cuts on the functional and axial surfaces of teeth prepared for crowns (Fig 9-4). How many know the diameter of the burs used to make the depth cuts? Without this knowledge, the depth cut has little value. Moreover, depth cuts often are made slightly shallower than needed. Once the tooth surface between the depth cuts has been reduced, the depth cuts themselves have lost their reference point. If they are not prepared initially at an adequate depth, further reduction assessment becomes important.

### Matrices

One useful way of assessing the amount of reduction is by the use of a matrix made of the tooth before preparation, sectioned either along the incisal edges of the anterior

or teeth or buccolingually (Fig 9-5). This is an extra step in the clinical procedure and therefore is often not easily adopted by practitioners. However, its use should be encouraged because it provides a definite indication of the amount of tooth preparation that has been carried out and specific information about the location and amount of reduction. It should be adopted by dentists, not necessarily for routine use, but as a way of checking their overall performance in tooth preparation from time to time. These matrices, formed from silicone putty, can be made directly on the tooth before preparation begins or on a diagnostic waxup or study cast.

### Provisional Crown

An excellent way of assessing the adequacy of the tooth preparation is by making use of the provisional crown. If the provisional crown is made and adjusted for both form and function, its thickness can be measured to ensure that the tooth preparation is adequate and appropriate (Fig 9-6). If it is found that reduction is



Fig 9-6 Measuring the thickness of a provisional crown.



Fig 9-7 Worn anterior teeth.

inadequate, modifications can be made. It goes without saying that the use of this technique requires that the provisional restoration is made before the working impression.

The use of techniques that measure the amount of space that has been created for the restoration is likely to result in more adequate crown preparations. This reflective practice is also likely to develop the preparation skills of the dentist.

## The Management of Worn Teeth

The reduction in dental disease and the continued developments in restorative materials have resulted in the provision of fewer full-coverage restorations. The appropriate use of adhesive restorative techniques provides significant opportunities for avoiding full-coverage ceramic and metal-ceramic restorations. However, one area where full-coverage restorations are frequently required is in the management of anterior teeth that have been extensive-

ly damaged through wear. It is also a clinical situation in which adequate preparations of teeth for crowns can be difficult to achieve.

### Changes Resultant from Wear of the Anterior Teeth

Wear of the maxillary anterior teeth that is slowly progressive generally leads to little change in the position of the incisal edges. This is caused by the continued eruption of the teeth. In adults whose teeth do not wear significantly, an increase in the total face height can be expected with increasing age.<sup>4</sup>

The continued eruption of the teeth as they wear is accompanied by coronal movement of the gingival soft tissues and the underlying alveolar bone. This results in an increased display of the soft tissues around the teeth (Fig 9-7). Patients with slowly progressive wear of the teeth generally do not suffer loss of occlusal vertical dimension. However, dentists commonly diagnose individuals who have worn teeth as having lost occlusal vertical

dimension. In such situations, it is more likely that the dentist is observing shortened teeth accompanied by the increased display of the gingival tissues.

Where the teeth are short and worn and require restoration, there can be difficulty in achieving adequate retention and resistance form in the preparation while creating sufficient space incisally for an adequate thickness of restorative material. Crowning worn anterior teeth without making any attempt to increase their length will achieve little esthetic improvement. Furthermore, reducing worn teeth still further in height in order to accommodate a crown is inappropriate.

## **Methods of Creating Space for the Restoration of Worn Anterior Teeth**

There are a number of ways to create or re-create space for the restoration of worn anterior teeth. Classically these have been based on altering the occlusal relationship between the mandible and the maxilla. The first method involves adjustment of the occlusion in order to change the jaw relationship while maintaining the existing occlusal vertical dimension. The second method of creating space is by the traditionally somewhat controversial method of increasing the vertical dimension of occlusion.

### **Creating Space by Occlusal Adjustment**

Occlusal adjustment for the purpose of creating space is only considered when the anterior teeth require restoration, there is a lack of space, and the posterior dentition is reasonably intact. The patient must

exhibit a discrepancy between their retruded axis (RAP) and their intercuspal positions (ICP). Furthermore, the discrepancy between these two positions must be associated with a significant translation of the condyles between the two jaw positions. These are individuals who are characterized as having discrepancies between the RAP and the ICP that have a large horizontal component and a smaller vertical component.

A new position of closure (intercuspal position) is created by adjusting the occlusal surfaces of the posterior teeth such that all the teeth meet evenly in the RAP but at their original vertical dimension of occlusion. When there is a significant amount of condylar translation between the RAP and the ICP, elimination of the discrepancy by occlusal adjustment will lead to an increase in the overjet. This can, under suitable circumstances, create sufficient space, and restoration of the worn anterior teeth is facilitated.

The adjustment of the dentition is not always straightforward or predictable. Before it is carried out, it should be rehearsed on a set of study casts accurately mounted in a semiadjustable articulator. The occlusal adjustment should create a new ICP that coincides with the RAP. However, the vertical dimension in this new position of closure must be the same as in the old ICP. If this is not achieved, the patient is unlikely to adopt the new ICP and will continue to use their old one.

This can be a useful technique but observation over a period of years indicates that the number of patients who possess this type of discrepancy is relatively small.

## Increasing the Vertical Dimension of Occlusion

Altering an individual's vertical dimension of occlusion has always been a somewhat contentious procedure.<sup>6</sup> The reasons for this are hard to discern but are likely to have originated in complete denture prosthodontics. Although there is still little research validating increasing the occlusal vertical dimension for restorative purposes, observation and clinical experience indicate that where moderate changes are made to the vertical dimension, coupled with a stable posterior occlusion and reasonable anterior guidance, little adaptation is required on the part of the patient.<sup>3</sup>

The process of increasing the occlusal vertical dimension has two primary functions in the restoration of worn anterior teeth. First, it creates space for the restorations and, second, it provides an opportunity for leveling a disturbed plane of occlusion. One limiting factor with this approach is that all the teeth in one arch and often the majority of the dentition require restoration to provide occlusal contacts at the new vertical dimension of occlusion. The second limiting factor is that as the vertical dimension is increased, the mandible comes to lie in a more posterior position and the overjet is relatively increased. The relationship can become such that it is impossible to maintain contacts on closure between the incisal edges of the mandibular teeth and the palatal surfaces of the maxillary anterior teeth. This is undesirable because it becomes impossible to develop useful anterior guidance. Because of these factors, the amount of space that can be created by this means is sometimes limited.

If esthetic restoration is to be achieved, surgical crown lengthening is frequently

used adjunctively prior to restoration. This exposes more of the tooth to allow the development of good retention and resistance form in the preparations and also allows the restoration to be longer gingivally. It is also helpful in reducing the amount of soft tissue that the patient tends to display. The increased display of soft tissues is the result of the continued eruption of the wearing teeth.

However, there is an adverse cosmetic effect of surgical crown lengthening. Apical repositioning of the soft tissues means that the marginal tissues come to lie on a relatively narrow portion of the tooth. This produces wider embrasure spaces that the crowns are unable to conceal without overcontouring. This can result in "black triangles" between the teeth (Fig 9-8). It is one of the significant disadvantages of traditional reconstruction involving crown lengthening. A further disadvantage is the overall time involved for both the patient and the dentist in making a full reconstruction.

## Relative Axial Tooth Movement

An alternative approach is to employ relative axial tooth movement to reverse the positional changes in the teeth and soft tissues that have taken place as the teeth have worn. Dahl and his coworkers described the technique nearly a quarter of a century ago. It is surprising that it has taken so long for it to be accepted by the dental profession.

In his original paper, Dahl described the treatment of elderly patients whose maxillary anterior teeth were worn.<sup>3</sup> His wish was to restore these teeth with crowns but there was inadequate space. The posterior dentitions in these patients





Fig 9-8 Widened embrasure spaces as a result of crown-lengthening surgery.

were considered to be stable and not in need of restorative treatment. Anterior bite planes made in chrome-cobalt were constructed. These were removable appliances that in function provided occlusion for the mandibular anterior teeth while separating the posterior teeth. The patients wore these appliances on a full-time basis for periods in excess of 3 months. Eventually the posterior teeth were found to be in occlusion while the mandibular anterior teeth still contacted the appliance. Consequently, when the appliance was removed, the posterior teeth were still in contact but sufficient space had been created anteriorly to facilitate restoration of the maxillary anterior teeth. Dahl quantified the changes that took place, indicating that in older patients, creation of the space was primarily dependent on intrusion of the teeth in contact with the appliance. In younger patients, although intrusion of the teeth in contact with the appliance occurred, there was also some continued eruption of the teeth that were out of contact.<sup>8,9</sup> A further advantage was that the gingival tissues accompanied the axial tooth movement. Consequently, the need

for surgical crown lengthening prior to the restorative procedures was significantly reduced.

Over the years, Dahl's original principle has been applied in a variety of clinical settings. Early on, it was found that patient compliance, and therefore speed of treatment, could be improved by making appliances that were cemented to the teeth.<sup>2</sup> These were constructed in cast-nickel chromium and cemented to the teeth using a glass-ionomer cement.

More recently, the definitive prosthesis has been used to produce the relative axial tooth movement. Figure 9-9 shows an adhesive fixed partial denture, which, as a consequence of the thickness of the retainers, prevented contacts between the majority of the teeth. Full contact of all the teeth was reestablished within 7 weeks of the fixed partial denture being cemented. The patient remained comfortable during this time.

Composite resin is being used increasingly to restore worn teeth and induce relative axial tooth movement to re-create appropriate space for the restored tooth. Figures 9-10 to 9-12 show two mandibular incisors worn by a combination of ceramic and parafunctional activity. The worn mandibular anterior teeth were restored with directly placed composite resin restorations. The maxillary central incisors were restored provisionally with metal-acrylic resin crowns. The mandibular incisors were restored to an appropriate length and the dentition left to undergo relative axial tooth movement.



Fig 9-9 An adhesive fixed partial denture using relative axial tooth movement to allow coverage of the occlusal surfaces of the abutments without prior tooth preparation.



Fig 9-10 Mandibular incisors worn against ceramic surfaces on the maxillary central incisors.



Fig 9-11 The worn mandibular incisors restored with directly placed composite resin restorations.



Fig 9-12 The effect on closure into the ICP.

## Conclusions

This chapter has reviewed the importance of accurate tooth preparation. It has further reviewed the traditional methods of restoring extensively worn anterior teeth. It has again posed the question as to why the

relatively simple technique of deliberate relative axial tooth movement has not been more widely embraced by the dental profession.' It is nearly 25 years since this technique was first described, and its efficacy has been documented repeatedly. 5

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## **The Control and Maintenance of Dentoperiodontal Relationships in Indirect Anterior Restorations**

Samuele Valerio

### **Introduction**

The performance, clinical integration, and esthetic qualities of indirect restorations are the result of effective multi-disciplinary care and the meticulous execution of each phase of treatment.

### **Patient Management**

Initial patient management is fundamental to the success of all subsequent phases of treatment. From the outset, the patient must understand and consent to the aims and methods of the treatment and be encouraged to contribute to a successful outcome through close cooperation to achieve, in particular, appropriate plaque control.

With periodontal health established, definitive restorative care can be planned with expectation of a successful outcome. Success, however, must be viewed in terms of long-term stability and patient satisfaction (Figs 10-1 to 10-3).

### **Biologic Width**

Fundamental to the preservation of dentoperiodontal relationships is the creation and maintenance of an appropriate biologic width of attached gingivae.<sup>15,22,27,29,30</sup> Each phase of restorative therapy must reinforce rather than threaten the biologic width of the attachment apparatus through the appropriate management of the margins of both temporary and definitive restorations. Such management extends to location, precision of fit, the quality of the surface finish, and the emergence profile.<sup>23,26,30</sup>

### **Combined Periodontal and Orthodontic Treatment**

In completing preparations for indirect restorations, the clinical protocol must make provision to optimize the architecture and thickness of the adjacent periodontal tissues. Combined periodontal and orthodontic procedures may form part of the phases of treatment immediately preceding the completion of the preparations.



Fig 10-1 Preoperative facial view illustrating the condition and altered morphology of the anterior teeth and associated periodontal tissues.



Fig 10-2 Postoperative view.



Fig 10-3 Ten-year follow-up illustrating the maintenance and improvements in the gingival architecture adjacent to the restorations.

The correction of gingival contours, through the orthodontic intrusion and extrusion of teeth,<sup>1,13,16,20,24,40,41</sup> greatly facilitates the reconstructive phase of treatment, irrespective of the type of restoration planned for the patient. With the correction of the gingival contours, the final phase of treatment may be undertaken with a degree of confidence and much greater ease than may have been otherwise possible (Figs 10-4 to 10-6).

The orthodontic extrusion of, for example, retained roots is particularly helpful in the management of traumatized teeth. Extrusion procedures allow the recovery

of periodontal health with the biologic width of attached gingivae necessary to ensure success of the reconstruction. Extrusion procedures may also preserve and, where necessary, correct the gingival contours.<sup>6,20,21,31-33,39</sup> Orthodontic extrusion is to be preferred over crown lengthening procedures that result in less favorable crown-root relationships and disharmonies in the gingival architecture. Crown-lengthening techniques are, however, indicated in situations where it is necessary to compensate for the effects of passive eruption and wear without loss of vertical dimension.<sup>3,4,8,9,10,14,18,38</sup>





Fig 10-4 Preoperative facial view.



Fig 10-5 Appearance following orthodontic alignment of the anterior teeth.

Fig 10-6 Following intrusion of the right central incisor and correction of the gingival contours, the difficulty of the case is greatly reduced.



In the anterior segments, the most important requirement in the control and maintenance of dentoperiodontal relationships in the provision of indirect restorations is the limitation of the extent of the preparation. The extent of the preparation is dependent on the type of restoration being planned, the position and nature of the necessary finishing lines, and the space required to achieve the desired esthetic result. At the same time, great care must be exercised to control the occlusal relationships and the preservation of the remaining tooth tissues, with due regard to their quality and configuration.

## Bonding or No Bonding?

The decision as to whether to select adhesive restorations is dependent on various factors, not least of which is the possibility of isolating the preparations with rubber dam to preclude moisture and other contamination at the time of luting.

Of the restorations that may be used in anterior segments and are not reliant on adhesive technology, the choice ranges from traditional metal-ceramic restorations to certain forms of all-ceramic restorations, with restorations of ceramics applied to electrodeposited metal substructures of-

fering a conservative alternative and the added advantage of excellent marginal adaptation.

## Case Presentation

### Baseline and Initial Treatment

The patient, a 53-year-old male, presented with advanced wear in the upper anterior segment, requiring rehabilitation by means of indirect restorations to restore function and esthetics (Fig 10-7).

Examination revealed that a number of posterior teeth were missing (Fig 10-8) but that periodontal health was well maintained (Fig 10-9). It was concluded that previous forms of treatment had been inadequate and, as a consequence of passive eruption, the patient had not lost vertical dimension with the wear of the anterior teeth. This was confirmed by subsequent functional, phonetic, and cephalometric analyses.

Given the decision not to increase the vertical dimension and the height of the clinical crowns to be restored, it was considered appropriate to undertake anterior crown lengthening by surgical means. This approach was viewed as necessary to ensure the clinical performance of the planned indirect restorations to include reconstruction of the posterior segments to correct and stabilize the occlusion.

As the patient presented with well-maintained periodontal health, no presurgery provisional restorations were required prior to the crown lengthening (Fig 10-10).

### The Reconstructive Phase

Six months after surgery, during which time the tissues stabilized, the reconstructive

phase of treatment was planned, based on a diagnostic waxup (Fig 10-11). Such a waxup determines the desired form and function of the definitive restorations. The decision as to which type of restoration should be employed was delayed, pending the 6-month assessment of the dentoperiodontal relationships and a risk analysis of occlusal function and susceptibility to failure. The decision was made to restore the teeth with metal-ceramic restorations as part of the posterior fixed partial denture, with the incisors being restored by means of single-unit restorations.

Following preparation, which resulted in the absence of enamel for adhesive bonding, and with due regard to the patient's parafunctional habits, the decision was made to restore the incisors by means of ceramic crowns on electrodeposited metallic substructures. Preparation was controlled using silicone indices, which were formed on the diagnostic waxup and sectioned axially (Figs 10-12 and 10-13).

During initial preparation, the finishing line was placed somewhat coronal to the predetermined final position, given that the finishing line would eventually be positioned in the gingival crevice for esthetic reasons. In this way, the risk of trauma to the marginal gingivae during initial preparation was minimized (Figs 10-14 and 10-15).

Provisional restorations were then produced, with great care taken to control the anatomic form, occlusal relationships, and color. Such restorations facilitate the creation of optimal features in the final restoration (Fig 10-16).



Fig 10-7 Preoperative facial view.



Fig 10-8 Preoperative occlusal view illustrating the loss of posterior teeth and the wear of the anterior teeth.

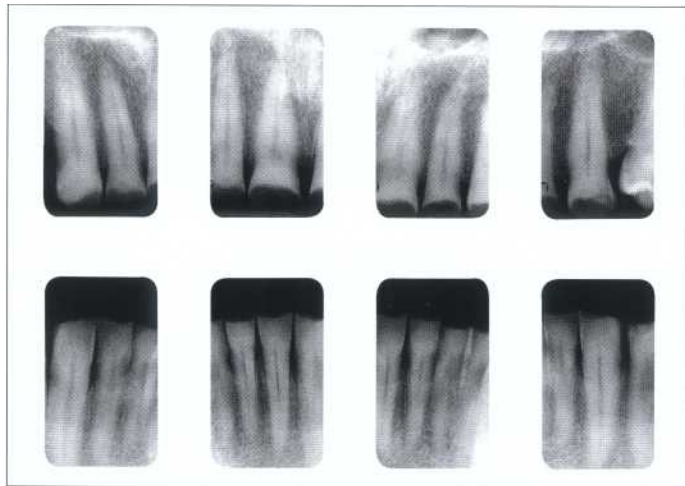


Fig 10-9 Preoperative radiographs showing the preexisting periodontal condition.



Fig 10-10 The anterior segment following crown lengthening.

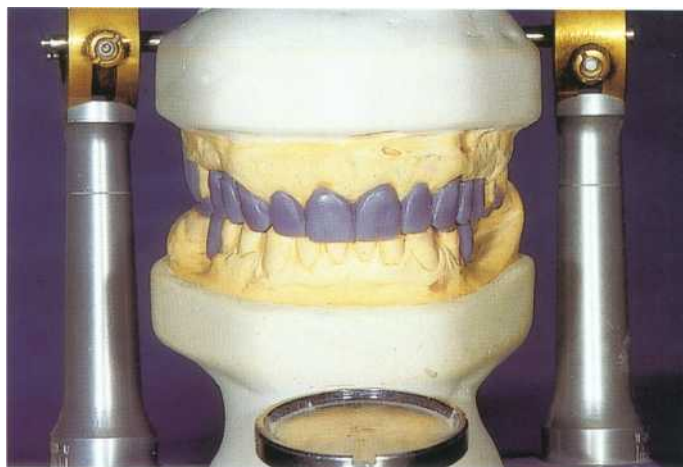


Fig 10-11 The diagnostic waxup.



Fig 10-12 The morphology of the waxup relative to the pre-operative condition.



Fig 10-13 The morphology of the waxup as a guide to the preparation of the remaining tooth tissues.

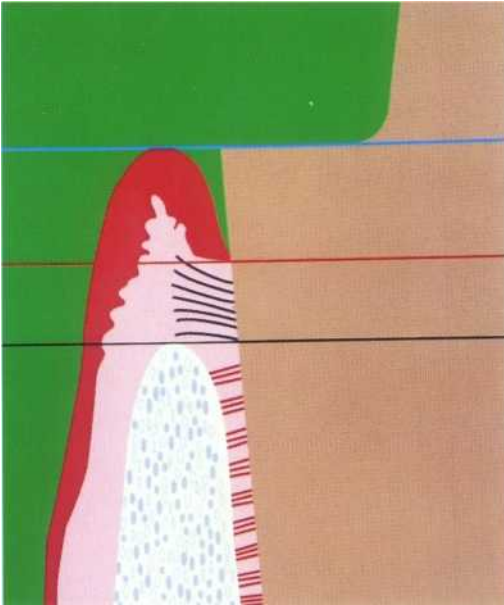


Fig 10-14 Juxtagingival preparation of the teeth.



Fig 10-15 Preliminary preparation to the level of the gingival margin.



Fig 10-16 Temporary restorations produced according to the waxup.

According to the clinical protocol, the two principal aims of the subsequent phase of treatment were:

1. To precisely place and finish the finishing lines without traumatizing the adjacent gingival tissues and crevice.<sup>5,17,25,35,36</sup> Trauma to the gingival tissues at this stage of treatment may lead to healing with unwanted variations in position relative to the finishing line.
2. To open the gingival crevice to allow the penetration of impression material beyond the margin of the preparation,

and thereby obtain an accurate cast on which to produce the crowns. Accuracy in the working cast is essential for the marginal fit of the restorations being provided, and for the creation of appropriate emergence angles to ensure a favorable soft tissue response, together with optimum contours for subsequent oral hygiene procedures.

Given that the finishing lines of the preparations had been placed in a juxtagingival position at the completion of initial preparation, it was possible to exercise





Fig 10-17 Placement of the retraction cord at the base of the gingival crevice.



Fig 10-18 The No. 000 cord causes apical displacement of the tissues with separation from the preparation.

precise visual control over the subsequent phase of preparation. The use of a No. 000 retraction cord, placed delicately in the gingival crevice, provided some apical displacement and dilation of the gingival crevice, exposing the margins of the preparations for accurate impression recording (Figs 10-17 and 10-18). Following removal of the retraction cord, the gingival margin adopted its former position, returning the margins of the preparations to their intended subgingival location. The margin could be located in a juxtapingival position or just apical to the margin of the conditioned tissue, preserving the possibility of leaving a minimum thickness of nonprepared surface between the margin and the No. 000 cord (Figs 10-19 to 10-21). This is of fundamental importance given that the material used

for the impression must record the full extent of the necessary detail without pushing the cord more apically, thus invading the epithelial and connective tissue attachment zones. After the preparation has been refined, a second retraction cord is used with the specific aim of dilating the crevice and facilitating the insertion of the impression material. Normally a No. 0 or No. 1 cord is used and only 50% of its diameter must rest in the crevice (ie, it must float) (Figs 10-22 and 10-23). Such care in soft tissue management is essential if the epithelial attachment and subjacent connective tissues are to be preserved.

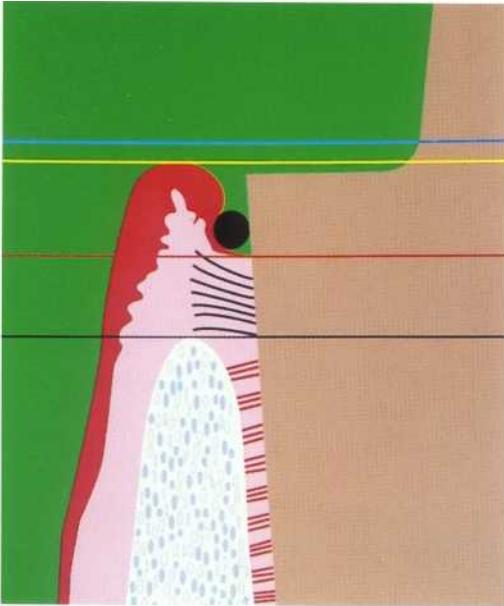


Fig 10-19 Level of the final preparation.



Fig 10-20 Final preparation completed without trauma to the gingival tissues.



Fig 10-21 Final preparation of the entire arch.



Fig 10-22 Position of the second cord to complete the preparation of the tissues prior to recording the impression.



Fig 10-23 Successful completion of the soft tissue management.



Fig 10-24 The dentogingival relationship following removal of the second cord.

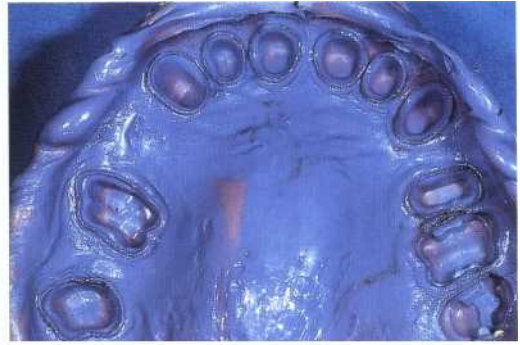
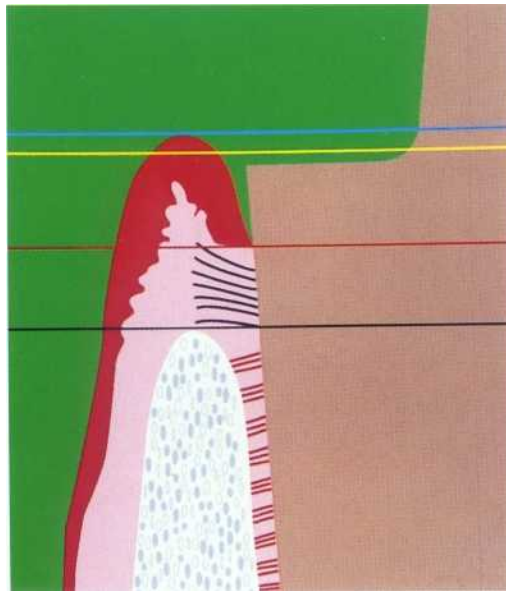


Fig 10-25 Appearance of the impression illustrating extent of the impression beyond the margins of the preparations.



Fig 10-26 Features of the cast, including evidence of the absence of trauma to the gingival tissues.



**Figs 10-27 and 10-28** Once the gingival tissues have returned to their original position, the margins of the preparations lie within the gingival crevice.



Fig 10-29 Postoperative facial view.



Fig 10-30 The cemented restorations with favorable soft tissue relationships and intracrevicular positioning of the margins.

If the retraction cord is forced apically, there will be two negative effects:

1. The gingival tissues will close in over the retraction cord, obscuring the margins of the preparations.
2. The epithelial attachment will be breached, causing inflammation of the gingival tissues, which may result in loss of esthetic qualities in the completed case.

The correct position of secondary No. 0 or No. 1 retraction cords ensures dilation of the crevice, facilitating the impression procedures (Figs 10-24 and 10-25).

Examination of the cast reveals perfect reproduction of the margins of the preparations, with maintenance of the structural integrity of the gingival tissues, including the interdental papillae. This is evidence of successful soft tissue management (Fig 10-26). If required, the use of retraction cords may be supplemented with chemical agents, including aluminium potassium sulphate and ferric sulphate.<sup>2,7,11,12,28,37,42</sup> However, if such agents are used, they

must be thoroughly washed away before recording impressions, as they may interfere with the polymerization of the impression material and the reproduction of detail in the cast.

Assuming preoperative health of the gingival tissues, a prerequisite to success in indirect restorations in terms of dentoperiodontal relationships, the gingival levels will return to their preoperative position following the impression procedures (Figs 10-27 and 10-28). This allows visual confirmation of the correct positioning of the margins of the preparations, provides opportunity to ensure masking of metallic margins and any associated discolorations, and guarantees the stability of the dentoperiodontal relationships. In this way, a favorable esthetic result will be obtained, an outcome of particular importance in the anterior segments of the mouth (Figs 10-29 and 10-30).

If the preoperative condition of the gingival tissues is less than ideal, particularly if they are thin, it is unnecessarily invasive and hazardous to attempt to use more than one retraction cord. In such situations





Fig 10-31 Level of preliminary preparation and its relationship with thin gingival tissues.



Fig 10-32 The displacement of thin gingival tissues following placement of a single retraction cord is greater than with normal tissues.



Fig 10-33 To complete the management of thin gingival tissues, a second retraction cord may be placed interdentally and palatally.



Fig 10-34 The ceramic restorations built on electrodeposited metal substructures.



Fig 10-35 Review of the case at 3 years.



the initial retraction cord tends to cause more apical displacement of the gingival tissues than would be seen when dealing with tissues of normal thickness (Figs 10-31 and 10-32). A large vestibular displacement makes it necessary to extend the preparation apically from a juxtagingival position to ensure a subgingival location once the cord has been removed. If required, a second retraction cord may be placed interdentally and palatally (Fig 10-33), allowing complete control of situations complicated by the presence of thin gingival tissues (Figs 10-34 and 10-35).

## Conclusion

The success of indirect restorations is dependent on the long-term stability of the biologic width and the clinical and esthetic qualities of restorations. Maintenance in clinical service is dependent on three factors: precision in provision, correct positioning of margins, and quality in surface finish. These can only be achieved when accurate casts are obtained without trauma to the adjacent gingival tissues. This is particularly demanding if the margins of indirect restorations are to be placed subgingivally. In all cases a meticulous multidisciplinary approach is required to successfully manage and ensure stability of dentoperiodontal relationships in the provision of indirect restorations.

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# Advances in Bonded Ceramic Restorations for the Anterior Dentition

Pascal Magne

## Introduction

The good overall clinical behavior of bonded porcelain laminate veneers in terms of fracture rates, microleakage, debonding, and soft tissue response is generally well recognized and attested to by numerous clinical studies. Continuous developments in the field of adhesive restorative techniques have permitted significant broadening of the original, anticipated spectrum of indications for ceramic laminate veneers. New generations of concepts emerging from biomimetics are now providing the operator with the ability to restore the biomechanical, structural, and esthetic integrity of compromised anterior dentition. These novel-design, bonded ceramic restorations are stress distributors involving the crown of the tooth as a whole in withstanding occlusal forces and masticatory function. They can be used in the treatment of crown-fractured incisors and the rehabilitation of worn dentitions, thus contributing to two of the major objectives of conservative dentistry: maximum preservation of sound tooth structure and maintenance of the vitality of the teeth to be restored. Mastering the basic principles of tooth preparation is fundamental to creating optimum conditions for the dental ceramist in the construction of

ceramic restorations. The meticulous application and handling of modern composite resins, including latest generation dentin adhesives will, in turn, guarantee the reliability and longevity of bonding. The related diagnostic procedures, sequential treatment planning, tooth preparation, and provisionalization, as well as the final adhesive placement procedure, are discussed.

## Biomimetic Concepts in Restorative Dentistry: Stiffer and Stronger Might Not Be Better

The future of restorative dentistry may be greatly influenced by the emerging interdisciplinary science of "biomimetics."<sup>42</sup> This modern concept involves investigation of both structures and physical functions of biologic "composites" and the design of new and improved substitutes. In restorative dentistry, biomimetics starts with an understanding of the structure and arrangement of the dental tissues, and the geometry and stress distribution within the intact tooth under loading.<sup>27,35</sup> Enamel and dentin form a "composite" structure that gives a tooth unique characteristics.<sup>18</sup> Hard enamel protects the soft underlying

dentin, while the crack-arresting effects of dentin, together with the presence of thick collagen fibers at the dentinoenamel junction, compensate for the inherently brittle nature of enamel.<sup>20</sup> This structural and physical interrelationship between an extremely hard tissue and a relatively pliable, softer tissue gives the natural tooth its unique ability to withstand masticatory loads and thermal stresses over a lifetime in clinical service. With improvements in adhesive procedures and the development of restorative materials, the behavior of the enamel-dentin complex can be partially mimicked by the combination of composite (compliant and adhesive component) and porcelain (hard shell).<sup>25</sup> This high performance combination has already proved its clinical reliability through the success of porcelain laminate veneers.<sup>6,13,15,17,36,37,39</sup> The first application was proposed in the early 1990s, when Andreasen<sup>2</sup> demonstrated that bonded porcelain veneers have sufficient strength to be used for the restoration of fractured-crown incisors. Examples of the dramatic consequences of "biomechanical mismatch" (lack of biomimetics) between tooth and restoration can be found in the prosthodontic literature. The simulated impact study by Stokes and Hood<sup>44</sup> showed the problematic root fracture pattern associated with extremely stiff and strong restorations (gold and metal ceramics) whereas teeth with traditional porcelain veneers performed similarly to intact teeth. This data calls into question whether new restorative approaches should aim to create the strongest restoration or a restoration that is compatible with the mechanical and biological properties of the underlying dental tissues.

## **New Classification of the Indications for Bonded Ceramic Veneers**

The considerable potential of porcelain veneers is not limited by scientific and objective parameters related to biologic considerations, function, and mechanics. Ceramic laminates provide the clinician with a powerful modality with regard to esthetics. Even in those cases in which it is not the primary objective, esthetics still require special consideration. Modifications of the form, position, and color of anterior teeth generate significant effects in the smile which, in turn, contribute to the personality and social life of patients.

Initially used to treat tooth discoloration of various causes, laminate veneers have been increasingly replaced by more conservative therapeutic modalities such as bleaching, microabrasion and macroabrasion. Such developments have not, however, led to a decrease in indications for bonded ceramic veneers. In contrast, the range of applications continues to develop.

Three principal groups of indications may be identified: tooth discoloration resistant to vital bleaching procedures (Type I), the need for major modifications in the morphology of anterior teeth (Type II), and the extended rehabilitation of compromised anterior teeth (Type III). Many Type I and II indications correspond to traditional indications for ceramic laminate veneers.<sup>6-9</sup> Some Type II and III indications are recent.<sup>1,4,21,22,24,28,31,33,45,46</sup> Figures 11-1 a to 11-1 h illustrate one end of the spectrum of applications for bonded ceramic restorations, allowing optimal results with minimum sacrifice of sound tooth substance. The clinical challenges of



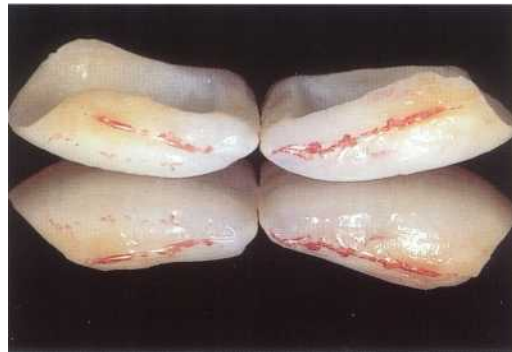
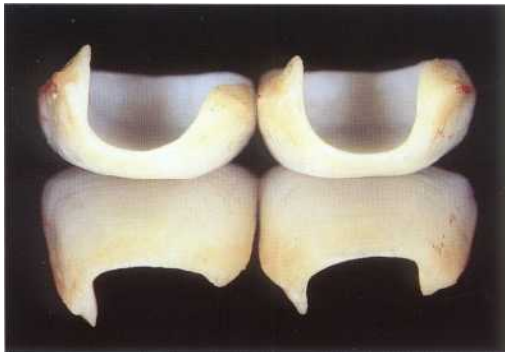
Figs 11-1a to 11-1h Case presentation illustrating Type II indications for bonded ceramic restorations.



Fig 11-1a Preoperative view of smile showing tooth migration, multiple diastema, and vertical loss of soft tissue associated with rapidly progressive periodontitis.



Fig 11-1b Following completion of periodontal therapy and the orthodontic redistribution of spaces, teeth 13 through 23 were prepared with the objective of shortening the incisors and closing the interdental spaces. Specific tooth preparation for horizontal insertion of the veneers was carried out.



Figs 11-1c and 11-1d Details of the porcelain veneers for teeth 11 through 21 characterized by a marked interdental extension of contour, creating a vertical proximal contact line.



Fig 11-1e Novel-design restorations improve both gingival and dental esthetics through the compensation of soft tissue loss by the use of more opaque and saturated porcelain in the interdental zone.



Fig 11-1f Note improved smile line with dramatic effect on patient's persona.



Figs 11-1g and 11-1h Follow-up view showing the stability of the result after more than 4 years of clinical service. The position of the teeth has been maintained by a bonded palatal splint.

Figs 11-2a to 11-2d Case illustrating combined indications for bonded ceramic veneers in a patient seeking improved incisal function and enhanced esthetics.



Figs 11-2a and 11-2b Preoperative appearance. Note the angulation of the central incisors.



Figs 11-2c and 11-2d Details of the existing restorations.



Figs 11-3a and 11-3b The treatment objective was defined using an additive waxup procedure. The corresponding sectioned silicone indices are placed intraorally. Note the repositioning of the midline (interincisal line) and the preexisting space for the proposed restorations.

the case illustrated in Figs 11-2a to 11-2d provide good examples of mixed indications for bonded ceramic restorations. The case is presented in detail in all subsequent figures in this chapter.

## Type I

Type I indications (tooth discoloration resistant to vital bleaching procedures) include teeth heavily discolored because of tetracycline therapy (degrees III and IV according to Jordan and Boksman, 16 group IA) and anterior teeth that present severely worn incisal edges that subsequently lead to staining of exposed dentin (group IB).

## Type II

Type II indications (anterior teeth in adult requiring major modifications in morphology) include peg shaped teeth (group IIA), diastema and interdental triangles to be closed or reduced (group IIB; see Fig 11-1), and augmentation of incisive length and incisive prominence (group IIC; Fig 11-2).

## Type III

Type III indications (rehabilitation of compromised anterior teeth) include extend-

ed coronal fractures (group IIIA; Fig 11-2) and malformations (group IIIB).

## The Additive Waxup and Acrylic Mock-up: Essential Elements of the Diagnostic Approach

Tooth preparation should not be commenced without having precisely determined the final shape, position, and length of the teeth to be restored. Above all else, the diagnostic approach should allow the patient to visualize, evaluate, and finally approve the treatment objective.<sup>21,32</sup> The first step always consists of redefining the desired morphology of the teeth to be restored on study casts (waxup). The second stage comprises a clinical evaluation of the diagnostic waxup. In most cases, an additive waxup is carried out because the tooth volume has to be redefined through augmentation (Figs 11-3a and 11-3b). This provides opportunity to form an acrylic template directly in the patient's mouth using a silicone matrix (Figs 11-4a to 11-4c). This removable template can be readily as-

Figs 11-4a to 11-4e After tooth surface corrections, an acrylic mockup is used to assess the proposed outcome.



Figs 11-4a and 11-4b The mockup is produced by placing a silicone matrix filled with uncured acrylic over the patient's teeth.



Fig 11-4c This thin removable mask is left with the patient for a week. If necessary, the mockup can be fixed using unfilled resin and enamel spot etching.



Figs 11-4d and 11-4e In the case in question significant improvements were obtained using this simple technique for the correction of tooth length and the smile line.



sessed by the patient (Figs 11-4c to 11-4e). Any subsequent modifications are incorporated into the original diagnostic wax-up, thereby allowing the production of a new template. Tooth preparations should not be commenced until the patient has approved the diagnostic template.

## **Tooth Preparation and Provisional Restorations: Fundamental Principles**

The adhesive properties and the physico-chemical characteristics of luting composites allow the tooth-restoration interface to withstand substantial stresses. Based on such thinking, the geometric and mechanical parameters of tooth preparation are of secondary importance. This facilitates maximum preservation of sound mineralized tissue during tooth preparation procedures and, as a consequence, a very conservative approach (Figs 11-5a to 11-5c). A minimum amount of preparation geometry is still required, however, to facilitate the insertion and positioning of a ceramic restoration during placement.

Extensive loss of tooth structure (a large Class IV defect) can be restored by means of a laminate veneer alone (simplified approach). The provision of a preprosthetic composite buildup restoration will not contribute to the strength of the tooth restoration complex, but may be considered to be a contributory resilient component. In this way, a preexisting Class IV restoration can function as a preprosthetic restoration. However, it is important to avoid a large mass of composite under a porcelain veneer restoration because there are still significant concerns regarding the cumulative effects of the curing contraction and

high thermal expansion of certain composite resins. The latter has been shown to have a significant influence on the development of postbonding flaws when used as a thick lute,<sup>3,30,34</sup> and to suffer marginal leakage when placed as a complete veneer.<sup>19</sup>

Existing Class III restorations should be carefully examined for their quality and need to be replaced. To avoid the unnecessary sacrifice of mineralized tissue, proximal preparation margins may be located within the bulk of an interdental composite restoration. When the effects of thermal stresses are considered, partial or total wrap-around of preexisting composite restorations is indicated.<sup>23</sup>

It is recommended that a cervical chamfer be formed, without internal line angles, following the scalloped gingival contour. The insertion of a thin gingival retraction cord (Gingibraid Oa, VanR) facilitates this task by highlighting the gingival margin contour. The preparation instrument is kept a constant distance away from the cord (approximately 0.5 mm), leading to the formation of a juxtagingival margin. Systematic incisal/proximal wrap-around is recommended. The extent of this wrap-around is dependent on the presenting problem and the prosthetic objective. If major modifications of form or the closure of diastema is planned, an extensive wrap-around is essential (see Fig 11-1). In a photo-elastic study, the authors underline the importance of incisal and interdental overlap, which appears to provide superior intrinsic resistance because of favorable stress distribution within the restoration.<sup>14</sup> This approach offers many advantages, facilitating treatment and, in particular, the placement of the final restorations (stabilization of the laminate veneers and easy

Figs 11-5a to 11-5d Preparation of the teeth.



Fig 11-5a Preparation guided by the silicone indices to conserve intact tissues.



Fig 11-5b Preparation of the left maxillary central incisor (21) was relatively extensive given its buccal positioning.



Fig 11-5c Preparation of the mandibular incisors.



Fig 11-5d Round-ended, tapered burs (D6 No. 235 and 237, Intensiv, Grancia, Switzerland) used to complete the preparations.

access to all the margins during the bonding procedure). Additionally, incisal coverage significantly enhances the opportunities available to the dental ceramist with respect to the form and emergence profile of the future restoration, as well as improved esthetic definition of the porcelain in the most crucial incisal zone.

There now exists scientific evidence regarding the type of incisal finishing line to be recommended as a function of the type and amount of incisal overlap.<sup>22</sup> Because of the geometry and elastic modulus of mineralized tooth structures, a concentration of tensile stresses occurs in the region of the palatal concavity of intact teeth.<sup>35</sup> Long chamfers extending into the palatal concavity are contraindicated because thin extensions of ceramic will be placed in the area of maximum tensile stresses. Minichamfers or even butt margins are generally recommended, notably in the presence of moderate crown fractures or severe wear.<sup>22</sup>

Most of all, it is essential to produce preparations without sharp angles. The quality of the preparation (smooth contours and an absence of undercuts) and final impression significantly influences the work of the dental ceramist, leading to a minimal use of die spacer, thus significantly reducing the risk of postbonding cracks.<sup>3,30,34</sup>

## The Importance of Waxups for Enamel Preservation

Neural tissues and enamel are the most specialized tissues in the body. The fact that enamel is "etchable" makes it exceedingly precious to the clinician. The long-term success of enamel-bonded porcelain veneers is evidence of the value of

enamel. However, tooth preparation techniques for laminates have not always promoted the preservation of enamel. Reduction burs with calibrated diamond rings have been proposed to cut enamel to controlled depths relative to the preexisting tooth surface. When enamel is initially thin, reduction based on such depth cuts may lead to substantial exposure of dentin. In cases in which the enamel is thin, the veneers should aim to restore the original form of the tooth. Therefore, a diagnostic waxup reproducing the original form of the tooth should be used as a reference for tooth reduction (ie, the use of silicone matrices sectioned horizontally in the midsection of the tooth; Fig 11-5a).<sup>21</sup> This simple procedure will save a significant amount of sound tissue, both enamel and the critical dentinoenamel junction. To ensure accuracy of the silicone guide and optimal intraoral repositioning, the silicone material should be polymerized on the study cast under a pressure of 4 atm.

Three different diameters of burs are recommended (Fig 11-5d), D6, 235, and 237 (Intensiv) or 856L014, 856L016, and 856L020 (Brasseler, Savannah, GA). The thinnest bur is used first to prepare proximal reduction grooves. The medium-sized bur is then used to produce facial reduction grooves. Gross axial reduction is best achieved using a larger bur to prevent repenetration into the grooves. In this way, uneven, "wavy" surfaces can be avoided. A uniform space of at least 0.7 mm with a minimum of 1.5 mm incisal clearance should be produced using this method, allowing for the same thickness of ceramic along the proximal and axial aspects of the preparation.

## **Preparations for Diastema and the Management of "Black" Interdental Triangles**

Cases in which diastema or black interdental triangles are to be closed require extended interproximal preparation to allow the ceramist to produce a progressive emergence of the interdental extension (see Fig 11-1).<sup>4</sup> Such situations necessitate careful planning of the path of insertion of the future laminate veneer. It is therefore recommended that diagnostic (trial) preparations on study casts be undertaken. In cases in which there has been gingival recession, a horizontal path of insertion is required to preserve the coronal tooth structure, given the reduced diameter of the tooth in the cervical area.<sup>4</sup>

## **Immediate Dentinal Bonding**

If a substantial amount of dentin has been exposed during preparation, the application of a dentinal bonding agent (DBA) is recommended. Clinically, two methods may be used to ensure effective dentinal adhesion when placing indirect resin-bonded restorations. The first, conventional approach consists of delaying the application of the DBA, ie, acid etching followed by the application of the primer and bonding resin luting immediately prior to placement of the veneer. To avoid incomplete seating of the restoration, it is usually recommended to leave the adhesive resin uncured when placing the veneer. However, loading of the luting composite during the seating of the veneer may cause the demineralized collagen fibers to collapse and thereby adversely affect cohesion within the adhesive interface.<sup>11,12,26</sup> A second alternative approach has been proposed to optimize the DBA application.<sup>5,38</sup> Given

that DBA appears to have more potential for adhesion when applied to freshly prepared dentin, its application should occur immediately after the completion of tooth preparation and prior to recording the final impression. A substantial clinical advantage of this precautionary measure is that the pulp-dentin complex is protected and sensitivity and bacterial leakage are reduced during the provisional phase. The use of a filled adhesive resin (Optibond FL, Kerr) may have particular advantages in this approach.

## **Production of Provisionals and Temporary Cementation**

The provisionals are produced in the same way as the diagnostic mockup, ie, using a mold of acrylic resin and a silicone matrix. Because of the extreme fragility of provisional veneers, it is not recommended that they be mechanically polished. A light-cure glazing resin may be used instead (Palaseal, Kulzer). Esthetic and comfortable provisionals can be obtained using layering techniques such as the intraoral application of the laboratory sandwich technique.<sup>29,32</sup> After spot etching of the enamel, temporary luting is achieved using unfilled adhesive resin that may be light cured through the restorations. This technique is not applicable in cases of immediate dentinal bonding.

## **Elaboration Techniques and Configuration of the Ceramic Workpiece**

In most cases, ceramic laminate veneers are used to restore the enamel portion of teeth. Logically, ceramics are the materials

of choice because their physical characteristics are close to those of enamel. This is in contrast to composite resins with physical properties that more closely resemble those of dentin. Composite laminates do not appear to be able to either restore the rigidity of the intact tooth<sup>40</sup> or to match the performance of ceramics in terms of marginal seal at the dentin-composite interface.<sup>19</sup> Numerous systems exist for the production of ceramic veneers. The correct use of a given system is more important than the selection of the system itself. The simple refractory die technique (eg, Ducera-Lay refractory die material, Duceram) is generally recommended because it does not require expensive devices or materials and has been found to result in satisfactory outcomes even in the most demanding of clinical situations.<sup>33</sup>

Most traditional feldspathic ceramics exhibit higher tensile strength than enamel. The ultimate success of the technique relies on the adhesion obtained between the luting composite and the ceramic substrate and between the luting composite and the mineralized dental tissues. It is, therefore, of primary importance to select ceramics that can be effectively etched, such as the porcelain normally used in porcelain-fused-to-metal techniques (eg, Creation, Klema).

Delamination and chip fractures are the most commonly reported reasons for the failure of veneers. Delamination is still poorly understood and may even occur in homogenous, well-fined porcelain.<sup>43</sup> It is therefore most important to obtain the best possible surface characteristics in the ceramic during glazing or mechanical polishing. It is also important to bear in mind that a sufficient and even thickness of ceramic, together with a minimum thick-

ness of luting composite, will provide the restoration with the most favorable configuration with respect to crack propensity (ie, a ceramic-composite ratio of thicknesses > 3.0). During laboratory procedures, die spacer should be used sparingly to avoid unnecessary luting composite thickness. A minimum of 0.6 mm of ceramic is required for an average composite thickness of 200  $\mu$ m. This poses challenges for the clinician during tooth preparation. Special steps and techniques must be used in cases in which the enamel has suffered wear. Since the restoration should aim to re-create the form of the tooth, worn surfaces may require relatively little preparation. As already mentioned, the use of a diagnostic waxup and subsequently silicone matrices during tooth preparation (Fig 11-5a) is particularly important in such cases to ensure appropriate thicknesses of composite and ceramic.<sup>21</sup>

## Try-in and Placement of Bonded Ceramic Veneers

The placement of ceramic restorations can be preceded by a try-in. When a refractory die technique is used, the restoration should be as complete as possible before try-in because only low-fusing ceramics can be added once the refractory die material has been sandblasted away.

As far as the success of the final bonding is concerned, it relies heavily on the preparation and conditioning of the surfaces involved. In most cases, the bonding procedure can be carried out using a light-cured composite because porcelain veneers rarely exceed a thickness of 1 mm and are generally translucent. The



physicochemical properties of dual-cured products cannot be considered optimal because there is a compromise between the degree of conversion and color stability.<sup>10</sup> In veneering, the indications for these materials remain limited to ceramic veneers of an extreme facial thickness (> 2 mm) and to situations where opaque veneers have been selected (eg, cases of severe discoloration). Traditional light-cured materials offer a considerable advantage because of their ease of manipulation (unlimited working time and ideal consistency). One should select a relatively neutral shade of composite to enhance translucency and permit even light distribution (Fig 11-6a). Such shades should also enhance the inherent luminosity (fluorescence) of the restoration. As with all adhesive techniques, the final insertion of the restorations has to be preceded by isolation of the area (Fig 11-6b) using rubber dam or at least a retraction cord if the application of rubber dam proves extremely difficult. A last try-in of the laminate is carried out under rubber dam. The bonding procedure is then performed, following the placement of segments of transparent matrices and interdental wedges (Fig 11-6b). Wedges facilitate the insertion of the laminate veneer and prevent the accumulation of excess luting composite in the interproximal area. Final seating of the restoration, however, is achieved after removal of the matrices and wedges.

### **Conditioning of the Ceramic Surfaces to be Bonded**

Following activation of the silane solution, (generally performed by mixing two components) the surface of the ceramic veneer to be bonded is etched for 90 seconds

with 10% ammonium bifluoride gel (Biodent Retentionsgel, Dentsply/DeTrey). This procedure has to be performed using strictly controlled protective measures, comprising rubber gloves, face mask, protection glasses, and specially designed instrumentation (Fig 11-6c). After abundant rinsing (including 2 to 3 minutes in 95% alcohol in an ultrasonic bath) and drying, the etched ceramic surface is covered with the activated silane solution (eg, Silicon P, Kulzer). The laminate is then placed in a furnace to dry at 100°C for at least 1 minute. This eliminates water and other contaminants and enhances the condensation of the silane on the ceramic surface.<sup>41</sup> Thermal treatment also can be carried out using a hair dryer.

### **Preparation of the Tooth Surface to be Bonded**

This comprises 30 seconds of etching with 37% phosphoric acid (Ultratech, Ultradent), assuming the prepared surface is largely enamel. However, if a considerable area of dentin has been exposed during tooth preparation, it is suggested that a dentinal adhesive be applied, strictly in accordance with the manufacturer's directions for use. As already indicated, a recommended approach comprises the application of the dentinal adhesive prior to taking the final impression (immediate sealing of the dentin). This precaution helps protect the pulp-dentin complex and avoids any tooth sensitivity during the provisional phase. At the time of the final bonding of the restoration, the adhesive-covered surface should be meticulously cleaned with pumice. The bonding procedure is then limited to the conditioning of the prepared enamel.

Figs 11-6a to 11-6c Preparation for placement of ceramic veneer.



Fig 11-6a The preferred light-cured luting composite is translucent and slightly fluorescent (Herculite XVR Incisal LT).



Fig 11-6b The operative field at the time of placing a veneer on tooth 23.

Fig 11-6c The restoration can be readily handled during etching and silanization using specially designed instrumentation (Accu-Placer, Hu-Friedy) in combination with sticky wax.

## Placement of the Laminate Veneer

The adhesive resin is applied to both the conditioned tooth surface and the etched ceramic surface to be bonded, followed by a gentle air blow, but without initiation of polymerization. From that moment on, the operating field should be free from any intense light (eg, operating light). A homogeneous mass of light-cured composite is then applied to the inner ceramic surface. Particular care should be taken to

avoid the incorporation of air bubbles between composite and the veneer. This would create areas of light absorption (gray spots) that would be visible following cementation. The veneer is slowly seated with gentle finger pressure along the insertion axis. Gross excesses of composite are then removed with the tip of an explorer previously impregnated with unfilled adhesive resin. The instrument is guided in a cutting motion parallel to the margin to avoid the removal of composite

from the margin. Matrices and wedges are removed at this stage. The veneer is then reseated under finger pressure and the removal of excess material repeated as often as is necessary. The final seating of the laminate veneer occurs when finger pressure no longer results in the extrusion of composite cement along the margin. A dry brush is then used to eliminate residual excess resin. Photopolymerization is performed through a layer of glycerin gel (K-Y Jelly, Johnson & Johnson), beginning from the palatal aspect with a 90-second exposure (regular curing mode). This is followed by a 90-second exposure from the buccal aspect with intermittent interproximal exposures. Any excesses of cured adhesive resin are removed using hand instruments (scalpel and scaler). The use of rotary instruments is not recommended because such instruments may damage the margins of the laminate. When multiple laminate veneers are to be placed, it is best to proceed in a systematic manner, applying the complete sequence for bonding (conditioning of the ceramic, preparation of the tooth surface, and insertion of the laminate veneer) one tooth at a time. It is not recommended to perform bonding procedures on several teeth simultaneously.

#### **Final Adjustments and Control of Occlusion**

The occlusion is adjusted, beginning with centric occlusion (maximal intercuspation). Under no circumstances should this step be carried out before the final bonding of ceramic veneers, given the high risk of fracture. The functional features of teeth restored with porcelain veneers are identical to those of intact natural teeth. Particular emphasis must be placed on restoring and maintaining functional anterior guidance during mandibular excursions (laterotrusion and protrusion) regardless of whether this guidance involves the newly placed veneer restorations.

#### **Conclusions**

The need for preprosthetic interventions (eg, root canal therapy and crown lengthening) and the placement of intraradicular posts can be significantly reduced by the use of bonded ceramic restorations. Such restorations provide a reliable, noninvasive and economical means of restoring extensive elements of the coronal tissues and length of teeth in the anterior dentition. The outcome of the case presented in this article is illustrated in Figs 11-7a to 11-7c, with the appearance after 3 years of clinical service being shown in Figs 11-7d and 11-7e.

Figs 11-7a to 11-7e Postoperative views showing only slight modifications compared to the diagnostic mockup and corresponding situation after 3 years of clinical service.



Figs 11-7a and 11-7b Postoperative intraoral views.



Fig 11-7c Postoperative clinical view of smile.



Fig 11-7d After 3 years of clinical service.



Fig 11-7e After 3 years of clinical service. Note natural effects through sophisticated incisal edge characterization (dental mamelons and transparent enamel).

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Fig 12-2 Machining of a ceramic laminate veneer with cylindrical and conical diamond-coated burs cutting simultaneously.



Fig 12-3 The range of Cerec 3 restorations. From top left, full ceramic inlay, onlay, veneer, anterior, and posterior crowns.

## Clinical Case

An 18-year-old female patient presented with caries-free teeth, including a partially erupted left maxillary canine in infraocclusion as a result of early extraction of the primary canine. This extraction created opportunity for the premolars to move mesially, thus reducing the space for the erupting canine (Figs 12-4 and 12-5). The patient was unhappy with the resulting esthetics

but refused orthodontic treatment because she was seeking an immediate solution to the problem. A proposal was made to manage the situation with a minimally invasive Cerec 3 veneer, which the patient accepted. To make provision for esthetic add-on layers of veneering ceramic, it was decided to produce the veneer indirectly with the optical impression being taken from a plaster cast.



**Fig 12-4** Lateral aspect of the partially erupted left maxillary canine standing in infraocclusion.



**Fig 12-5** Incisal view of the left maxillary canine illustrated in Fig 12-4.

## Shade Selection

Mark II ceramic' (Vita, Sackingen, Germany) was chosen for this case. The Cerec 3D-Master shade guide (Vita) was used to select the basic color of the ceramic block. The monochromatic Cerec Vitabloc shade 2M2C was found to offer the best match. Individual shade characteristics including highly colored areas at the neck of the tooth and areas of high translucency incisally were planned. Vitadur Alpha (Vita) ceramic was used as an add-on veneering material to create translucent incisal effects.

## Preparation, Impression, and Plaster Cast

Minimal reduction of the labial enamel, not exceeding 0.4 mm in the cervical area, was sufficient for the construction of the veneer. The cervical margin was placed epigingivally and finished as a chamfer (Fig 12-6). All margins were within enamel. To preserve hard tissue, the incisal margin of the preparation was located along the incisal edge of the tooth rather than being

extended palatally with incisal coverage (Fig 12-7). The proximal margins of the preparation were placed midproximally by reducing the proximal contact area by less than 50%. Gingival displacement was accomplished using a thin retraction cord inserted into the gingival crevice. The impression was recorded using polyether impression material (Permadyne, Espe, Seefeld, Germany).

## Provisional Restoration

Heliobond (Vivadent, Schaan, Liechtenstein) was applied to the unconditioned surface of the preparation, followed by a layer of composite restorative material (Tetric-Ceram, Vivadent). The material was light-cured and the surface trimmed and finished with flexible discs (Sof-Lex, 3M, St. Paul, MN) and an abrasive bristle-brush (Occlubrush, Hawe Neos, Switzerland). As the enamel had not been etched, the temporary restoration could be readily removed with a scaler.



Fig 12-6 Veneer preparation of the left maxillary canine as seen in the cast powdered (Cerec powder, Vita) for the optical impression.



Fig 12-7 Recording the optical impression of the veneer preparation using the Cerec 3D measuring camera.

## Computer Aided Design of Veneer

Cerec Liquid (Vita) was applied to the preparation and the neighboring teeth in the cast obtained from the impression. A thin opaque layer of Cerec-powder (Vita) was sprayed on the treated surfaces to permit high-contrast 3D scanning to obtain the so-called "optical impression" (Fig 12-7). Following start-up of the Cerec 3 CAD unit, the veneer design mode was selected, the morphological database was activated, and the tooth to be veneered was entered. The optical impression was recorded using the Cerec 3D measuring camera with the preparation centered in the middle of the screen, the teeth aligned vertically, and all parts of the preparation being well focused (Fig 12-7). The mesial and distal reference "equator" lines were then identified on the adjacent teeth, allowing the proximal positions of the neighboring teeth to be entered. The "bottom line" marking of the 3D course of the preparation margins was then completed (Fig 12-8). The system then automatically proposed the "contact line," rep-

resenting the maximum circumference of the veneer, and established the proximal contacts with the adjacent teeth (Fig 12-9).

The proposed veneer was extended beyond the incisal limit of the preparation to form a new incisal edge to the canine. This editing involved drawing the contact line according to the envisaged profile of the incisal edge of the canine (Fig 12-9). The system then proposed two lines running mesiodistally from the labial surfaces of the adjacent teeth across the veneer preparation, the upper cross line defining the upper part of the labial surface of the veneer and the lower cross line defining the lower part. Both lines were edited to the particular morphological requirements of the case (Fig 12-10). The resultant veneer design was refined on the screen using the surface tool. This tool allows the examination of cross sections of the veneer in any direction. The incisal-cervical cross section line is shown in Fig 12-11. Figure 12-12 illustrates the corresponding cross section through the veneer construction. A horizontally orientated mesio-distal cross section line is reproduced in





Fig 12-8 Bottom line (blue) marking the 3D course of the preparation margins.



Fig 12-9 Contact line (automatically proposed by the CAD system), representing the maximum circumference of the veneer.

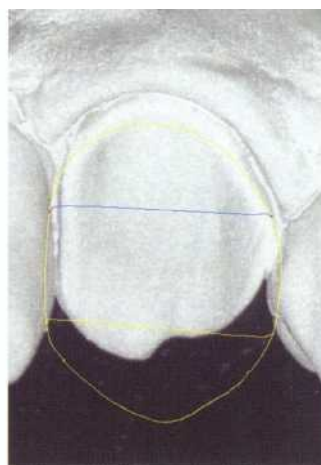


Fig 12-10 Incisal (yellow) and cervical (blue) cross lines defining the labial surface of the veneer.

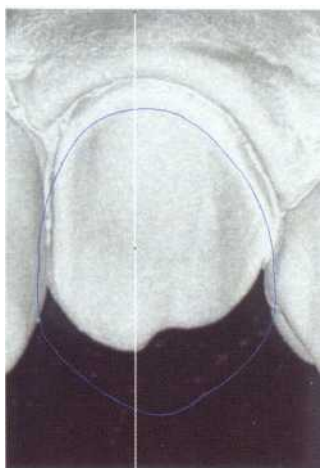


Fig 12-11 Vertical incisal-cervical cross section line (white).

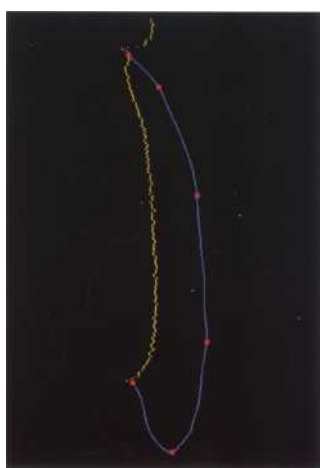


Fig 12-12 Incisal-cervical cross section through the veneer construction as marked in Fig 12-11.

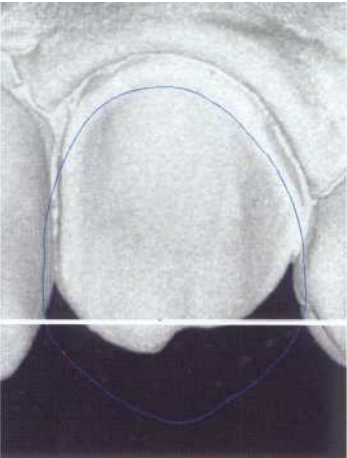


Fig 12-13 Horizontal mesiodistal cross section line (white).

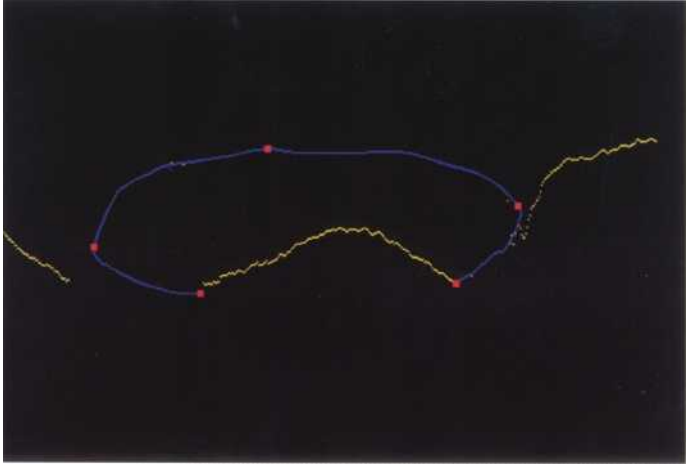
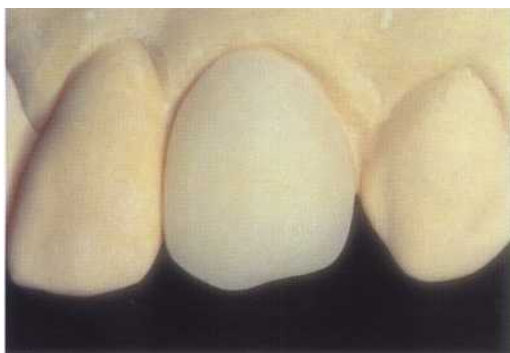


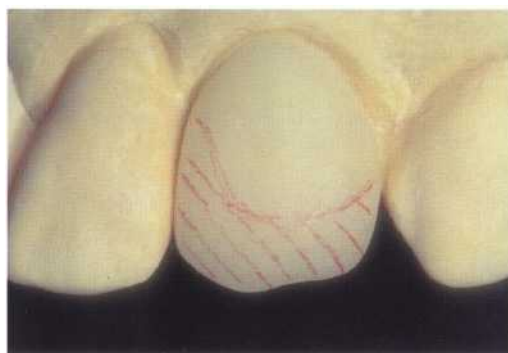
Fig 12-14 Cross section through the veneer construction in the mesiodistal direction as marked in Fig 12-13.



Fig 12-15 Machined ceramic laminate veneer ready to be cut off the machining stub.



**Fig 12-16** Try-on of the laminate veneer on the plaster cast.



**Fig 12-17** Defining the incisal area to be reduced for the individual buildup.

Fig 12-13 with the corresponding cross section of the veneer being shown in Fig 12-14. When the machining icon is activated, the construction is automatically saved on the hard disc and the user is requested to insert a ceramic block of adequate size. The system computes the shape of the veneer from the data obtained from the optical impression and the selected construction lines.<sup>8</sup> During the machining process the two diamond-coated burs, one cylindrical and the other cone-shaped, operate simultaneously. After 10 minutes of form grinding, the ceramic veneer is presented ready to be cut off the machining stub (Fig 12-15).

### **Esthetic Buildup**

The veneer was tried on the plaster cast and found to have excellent fit (Fig 12-16). To define the buildup of the veneer, an area comprising the mesioproximal and the upper incisal third of the buccal surface was identified with a red pencil (Fig 12-17). The machined thickness of this portion of the veneer is shown in Fig 12-18. The marked

labial area was then reduced in thickness by approximately 50% (Fig 12-19) using a diamond bur. Vitadur Alpha veneering ceramic (Vita) was used for the buildup (Fig 12-20). The incisal portion was formed with "transparent blue," "opalescent," and "clear" ceramic together with enamel ceramic (Figs 12-21 and 12-22). Dentine ceramic, a shade darker than the shade of the body of the veneer, was applied to the gingival third (Fig 12-23). After 5 minutes of drying, the veneer was fired in a Vacumat 40 furnace (Vita) at 950°C (Fig 12-24). The fired veneer (Fig 12-25) was smoothed and contoured (Fig 12-26) using a flame-shaped diamond bur. To perfect the esthetics of the veneer, ceramic paint-on shades (Fig 12-20; Akzent, Vita) were applied to further individualize the surface (Fig 12-27). After a second firing at 850°C to fix the ceramic shade, a thin layer of ceramic glaze was applied to achieve a natural luster (Fig 12-28). The veneer was fired again at 940°C in the Vacumat 40 furnace and tried on the model (Figs 12-29 and 12-30). Finally, the internal surface of the restoration was sandblasted with

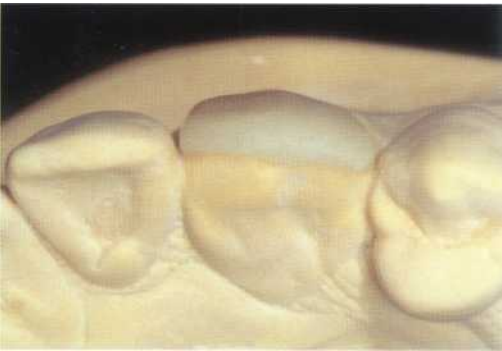


Fig 12-18 Machined thickness of the incisal aspect of the veneer.

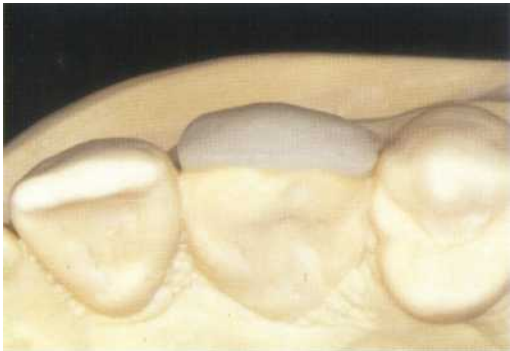


Fig 12-19 Incisal edge manually reduced in thickness by approximately 50%.



Fig 12-20 Vitadur Alpha veneering ceramic (left) was used for the buildup and Vita Akzent stains and glaze (right) was used for external characterization of the laminate.

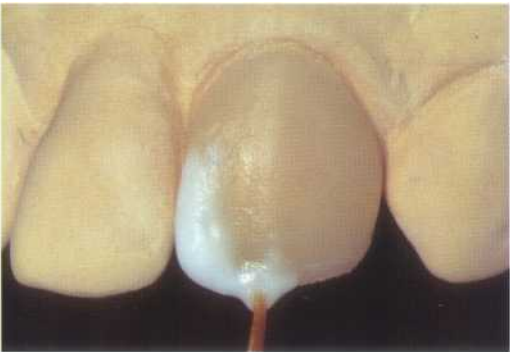


Fig 12-21 The incisal portion of the veneer was formed using transparent, opalescent, and clear veneering ceramic.



Fig 12-22 The form of the incisal edge was established.



Fig 12-23 Dental ceramic was applied to the gingival third of the laminate.



Fig 12-24 The veneer was fired in a Vacumat 40 furnace at 950°C.

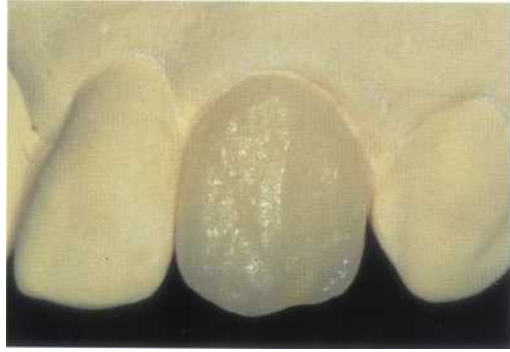


Fig 12-25 The fired laminate on the cast.

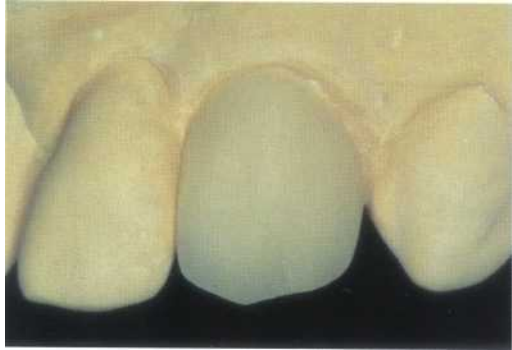


Fig 12-26 The veneer was smoothed and contoured with diamond burs.

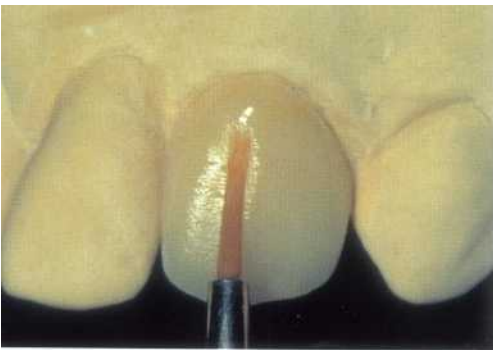


Fig 12-27 Ceramic paint-on stains were applied to further individualize the surface.

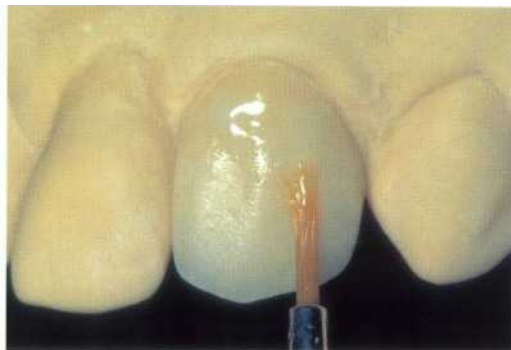


Fig 12-28 After a firing to fix the ceramic stains, a thin layer of ceramic glaze was applied.





Fig 12-29 The fired laminate veneer on the cast.



Fig 12-30 The same veneer, in an anterolateral view.

50  $\mu$ m aluminum oxide to remove any excess glazing ceramic.

### Adhesive placement

The provisional veneering composite was removed with a scaler and the preparation surface cleaned with pumice and a rotating brush. After try-in, the internal surface of the veneer was etched with 4.9% hydrofluoric acid (Ceramics Etch, Vita) for 60 seconds, silanized for 60 seconds using Monobond S (Vivadent) and covered in bond (Heliobond, Vivadent). For seating the veneer, retraction cord was used to expose the gingival margin, and the mesial and distal interdental spaces were protected with acrylic strips firmly secured with wooden wedges. The enamel was etched for 30 seconds with 37% phosphoric acid gel (Ultradent), rinsed off (20 seconds) and then dried using an air syringe. After application, allowing 20 seconds of penetra-

tion time, the bonding was blown out to a thin layer and light cured for 60 seconds (Heliolux DLX, Vivadent). The veneer was then placed using the light reactive base paste of Variolink Ultra (Vivadent). Light curing was achieved by 60-second exposures on the buccal and palatal aspects of the tooth.<sup>2,7</sup> Excess luting material was removed along the proximal margins using diamond-coated oscillating files (Proxoshape, Intensiv, Grancia, Switzerland) and diamond-coated strips (GC). The margins were then polished with flexible discs (Sof-Lex).

Figures 12-31 and 12-32 show the pleasing esthetics of the individualized Cerec veneer relative to the adjacent natural teeth. The incisal view demonstrates the new harmonious contour of the buccal surface and the altered alignment of the canine (Fig 12-33). The satisfied patient had good reason for smiling (Fig 12-34).



Fig 1231 Situation before the veneering of the left maxillary canine.

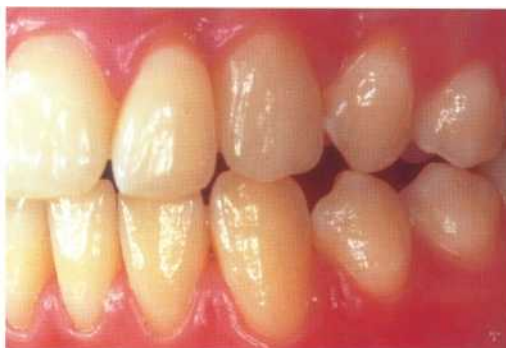


Fig 12-32 Cerec laminate veneer providing excellent esthetics.



Fig 1233 The incisal aspect after bonding of the veneer.



Fig 12-34 Clinical view of smile.

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## Esthetic Posterior Indirect Restorations

Jean-Francois Roulet and Roberto Spreafico

### Adhesion-The Basic Principles

With few exceptions, bonding in dentistry means micromechanical retention, based on the following principles:

- The larger the surface to be bonded the better.
- The surface energy of the bonding substrate must be much higher than that of the adhesive in order to be able to completely wet the substrate with the adhesive (intimate contact)
- The less the bonded interface is stressed (eg, by polymerization shrinkage or mechanical stress) the better it is for the bond.

### Bonding to Tooth Substrates

For enamel etching, hydrophosphoric acid is the etchant of choice. If the surface is dried perfectly, the hydrophobic acrylates are able to wet it completely and create a micromechanical bond. Modern self-etching primers for dentin may also create sufficient structural changes in enamel for bonding (Hannig M, et al, oral communication, 2000).

In dentin, the situation is more difficult. There are two things which must be accomplished. First, one must be willing to

etch dentin with acids, in order to expose the collagen network. Second, hydrophilic monomers (primers) must be used to wet the hydrophilic dentin and to prepare the way for the penetration of the more hydrophobic bonding resins. This approach demands a meticulous application of the methodological sequence, because only then is it possible to achieve the goal of complete penetration. This technique is very user sensitive because it is easy to make errors, eg, the dryness or wetness of dentin are crucial parameters that cannot be standardized clinically. Today, multipurpose or universal bonding agents are promising because there is relatively limited opportunity for error (Blunck U and Roulet JF, oral communication, 2000).<sup>21</sup>

### Bonding to Restorative Materials

Bonding to glass-based ceramics (feldspathic and glass ceramics) follows the same principles as does bonding to enamel because etching with hydrofluoric acid dissolves the glass phase, thus exposing the crystals and creating a microretentive surface.' Silanization renders the etched surface hydrophobic, thus enabling the diacrylates to wet it perfectly.<sup>23</sup>

Ceramics that do not contain a glass phase, eg, Al<sub>2</sub>O<sub>3</sub>- or zirconium oxide-based ceramics, may not be etched with hydrofluoric acid. Surfaces of these ceramics are roughened by sandblasting. Better wettability may be achieved by applying silane, but only after the surface has been silicatized by depositing an extremely thin layer of silica on the surface by means of either a pyrolytic (Silicoater, Kulzer, Weilheim, Germany) or tri-bochemical (Rocatec, Espe, Seefeld, Germany) process. However, there are some indications that bonds obtained by these methods are not stable over longer periods, probably because of hydrolytic degradation.<sup>12</sup>

The third alternative for bonding to ceramics is to use active monomers with the ability to bond to surface metal oxides present in ceramics. A good example is Panavia-7 (Kuraray, Osaka, Japan), a resin-based luting agent containing 4 META. With this type of resin, excellent long-term tensile strength data have been reported with zirconium-based ceramics.<sup>38</sup>

Bonding to composites is quite complex and still challenging. Modern composites are highly filled materials that have few double bonds for copolymerization, in particular when they are used for indirect restorations cured to a high degree of conversion. Assume that a resin is filled to 60% volume. This means that in a cross section only 40% of the surface is left for copolymerization. In this 40% of the surface, one can assume that at least 60% of the double bonds are consumed. Therefore, chemical copolymerization is not very successful. An approach to increase the composite-composite bond is to roughen the substrate surface by sandblasting and then increase the wettability by silanating

the silica-containing filler. With this technology, 90 MPa fracture strength is obtainable, in contrast to the 170 MPa strength that is obtainable for unbonded beams.<sup>14</sup> Another reliable technique is to sandblast the composite surface with a silica-coated Al<sub>2</sub>O<sub>3</sub> powder (Rocatec or Coe-Jet, Espe) prior to silanization.

## Rationale for the Indirect Approach

Composites shrink by approximately 3% (volume) upon polymerization, thus challenging the adhesive bond. The forces developed at the bonding interface depend on the configuration of the cavity and the speed of the polymerization reaction<sup>7</sup> and may exceed the adhesive forces, thus creating debonding. The indirect approach is one solution to counter the polymerization shrinkage of composites. With the bulk of the restoration being manufactured outside the oral cavity, the absolute value of the polymerization shrinkage of the luting composite only is very low and has only a minor effect on the interface. It is therefore possible to place inlays with finishing lines cervically in dentin, where the adhesion of composites is inferior to that obtained in enamel.<sup>3</sup>

## Composite Inlays and Onlays

Composite inlays and onlays can be constructed using different techniques, including semidirect techniques (intraoral and extraoral) and indirect techniques.

The semidirect techniques allow inlay to be constructed at the chairside and luted at the same appointment. Indirect tech-



niques involve laboratory collaboration and at least two clinical sessions.

The cavity is prepared according to the same principles and using the same instrumentation as that employed for ceramic inlays and onlays. The luting phase is the same except for the management of the bonding surface.

## Technique Selection

Four main clinical parameters have been defined to facilitate the selection of the most appropriate restorative option<sup>3</sup>:

- Number of restorations
- Size of restorations
- Cavity geometry
- Location and anatomy of the teeth

## Semidirect Intraoral Technique (Direct Composite Inlay)

This technique is indicated for the restoration of one or a maximum of two teeth at any one time.

The inlay is formed by placing a few composite increments into a tapered cavity previously insulated with two coats of an insulating glycerin gel medium (Separator, Coltene, Altstätten, Switzerland). A base of a conventional glass-ionomer cement is placed to eliminate undercuts. It is recommended that using any resin-based material, such as resin-modified glass-ionomer cement (RMGIC), compomer, or composite, be avoided because, despite appropriate cavity insulation, the composite inlay may adhere to the base, impeding removal of the inlay.

After in-mouth polymerization, the inlay is removed and the proximal anatomy, if necessary, is corrected and refined. Lastly,

following the heat and light treatment in a special oven (DI 500, Coltene), the restoration can be luted with composite resin cement. The intraoral composite inlay is perhaps the most economical way of producing luted restorations and undoubtedly permits the provision of inlays of optimal accuracy.<sup>22</sup>

The principal disadvantage of this procedure is the difficulty encountered in removing the inlay from the cavity following light curing. This necessitates careful case selection. Intracoronal cavities of one or two surfaces with a regular, simple design are best indicated for this purpose. Cavities with three surfaces or with several walls are not ideal because the composite resin tends to lock against the walls during polymerization, thereby hindering removal. Cuspal coverage should be avoided with this technique because of the lack of the antagonist reference. Furthermore, cavity walls must be free of undercuts, smooth, and characterized by a divergence of more than 18°. <sup>36</sup> This invariably requires a sacrifice of sound occlusal tooth tissue.

The principal advantage of this technique is the chairside production of a luted restoration without the need to take an impression.

## Extraoral Composite Inlays (Indirect Chairside Inlays)

Composite inlays and onlays can be produced chairside with the involvement of extraoral steps. This method is best suited to the restoration of large intracoronal cavities (Class I and II).

This technique relies on preparing the composite restoration on a silicon cast obtained from an impression. In contrast to the intraoral technique, the walls of the



Fig 13-1 Preoperative view of a maxillary quadrant. The restorations in the premolars and molar must be replaced because of recurrent caries and poor marginal adaptation. The first premolar will be restored by means of a direct composite restoration; the second premolar and the molar, because of the extent of the previous restorations, will be restored using a semidirect composite resin technique.



Fig 13-2 The first premolar is restored by means of a direct composite filling. Following restoration removal, the second premolar and the molar are lined with a flowable composite to complete cavity preparation for chairside composite inlays.

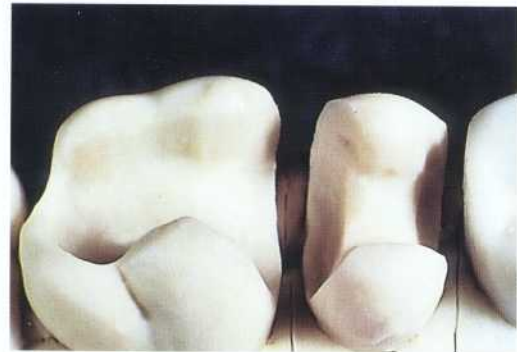


Fig 13-3 A silicon cast is prepared and the dyes are separated with a scalpel.

preparation should have a divergence of only 10°, allowing a more conservative approach during cavity preparation (Figs 13-1 and 13-2). The impression can be recorded using alginate, but a more accurate impression using silicon is preferable. A specially formulated, fast-setting vinyl polysiloxane (Mach-2 Die Silicone, Parkell, Farmingdale, NY) is injected into the impression following insulation with an insulating spray (New Break Agent, ADM SRL, Muggio, Italy). In this way a working cast is obtained within a few minutes. Dyes can be separated with a scalpel to obtain opti-

mal adaptation and contour of the restorations in the cervical region, together with appropriate proximal contacts (Fig 13-3). Small internal undercuts can be tolerated given the flexibility of the silicon cast. However, such undercuts must be removed from the fitting surface of the restoration prior to luting.

The restoration is completed with small increments of opaque and translucent composite (Figs 13-4 to 13-6) and luted in the same appointment (Figs 13-7 to 13-9). In the case of intracoronal restorations, the occlusal anatomy can be readily created.



Fig 13-4 A dentinal composite is applied to the floor of the preparation. An enamel composite is used to build up the proximal wall.



Fig 13-5 An increment of enamel composite is placed occlusally.



Fig 13-6 The two inlays after finishing and polishing.



Fig 13-7 During the same appointment, the inlays are seated in the cavities for the try-in.



Fig 13-8 The restorations after luting.



Fig 13-9 The same quadrant 1 month later.



Fig 13-10 Preoperative view of a mandibular quadrant. The two molars include extensive caries.

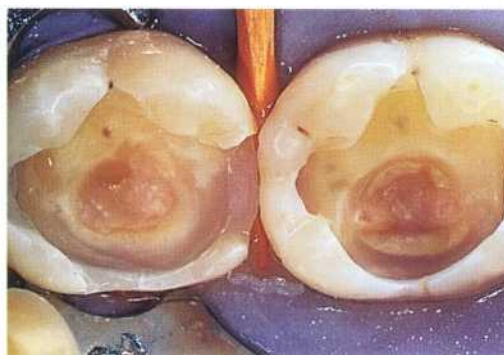


Fig 13-11 The cavities are prepared to receive a composite base. Given the reduced thickness of the lingual walls, these cusps should be reduced during the final stages of cavity preparation.

However, with this technique, the opposing reference tooth is not available and complex restorations may only be built up with reference of the adjacent teeth, resulting occasionally in the unavoidable need for occlusal adjustment following luting.

### Indirect Inlays (Lab-Made Composite Inlays)

Abutting Class II cavities involving partial or full coverage cannot be properly restored using the above techniques. Attempts to use semidirect techniques would require a segmental procedure, leading to extended chairside time and senseless clinical effort.

Therefore, indirect composite techniques are best suited for such cases, although they involve at least two clinical sessions with provisionalization and the laboratory construction of the restorations. The main advantage of the indirect technique is the provision of restorations with optimal occlusal anatomy, the restoration having been formed with reference to the opposing arch.

Indirect composite inlays and onlays can be constructed using conventional light-cured, small-particle hybrid materials normally used for direct restorations. Figs 13-10 to 13-28 illustrate a case managed using this technique.

Some new materials specifically developed for crown and bridge work are also indicated for indirect restorations (eg, Belle-Glass, Kerr; Sculpture FibreKor, Jeneric/Pentron; Targis-Vectris, Ivoclar). These systems require special, expensive devices for cure and postcure procedures. However, the manufacturers claim optimal mechanical and physical properties, together with excellent surface stability. Different clinicians have demonstrated that excellent esthetic results can be achieved with such materials<sup>2,6,17,26</sup>; however, to date little scientific data are available concerning the clinical behavior and longevity of restorations formed using these systems.



Fig 13-12 The completed preparations for two composite onlays. In such situations, only the indirect technique creates opportunity to achieve ideal occlusal anatomy.



Fig 13-13 A conventional plaster cast is obtained from a silicon impression. The first step involves placing wax as a spacer.



Fig 13-14 An initial layer of dentin-colored composite is applied.



Fig 13-15 The lingual walls are built up with translucent composite.



Fig 13-16 The finished restorations.





Fig 13-17 The composite onlays after polishing.



Fig 13-18 The use of rubber dam is essential in adhesive procedures.



Fig 13-19 The composite onlays at the time of try-



Fig 13-20 The restorations should be luted sepa-in. stored tooth.

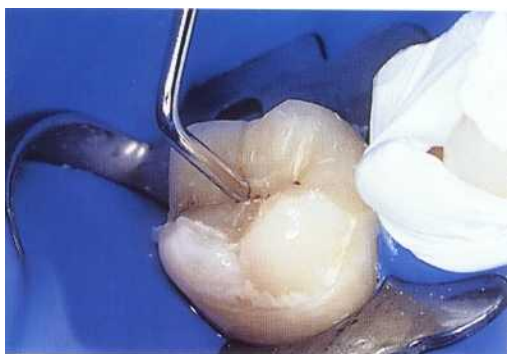


Fig 13-21 The luting cement is applied to the cavity and the onlay is inserted and seated manually.

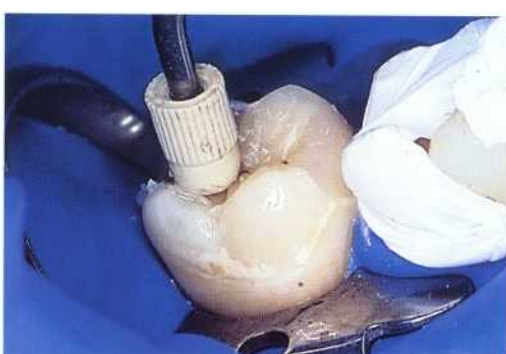


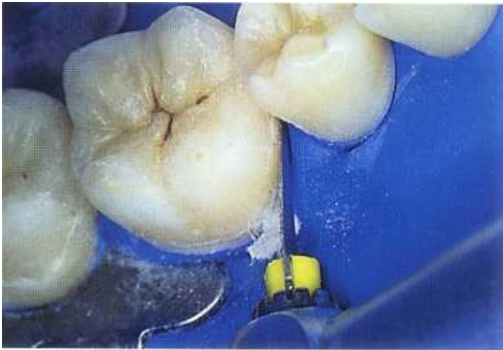
Fig 13-22 An ultrasonic tip is applied to the restoration to ensure complete seating.



**Fig 13-23** Cement excesses must be carefully removed before polymerization using a probe and dentotape interproximally.



**Fig 13-24** The flat exposed surfaces are finished with abrasive disks.



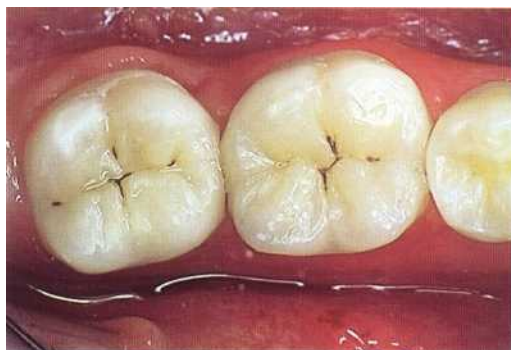
**Fig 13-25** The cervical margin is finished using an oscillating finishing tip.



**Fig 13-26** The final luster is obtained using polishing brushes.



**Fig 13-27** The restorations after finishing and polishing.



**Fig 13-28** The same quadrant 1 week later.

## Indirect Ceramic Restorations-Step By Step

Prior to cavity preparation, a silicon impression of the quadrant to be restored is taken and set aside to be used in the manufacture of the temporary restoration. The cavity preparation is similar to that of a composite inlay. The general rule is the less complex the cavity shape the better. The preferred burs are the Cerinlay diamonds (Intensiv, Grancia, Switzerland). As shown in the case presented in Figs 13-29 to 13-81, tooth buildup, if required, must be completed prior to final preparation (Figs 13-29 and 13-30). This can be achieved with either a glass- ionomer cement (Fig 13-31) or with composite and adhesive techniques (Fig 13-32). During final cavity preparation the clinician must allow for the minimal thickness of the restorative material (1.5 mm). If not done prior to cavity preparation, undercuts (from caries or former cavities) are filled with glass-ionomer cement, resin-modified glass-ionomer, or adhesively placed composite. Bevels are not prepared because the ceramic cannot be cast or sintered into knife edges. Thin proximal enamel portions (Fig 13-33) are eliminated with either axial wall trimmers (LM 161/162 and LM 165/166, HU Friedy, Chicago, IL) (Fig 13-34) or very fine diamonds (Comet No. 8889 314 010 and No. 889EF 314 010, Brasseler, Lemgo, Germany) (Fig 13-35). Internal features should be rounded to avoid stress concentrations (Fig 13-36).

Before recording the working impression it is important to expose the cervical margin, if it is located subgingivally, either by placing a retraction cord (Fig 13-37) or by undertaking a small papillectomy with an electrotome. The impression materials

of choice are the polyvinyl siloxanes, however, it is important to know the limitations of these materials. It is also important to be able to dry the cavity before taking the impression. Furthermore, it is to be remembered that these materials reach their fully elastic properties only after 10 minutes. If the correct procedure is followed, the dental technician may get a perfect, distortion-free impression (Fig 13-38), which may be made into an accurate cast. A bite registration is obtained using a stiff silicone, eg, Silagum AV-Quick-Bite (DMG, Hamburg, Germany).

For temporization, the silicon impression obtained prior to the preparation of the teeth is trimmed back to the center of the adjacent teeth (Fig 13-39). It is then filled with a composite for provisional restorations, eg, Luxatemp Automix (DMG), and repositioned in the mouth (Fig 13-40). It is important to verify the repositioning of the impression to avoid provisionals that are too high. The provisional inlay is removed during the elastic phase of the material (Fig 13-41) and subsequently trimmed with a scalpel blade, and if necessary with tungsten carbide burs. The provisional inlay is then cemented with a provisional cement and adjusted occlusally as necessary (Fig 13-42).

It is beyond the scope of this publication to explain in detail the laboratory procedures for the manufacture of ceramic inlays. Readers are referred to other publications for the description of this technology.<sup>3,30</sup> However, some points of detail are of particular importance. It is an advantage to provide the dental technician with a simple face-bow registration to ensure that the casts are articulated accurately. Furthermore, the technician should obtain two casts from the impression. One is





Fig 13-29 Amalgam restorations in teeth 14 and 15 to be replaced given recurrent caries.



Fig 13-30 The restorations are removed and the caries is excavated.



Fig 13-31 Reconstruction of tooth 15 using glass-ionomer cement.



Fig 13-32 Tooth 14 is reconstructed using a composite core.

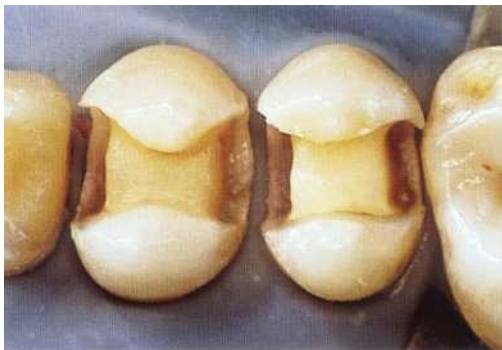


Fig 13-33 Appearance following cavity preparation. Note the inappropriate configuration distobuccally in tooth 15.

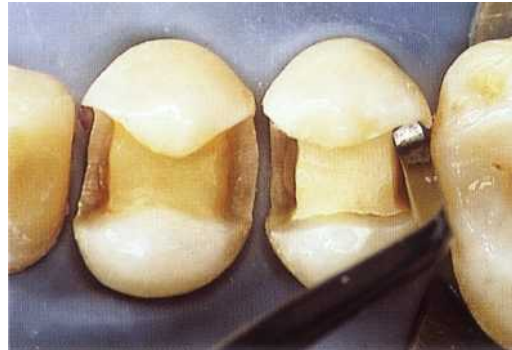


Fig 13-34 The shape of the distolingual wall in tooth 15 is adjusted using an axial wall trimmer.



Fig 13-35 The enamel finishing line is given a butt-joint configuration using a fine diamond tip.

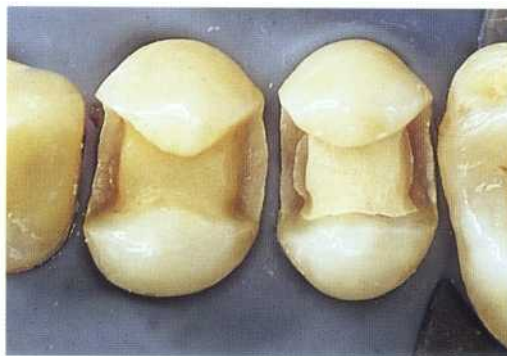


Fig 13-36 The completed cavity preparations.

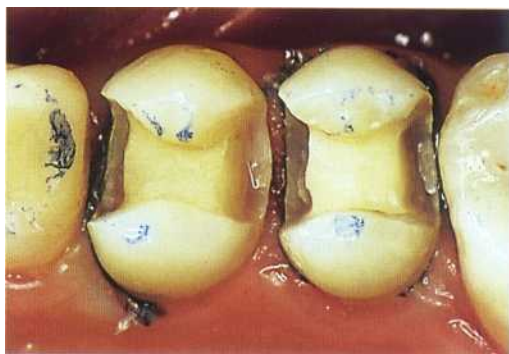


Fig 13-37 Retraction cord is placed to expose the cervical margins.

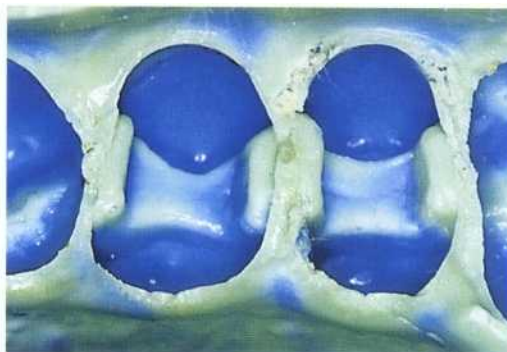


Fig 13-38 The polyvinyl siloxane impression. Note that the margins of the preparations are accurately recorded.

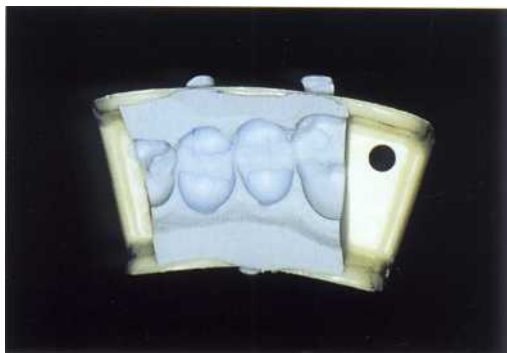


Fig 13-39 The initial silicon impression is trimmed to facilitate reseating in the mouth.



Fig 13-40 The filled impression (Luxatemp) is repositioned. Note the opportunity to ensure accurate reseating.



sectioned and used as a working cast. The other is left unsectioned and used as a fixed (control) cast. Delivery of the finished restorations should be on the unsectioned control cast (Figs 13-43 to 13-45). At the cementing appointment, the provisional inlay is removed (Fig 13-46) and rubber dam is applied. The cavity is thoroughly cleaned (Fig 13-47). An airborne particle abrasion instrument, using soluble phosphates as an abrasive, is convenient for this purpose. The inlay is then tried in and tested for fit and proximal contacts (Fig 13-48). Only then is the inner surface of the inlay conditioned for bonding. First, the inlay is degreased with an organic solvent (eg, acetone) (Fig 13-49). For the subsequent steps it is a good practice to put the inlay on a support of boxing wax (Fig 13-50). The inner surface of the inlay is etched with hydrofluoric acid (eg, Cerec Etch, Vita, Sackingen Germany) (Fig 13-51) for 90 seconds and thoroughly rinsed (Fig 13-52). To improve wettability with resins and subsequently the bond strength, the etched surface is coated with a silane.<sup>23,31</sup> An alcohol-based MPS solution (5%), freshly activated with an alcoholic acetate solution (5%) is preferred. The solvent can be evaporated efficiently with a blast of hot air (hair dryer) for 30 seconds. This significantly increases the bond strength.<sup>31</sup>

After protecting the adjacent teeth with matrix bands, the enamel is etched for 30 seconds (Fig 13-53) and the dentin (total etch) for 15 seconds (Fig 13-54) using a phosphoric acid gel. This step is followed by careful rinsing (Fig 13-55). With this technique it is important not to excessively desiccate the dentin; it should remain glossy (Fig 13-56). The bonding system is then applied (Figs 13-57 and 13-58) but not cured. An alternative to this procedure is

the use of a universal bonding agent, capable of etching enamel and dentin, priming, and bonding. However, this technology is not yet fully investigated. For luting, a dual-cure, high-viscosity luting composite (Sonocem, Espe) (Fig 13-59) is used in conjunction with ultrasonic energy (Fig 13-60).<sup>5,19,29</sup> If it is decided not to use the ultrasonic technique, then a low-viscosity, dual-cured luting composite should be used. Once the inlay has been fully seated (Fig 13-61), all excess composite material must be removed (Fig 13-62). Before any composite excess is removed proximally with dental floss, the inlay must be held in its final position with a spatula or a ball-point explorer (Fig 13-63). Finally the marginal area is covered with a glycerin gel (Airblock, Dentsply, Konstanz, Germany) (Fig 13-64) and the composite is carefully cured from all aspects (Figs 13-65 and 13-66). Occlusal adjustment is completed very carefully with fine finishing/polishing diamonds (Figs 13-67 to 13-71). Trimming, finishing, and polishing is commenced with scalpel blades or scalers (Figs 13-72 and 13-73) and then with ultrafine diamonds (Comet No. 889EF 314 010, Brasseler) (Fig 13-74). Final polishing is completed using aluminum oxide-coated finishing/polishing disks (eg, Soflex, 3M, St. Paul, MN) (Figs 13-75 to 13-77) and strips (eg, Epitex Composite Finishing Strips, GC Dental Products Corp, Kasugai, Aichi, Japan; SoflexStrips, 3M) (Figs 13-78 to 13-79). Final surface gloss is obtained with silicanitrite-impregnated nylon brushes (Occlubrush, Hawe Neos, Switzerland) (Fig 13-80). Because it is unavoidable to remove some enamel during the polishing procedures, the field is finally fluoridated with a fluoride gel (Fig 13-81).

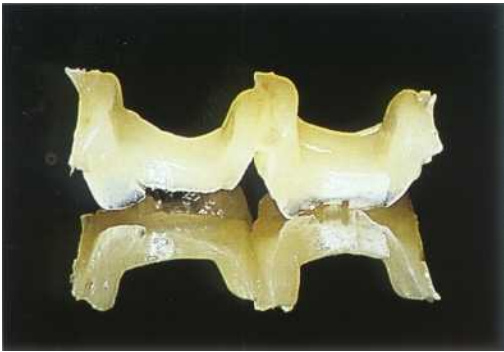


Fig 13-41 The provisional inlays immediately following removal. The excesses can easily be trimmed with a scalpel blade.



Fig 13-42 Try-in of the provisional inlays.



Fig 13-43 The ceramic inlays on the control cast (occlusal view).

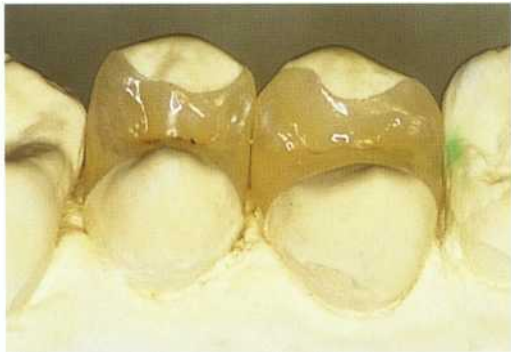


Fig 13-44 The ceramic inlays on the control cast (palatal view).



Fig 13-45 The ceramic inlays.

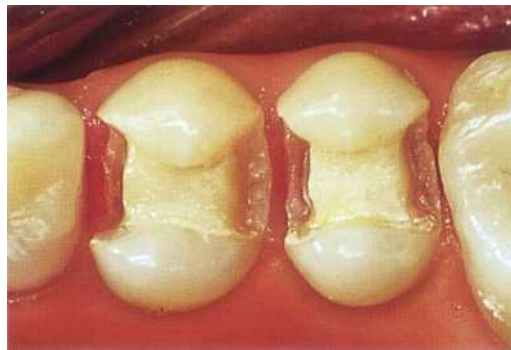


Fig 13-46 The preparations following the removal of the provisional inlays.



Fig 13-47 After rubber dam placement, the cavities are thoroughly cleaned.



Fig 13-48 The inlays are tried in. Fit and proximal contacts are checked.

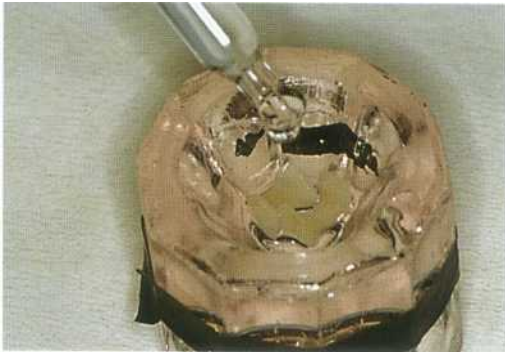


Fig 13-49 The inlays are degreased with acetone.



Fig 13-50 The inlays are fixed on sticky wax.

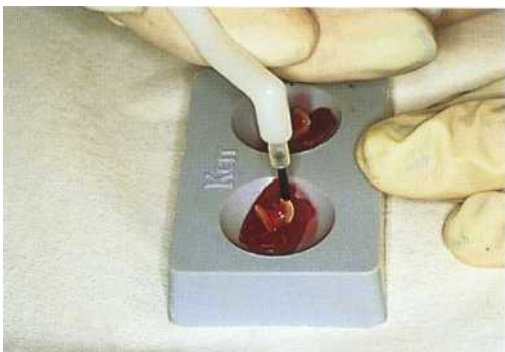


Fig 13-51 The fitting surface is etched with hydrofluoric acid.



Fig 13-52 Careful rinsing.



Fig 13-53 Etching of the enamel for 30 seconds. Note the protection of the adjacent teeth with matrix bands.



Fig 13-54 Total etching.



Fig 13-55 Careful rinsing.



Fig 13-56 Gentle drying. The dentin must remain moist (glistening).

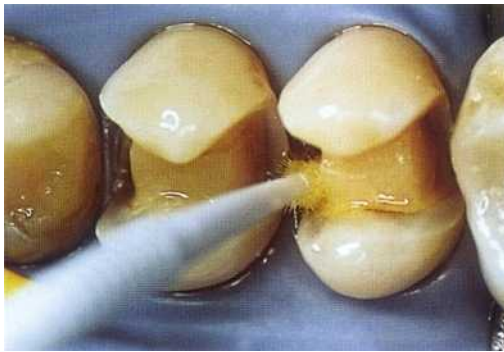


Fig 13-57 Primer is applied.



Fig 13-58 Adhesive is applied.



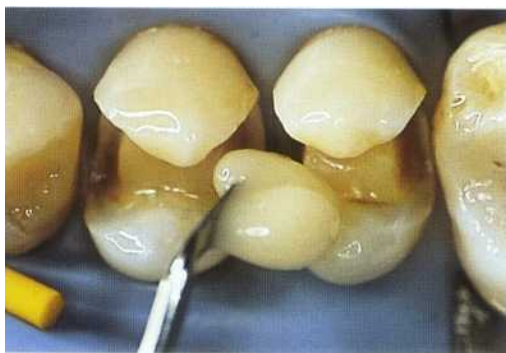


Fig 13-59 The highly viscous luting composite is introduced into the cavity.

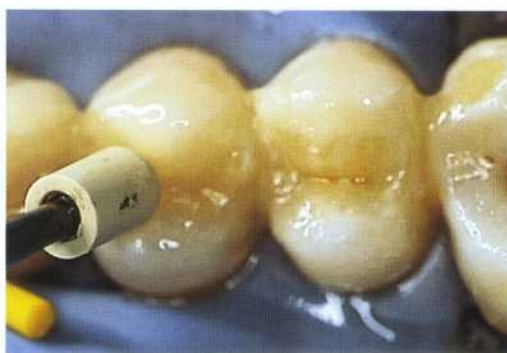


Fig 13-60 The inlay is positioned with ultrasonic energy.



Fig 13-61 Complete seating is verified with an explorer.



Fig 13-62 Excess composite material is removed.

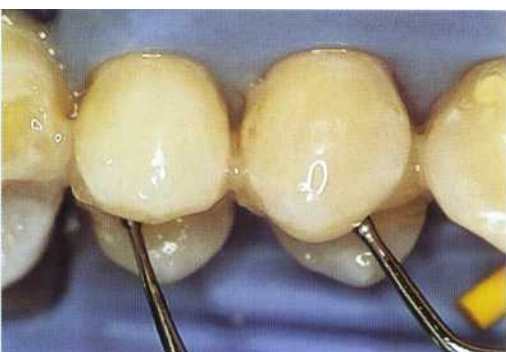


Fig 13-63 The inlays are held in position with small ballpoint instruments during proximal flossing.

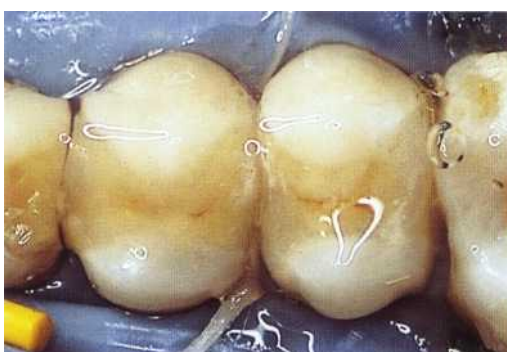


Fig 13-64 The margins are covered with glycerin gel.



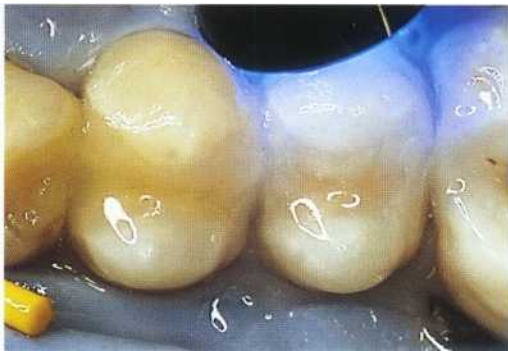


Fig 13-65 Light curing from proximal aspect.

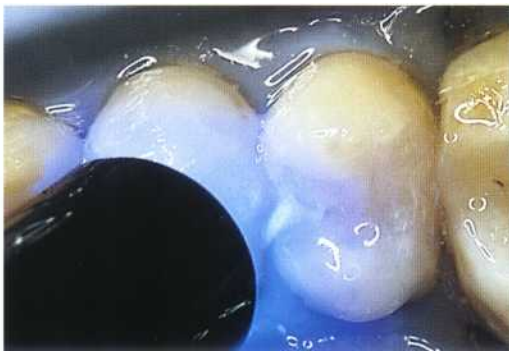


Fig 13-66 Light curing from occlusal aspect.



Fig 13-67 Occlusal adjustment. The inlays are in hyperocclusion.



Fig 13-68 Removal of occlusal interferences with a fine diamond bur.



Fig 13-69 Correction of residual occlusal interference using an ultrafine diamond bur.



Fig 13-70 Centric occlusal contacts after correction.

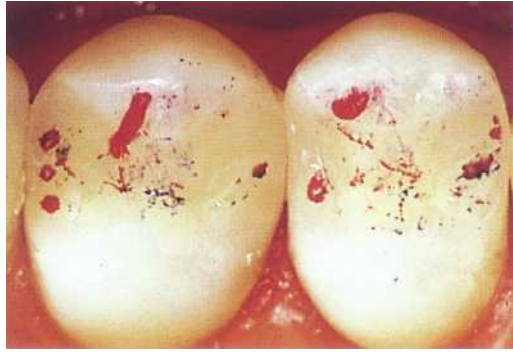


Fig 13-71 Occlusal contacts in function (working side).



Fig 13-72 Removal of excess composite fins with scaler.



Fig 13-73 Removal of excess composite fins with scalpel blade.

Fig 13-74 Removal of excess composite fins with ultrafine diamond tip.



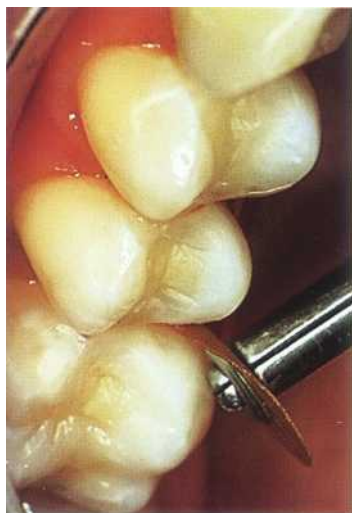


Fig 13-75 Polishing of proximal surface with Soflex disk.

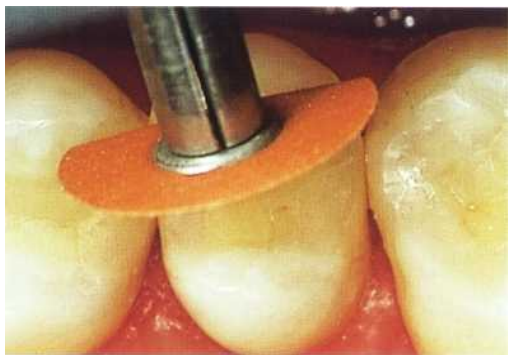


Fig 13-76 Polishing of occlusal surface with Soflex disk.

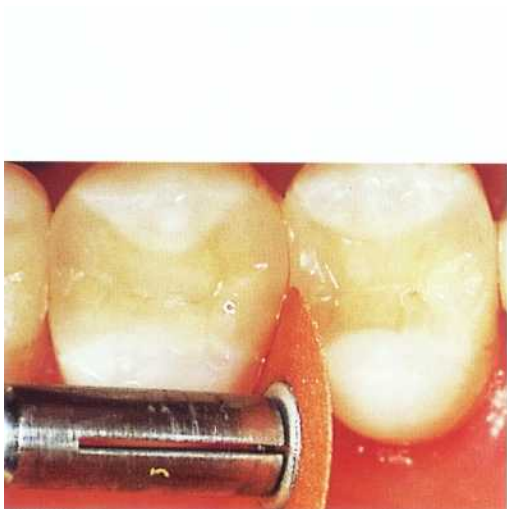


Fig 13-77 Polishing of proximal surface with Soflex disk.



Fig 13-78 Soflex finishing strips have an uncoated central section that enables the dentist to insert them through the contact point without damaging the approximating surfaces.

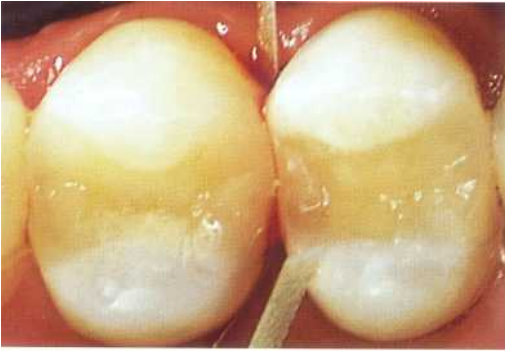


Fig 13-79 Polishing the proximal-cervical area with a finishing strip.



Fig 13-80 High gloss is obtained with an Occlubrush.



Fig 13-81 Fluoridation of the area with a gel.

## Longevity of Indirect Posterior Restorations

Esthetic posterior indirect restorations have been available for more than 15 years. They have proven their clinical reliability in many controlled studies. The longevity of composite inlays is documented in the studies summarized in Table 13-1. The low number of reports exceeding 5 years of observation time may be explained by the rate of development of new composite materials.

Ceramic inlays are better documented. Studies with observation times of up to 10 years are listed in Table 13-2. Annual failure rates for ceramic inlays range from 0% to 4%. The mean annual failure rate for the reported studies (observation times between 5 and 10 years) is 1.2%. However, the wide differences in clinical success and failure rates indicate that the procedures are technique sensitive. Good results seem to require extremely careful and skilled completion of the restorations.



Table 13-1 Longevity of composite inlays and onlays

Year	Authors (first)	Length of observation (y)	Class	Material	Number of restorations	Survival rate (%)	Annual failure rate (%)
1994	van Dijken <sup>33</sup>	5	II	Brilliant	100	88	2.4
1996	Krämer <sup>13</sup>	6	I and II	Visio Gem	118	41	9.8
1998	Wassell <sup>37</sup>	5	II	Brilliant	65	88	2.4
1997	Wiedmer <sup>39</sup>	5	I and II	Brilliant/ APH	24	100	0
1999	Donly <sup>4</sup>	7	Inlay	Concept	32	75	3.6

Table 13-2 Longevity of ceramic inlays in studies with observation times > 5 years

Year	Authors (first)	Length of observation (y)	Class	Material	Number of restorations	Survival rate (%)	Annual failure rate (%)
1992*	Mörmann <sup>18</sup>	5	II	Cerec	8	100	0
1994	Walther <sup>35</sup>	5	I and II	Cerec	1011	95	1
1995	Otto <sup>20</sup>	5	II	Cerec	100	98	0.4
1996	Kanzler <sup>11</sup>	6.5	II	Ceramco	280	85	2.3
1997	Roulet <sup>27,29</sup>	6	I and II	Dicor	123	76	4
1998	Felden <sup>8</sup>	7	inlay/ onlay	Dicor, Empress, Cerec, Ducera	287	94	0.8
1998	Fuzzi <sup>9</sup>	10	I and II	Microbond Nat. Cer, Fortune	183	97	0.3
1998	Hayashi <sup>10</sup>	6	I and II	G-Cera, Cosmotech II	49	92	1.3
1998	Lehner <sup>15</sup>	6	inlay/ onlay	Empress	138/17	95	0.9
1998	Reiss <sup>25</sup>	7.5	I and II	Cerec	1011	92	1.1
1998	Sjögren <sup>32</sup>	5	II	Cerec	66	89	2.2
1998	van Dijken <sup>34</sup>	6	II	Mirage (resin cement)	58	88	2
1998	van Dijken <sup>34</sup>	6	II	Mirage (GIC)	57	74	4.3
1999	Malament <sup>16</sup>	11.3	inlay/ onlay	Dicor	114	92	0.7
2000	Reiss <sup>24</sup>	10	I II	Cerec	1010	90 85	1 1.3

\*Two inlays were fractured in this study.



## Conclusions

Esthetic indirect restorations have proven to be a good solution if large cavities are to be restored or if there is more than one restoration required per quadrant. Under such circumstances the indirect approach is less

time consuming and more controllable than alternative techniques. However, to provide inlays and onlays it is generally necessary to sacrifice more sound tooth tissue than is necessary with direct techniques to create the necessary path of insertion.

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## Bonded Partial Restorations for Endodontically Treated Teeth

Figs 14-1a to 14-1c Posts do not reinforce endodontically treated teeth , but are indicated when tooth structure is insufficient to retain a core and crown.



Fig 14-1a Postoperative view of an endodontic re-treatment with cast post and core.



Fig 14-1b Clinical view of a cast, semiprecious alloy core luted with glass-ionomer cement (GC Fuji Plus).



Fig 14-1c Full-coverage metal-ceramic crown.

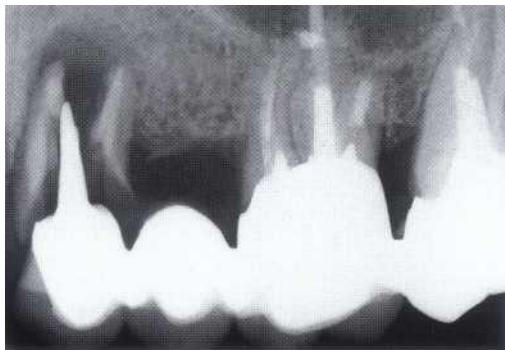


Fig 14-2 A root fracture of an endodontically treated tooth induced by iatrogenic restorative intervention. The maxillary premolar was restored with a cast post and core prior to being used as a fixed partial denture abutment.



## Problems with Endodontically Treated Teeth

In many papers dealing with endodontically treated teeth, post and core restorations are the recommended treatment option<sup>20,29,30</sup> based on the view that all endodontically treated teeth should be crowned. As reported by Sabek,<sup>28</sup> it therefore is not surprising that the majority of practitioners consider most endodontically treated teeth to require a post and core and crown. Concurrently the endodontically treated tooth is generally considered to be fragile and at risk of fracture. Irrespective of the fragility of the remaining tooth tissue, it is suggested that BPRs offer advantages over posts and cores and crowns, including the preservation of dental tissues and the strengthening of the tooth through bonding. BPRs should, however, be considered as an alternative rather than as a substitute for post and crown restorations.

## General Advantages of Bonded Partial Restorations

When considering the reconstitution of an endodontically treated tooth, it is wise to think both in terms of restoration resistance and the durability and function of the restored tooth unit. The key issue is to determine the method of restoration that will offer the best opportunity to preserve the tooth in the dental arch during the patient's lifetime with the safest and least destructive form of intervention.

Dental tissues do not regenerate. Choosing the most conservative solution is therefore essential to stop the "dental apoptosis cycle."<sup>16</sup> The inevitable demise

of this cycle, ie, the loss of the tooth, should be avoided. Therefore alternatives to crowns that do not involve the placement of a post should always be favored.<sup>14</sup>

Prefabricated metallic screw and cast posts are often associated with radicular fractures.<sup>4</sup> They cause unnecessary failure that in most cases are untreatable (Fig 14-2). Once considered as a means of reinforcing roots, a post is now considered to have a major weakening effect on the remaining tooth tissue.<sup>10,29,40</sup> In posterior teeth, posts are dangerous at certain root levels; moreover, they are contraindicated for many short, curved, and ribbon-shaped root canals (Figs 14-3a to 14-3e).

There are important differences between the volumes of coronal and radicular dentin in anterior as opposed to posterior teeth.<sup>29</sup> In anterior teeth the coronal dentin is relatively thin and of low volume compared to the relatively thick, high volume of the radicular dentin. In posterior teeth this relationship is reversed, making the use of posts in posterior teeth all the more hazardous.

Because posterior teeth function mainly in compression, the benefit of a post is limited. When using a BPR that involves an adhesive interface over a large surface area, the placement of a post for retention is unnecessary, especially if the residual tissues are maximally exploited for bonding. This situation is increasingly common in clinical practice.

In anterior teeth and bicuspid, the need for a post and core is more often the rule. However, in such situations a much-debated alternative is the use of a bonded non-metallic post and core. Examples of such systems are based on zircon or carbon fiber posts.<sup>36</sup>

Figs 14-3a to 14-3e An endodontically treated molar requiring a full-coverage crown. A post is not indicated if a moderate amount of coronal tissue remains. In contrast, a direct partial-bonded core is recommended.

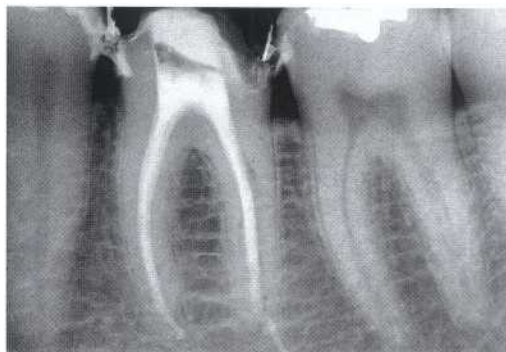


Fig 14-3a Immediate postendodontic view of the first mandibular molar.



Fig 14-3b Rubber dam isolation and access to the pulpal chamber.



Fig 14-3c After dentinal conditioning with poly acrylic acid (GC Dentin Conditioner), resin-modified glass ionomer (GC Fuji IILC) is injected into the pulpal chamber.

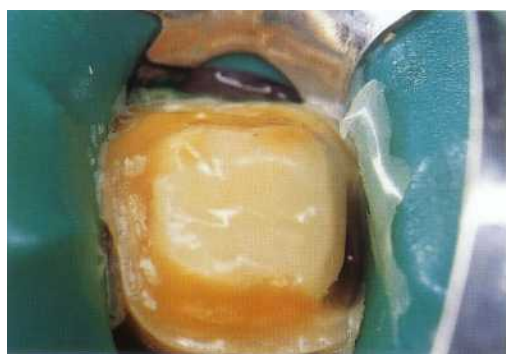


Fig 14-3d The completed core restoration (Tetric, Vivadent) following bonding and microhybrid composite layering.



Fig 14-3e The all-ceramic crown (In-ceram).

New root canal preparation techniques<sup>5</sup> and means to assess the prognosis of endodontic treatments<sup>26</sup> are of additional assistance in treatment planning. Sealing of the root filling prior to restoration of the crown is a critical determinant in ensuring a favorable prognosis.<sup>3°</sup> Recent data indicate that failures classified as endodontic failures are, in many cases, a consequence of bacterial microleakage due to a failure to seal the root canal filling prior to prosthetic treatment.<sup>24</sup> Leakage of a temporary crown and exposure to saliva during preparation of the post space and at the time of impressions, notwithstanding subsequent leakage at the margins of the final crown, are well-known causes of failure. Consequently, it is preferable, whenever possible, to avoid the placement of a post that requires the partial removal of the root filling. For the same reason, it is necessary to effectively restore a tooth immediately following endodontic treatment, even in cases with preexisting apical periodontitis (Figs 14-4a to 14-4e). If the permanent prosthetic solution must be delayed, a transitional BPR will provide a better seal than a temporary crown.

In the event of recurrent infection, retreatment may be carried out more easily when a provisional rather than a permanent restoration has been placed. Such restorations facilitate the placement of rubber dam and provide a four-walled access cavity that helps contain root canal irrigation solutions. In contrast, the presence of a post and core crown greatly complicates retreatment with the added risks of weakening, perforation, and fracture.<sup>19</sup>

In the case of immature teeth, BPRs are necessary during apexification treatment and in the management of the sequelae of trauma. After gutta-percha obturation, a

BPR helps compensate for the weakening of the residual radicular walls, and thereby helps overcome some of the problems associated with the interruption of the development of the root.

The choice of a partial rather than a full-coverage restoration promotes periodontal health by leaving cervical emergence axial profiles unchanged and placing the restoration margins supragingivally.<sup>14</sup> Furthermore, in situations where the gingivae are thin or lack adequate width of attachment, the provision of partial rather than full-coverage crowns may preclude the need for preprosthetic mucogingival surgery.<sup>1°</sup>

A further advantage of partial crown restorations is their cost relative to that of full-coverage crowns.

## Biomechanic Advantages of Bonded Partial Restorations

Data on the fracture resistance of vital and nonvital teeth are confusing, given that the results and conclusions of the available studies vary according to the methods used.

In numerous studies the mechanical properties of dentin in vital and nonvital teeth have been found to be similar.<sup>13,25,31</sup> However, nonvital teeth tend to be regarded by the majority of practitioners as weakened relative to vital teeth. The most important factor on which authors agree is the weakening effect of the loss of tooth structure.<sup>25,31-33,42</sup> The clinician should, therefore, take account of various aspects of remaining dental structures, namely:

- The number and thickness of the remaining walls.

Figs 14-4a to 14-4e To prevent coronal leakage, a bonded restoration should be placed immediately following successful completion of root canal treatment.



Fig 14-4a Upon completing the root filling, rubber dam is left in place. The pulpal chamber is cleaned of excess endodontic materials and the dentinal walls of the access cavity are etched with phosphoric acid.



Fig 14-4b Sealing is performed using an appropriate adhesive system (Optibond Solo, Kerr).



Fig 14-4c The pulpal floor is covered with a flowable composite (Revolution, Kerr).



Fig 14-4d The first increment of posterior composite (Prodigy Condensable, Kerr) is placed using a layering technique.



Fig 14-4e The final restoration.

- The nature of tooth tissue loss, with the loss of marginal ridges being an unfavorable factor.
- The morphology of the defect. Internal angles generate corner effects and may be difficult to eliminate.

All operative procedures generate a significant amount of stress in remaining tooth tissues. Procedures including endodontic treatment and cavity preparation may induce cracks in the hard dental tissues. Such cracks may remain unnoticed but may subsequently lead to fractures. To prevent cracks and cracked tooth syndrome, it is necessary to select a therapeutic solution that favors the reinforcement of the remaining dental structures and allows the absorption of mechanical stresses. Bonded restorations meet these requirements.

Many studies have focused on the issue of the reinforcing effect of bonding, but results differ from one author to another, mostly in relation to the type of restoration:

- Ceramic inlays?
- Resin composite inlays<sup>18</sup>
- Bonded metallic inlays<sup>9</sup>
- Direct composite fillings<sup>1,2</sup>
- Bonded amalgams<sup>23</sup>

It is important to note that all of these studies were laboratory based, typically using intact premolars extracted for orthodontic reasons. The possibilities to reinforce structures clinically may, however, be limited because problems in vivo tend to focus on endodontically treated teeth. However, data obtained by Ausiello et al<sup>1,2</sup> in two studies on endodontically treated teeth give promising results.

The purpose of the first study<sup>2</sup> was to determine the fracture resistance of endodontically treated premolars, restored with bonded MOD restorations. The results showed that the restored teeth had similar resistance to fracture as did intact control teeth. In contrast, the resistance to fracture of teeth restored with either bonded amalgam or a sandwich restoration, including a 2- to 3-mm thick dentinal substitute (a glass-ionomer cement-composite sandwich or a polyacid modified resin-composite sandwich), was inferior to that of intact teeth, but greater than that of endodontically treated teeth with an unrestored mesio-occlusodistal cavity.

In their second study, also involving endodontically treated teeth, Ausiello et al showed that under loading, bonded amalgam and sandwich restorations suffered significantly more degradation than did composite restorations through separation of the interfaces.

However, no clinical study is known to have confirmed these laboratory data. The long-term clinical benefits of bonding endodontically treated teeth must remain speculative, in the absence of further scientific evidence. Prospective clinical studies are required to test the clinical performance of BPRs, relative to traditional restorations requiring substantially more tissue loss.

## Indications for Bonded Partial Restorations

The decision to select a conservative solution to a problem, which would normally be an indication for a crown, must be based on considerations arising from clinical and radiographic examinations.



**Table 14-1** Clinical indications for BPRs compared with those for full crowns

Factors	BPR	Full crown
Patient age	All ages	Adult and elderly patient with healthy periodontal support
Time since devitalization	Recent devitalization: No loss of the mechanical resistance of the residual tooth structure	Previous devitalization: Low mechanical resistance within the residual tooth structure
Occlusion	<ul style="list-style-type: none"><li>• Stable maximum intercuspation</li><li>• Cuspal protection</li><li>• Overbite</li></ul>	<ul style="list-style-type: none"><li>• Unstable maximum intercuspation</li><li>• Group function</li><li>• Bruxism</li></ul>

**Table 14-2** SISTA classification applied for the loss of tooth substance in devitalized teeth<sup>17</sup>

Site (topography of the lesion)	Stage (extent of the lesion)
1: Occlusal loss of tooth substance 2: Proximal loss of tooth substance 3: Cervical loss of tooth substance	0: Any loss of tooth substance 1 & 2: Moderate loss of tooth substance; remaining tooth structure retains sufficient strength 3 & 4: Large/extensive loss of tooth substance, with weakened or lost cusps

Besides the loss of tooth structure, which is the most significant local factor, general factors must also be considered. These include the patient's age, the prognosis of the endodontically treated tooth,<sup>22</sup> and occlusal function (Table 14-1).

To simplify the quantitative and qualitative assessment of the loss of tooth structure, reference will be made to the classification proposed by Mount and Hume<sup>21</sup> and subsequently modified by Lasfargues

et al.<sup>17</sup> Although this classification, the SISTA concept, is based solely on the loss of dental structures without any reference to pulpal vitality, it allows the loss of tooth structure in endodontically treated teeth to be categorized according to the location of the lesion (site) and the extent (stage) of the lesion (Table 14-2). In this way, an occlusoproximal loss of tooth structure may be qualified in the following ways.

- SISTA 2.2: a lesion involving only one proximal surface
- SISTA 2.3 or 2.4: a mesio-occlusodistal lesion in which one or more cusps have been lost

Stages 0 and 1 do not relate to endodontically treated teeth. Stage 2 is mostly found in traumatized anterior teeth in which the loss of tooth structure is caused principally by the access cavity to the root canal system. The most frequently encountered situations are the loss of hard tissues found in stages 3 and 4 associated with sites 1 and 2. In these situations, the extent of tissue loss must be considered in terms of buccolingual width and depth. A large, thick residual enamel margin is a favorable criterion for a BPR.<sup>8</sup> In other cases, a composite/metallic onlay with a metal finishing line should be considered as an alternative.<sup>39</sup>

## Operative Procedures

Different procedures may be considered, depending on the type of tooth and the extent of the loss of tooth tissue.

### Anterior Teeth

In general, BPRs are an option for the treatment of traumatized anterior teeth; more invasive solutions are a last resort. According to many authors,<sup>14,20,27,32,33</sup> a direct composite restoration is the preferred option for the management of endodontically treated anterior teeth with moderate loss of tooth tissue, including an endodontic access cavity (Figs 14-5a to 14-5h). In such situations, it remains to be shown that the use of a ceramic post is a valid option.<sup>36</sup>

Direct BPRs may be considered an option for endodontically treated anterior teeth classified as stage 3. BPRs are mostly indicated when both marginal ridges are intact and the buccal wall is reasonably thick (SISTA 1.2 and SISTA 1.3).

In stage 4 cases, a full-coverage crown will generally be found to be the most suitable option. However, extension of the preparation lingually for ceramic or composite veneers may be considered in the management of a fractured incisal edge in incisor teeth. The endodontic access cavity may be filled using a direct technique or incorporated in the design of the preparation to increase retention and the stability of the veneer.

### Posterior Teeth

A direct restoration of a heavily filled microhybrid composite may be considered in posterior teeth in the following situations.

Defect (up to stage 3) present in site 1 with the occlusion allowing retention by means of the weakened walls.

Defect (up to stage 2) present in site 2 with the loss of tooth structure involving only one of the two marginal ridges.

For a mesio-occlusodistal defect, indirect restorations are necessary.

In order to facilitate endodontic retreatment, the canal orifices and pulpal chamber should be filled with a resin-modified light-cured glass-ionomer cement. The placement of a flowable composite<sup>3</sup> as a dentinal substitute may also be considered to contribute to the distribution of occlusal loads transmitted by the overlying composite restoration and to limit the consequences of polymerization shrinkage.<sup>37</sup>

Figs 14-5a to 14-5h Esthetic bonded partial restoration of an anterior tooth combining bleaching and a direct adhesive technique in a young patient.



Fig 145a Preoperative view. Despite successful apexification, post core and crown restoration of this traumatized incisor is contraindicated.



Fig 145b The unsightly facial aspect of the discolored incisor, including an incisal composite.



Fig 145c The esthetic improvement following external home bleaching (Opalescence, Ultradent, South Jordan, UT).

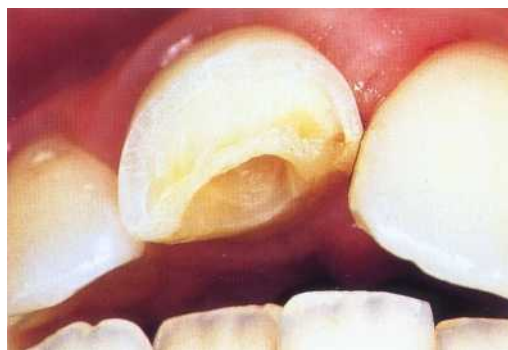


Fig 145d With the composite restoration removed, the opening to the root canal is sealed with a light-cured glass-ionomer cement. The increased overjet with no intercuspation position contact is a favorable situation for a direct restoration.



Fig 14-5e In profile, the unfavorable buccal positioning of the incisor is apparent. The contraindications for veneer or crown placement may be apparent.

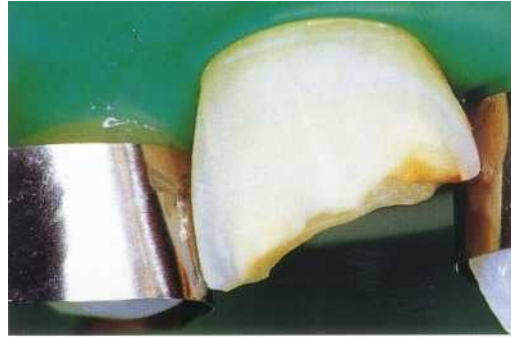


Fig 14-5f Rubber dam placement, etching, and the placement of matrix strips to protect the adjacent teeth.



Fig 14-5g Incremental layering using saturated dentinal shades and translucent incisor enamel composite (Silux Plus, 3M, St. Paul, MN).



Fig 14-5h The final esthetic result.

Figs 14-6a to 14-6f Restoration of a first maxillary molar using an adhesive semidirect technique.



Fig 14-6a The restoration is built up directly in the cavity following the application of a separator (Coltene, Altstätten, Switzerland).



Fig 14-6b Following polymerization, the onlay can be removed. A tapered cavity preparation, free of undercuts and finished with fine diamond burs, is necessary to avoid locking in of the restoration.



Fig 14-6c Adjustment of the proximal contact, occlusal relationships, and morphological features.



Fig 14-6d The finished onlay is postcured by photothermal treatment to improve hardness and wear resistance.





Fig 14-6e Rubber dam is placed prior to cementation. The occlusal view shows the flat pulpal floor of glass ionomer and the tapered cavity design.



Fig 14-6f The restoration is cemented adhesively.

However, the use of materials of different composition and construction may diminish internal cohesion within the restoration and thereby compromise the mechanical resistance of the restored tooth unit.

In case of extensive tooth tissue loss, a semidirect or indirect restoration is the preferable option. Such restorations are strongly recommended for SISTA 2.3 situations and are considered essential for SISTA 2.4 cases (Figs 14-6 to 14-8).

Partial and full cuspal coverage restorations may be indicated for mechanical resistance and for occlusal and esthetic reasons.<sup>11</sup> Many authors agree on the need for cuspal coverage in such clinical situations.<sup>27,33</sup> This solution can restore

the strength of the restored tooth unit.

Wiskott<sup>42</sup> suggests that a mesio-occluso-distal cavity in an endodontically treated posterior tooth is sufficient indication for the placement of a full crown. For this author, mechanical considerations prevail over biological constraints. This is in conflict with the results of the study by Ausiello et al.<sup>2</sup> In the future, clinical studies should focus on questions that influence treatment decisions. In the meantime, evaluations of clinical parameters will continue to dictate the placement of either a BPR or a crown.

Figs 14-7a to 14-7f Restoration of a first maxillary molar with a partial coverage bonded onlay using the indirect adhesive technique.



Fig 14-7a Preoperative appearance following removal of the intracoronar amalgam and endodontic retreatment.



Fig 14-7b The loss of tooth substance is classified SISTA 2.4. Rubber dam isolation is essential to prevent root canal contamination.



Fig 14-7c Tapered intracoronar design, enamel coverage, butt joint finishing along the cervical margin, and a flat pulpal floor (restored with flowable composite) are the main features of preparations for bonded composite onlays.



Fig 14-7d The laboratory-made onlay (Tetric laboratory composite and variolink adhesive system, Vivadent, Schaan, Liechtenstein) immediately after bonding.



Fig 147e The clinical result after the replacement of the lingual amalgam with a direct composite.



Fig 14-7f Postoperative view illustrating the concept of the endodontic continuum, including the root filling and the coronal restoration aimed at preventing root canal treatment failures.

Figs 148a to 14-8f Bonded partial restoration of a second maxillary molar using a metal-composite inlay.



Fig 148a Preoperative occlusal view. The loss of tooth substance is classified SISTA 2.3 with three remaining walls (buccal, lingual, and distal). A metal-composite mesio-occlusal inlay is indicated.

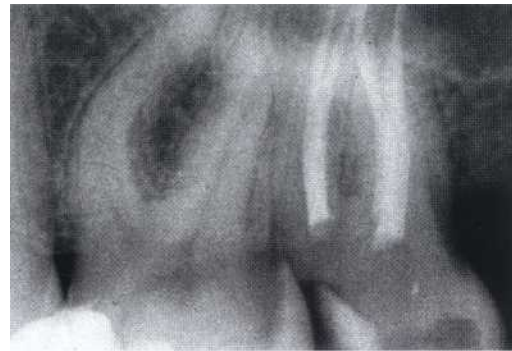


Fig 14-8b After endodontic retreatment.



Fig 14-8c After preparation. Full crown preparation is not indicated because the remaining tooth structure extends beyond the buccal plane of the dental arch.

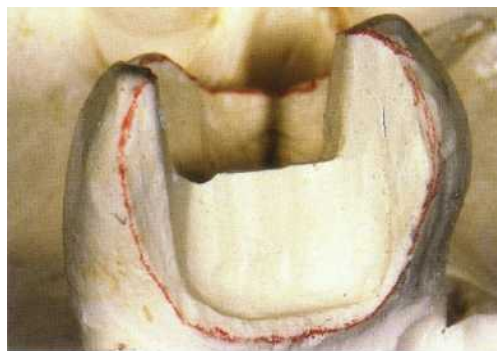


Fig 14-8d As seen in the laboratory model, resistance form is afforded by the remaining wall being reinforced by bonded composite (as a dentinal substitute) and the short cervical bevel.

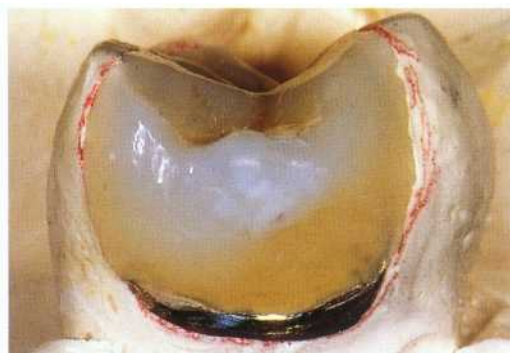


Fig 14-8e The composite-metallic inlay on the laboratory model. In cases in which cervical enamel has been lost, a cervical metal finishing line helps prevent recurrent caries.



Fig 14-8f After cementation with a glass-ionomer luting cement (Ketac conditioner and Ketac Cem, Espe, Seefeld, Germany). The functional and esthetic integration of the onlay is apparent.

## Conclusion

Existing literature indicates that the loss of tooth structure rather than the loss of the pulp causes weakening of devitalized teeth. Therefore, it appears desirable to favor more conservative solutions to problems necessitating the strengthening of damaged teeth. BPRs are an interesting option in such situations. However, in light of current knowledge, the use of BPRs

cannot be recommended for the restoration of all endodontically treated teeth. In planning the restoration of endodontically treated teeth, the advantages and limitations of the treatment options must be considered when formulating a management strategy. The fixed view that all endodontically treated teeth must be restored with a full crown has no scientific base and should therefore be reviewed.



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# The Oral and Dental Effects of Aging

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## Introduction

What do we mean by the term old? People rarely accept that they are old, preferring to think that there is always someone who is a bit more frail, with a few more grey hairs (or fewer hairs) than they have. A reasonable estimate from most people is that the elderly are about 15 to 20 years older than the person you ask. The stereotype of an older person as one with limited mobility, limited access to care and consequently high levels of dependence is false. The vast majority of older people live freely within their communities and have high levels of motivation and self-esteem. Even those who are relatively frail make great efforts to try to maintain as much independence as they can. Indeed, the loss of independence is one of the key variables leading to social decline in an older population. For this reason, little things such as having a lock on your door so that you can shut people out and having your own space are important, particularly if you live in a nursing home or with your children.

Older people are an important population group because in virtually all western countries there is a greater percentage of the population surviving into old age. For

example, it is estimated that at the present time 8.44 million people in the UK are aged 65 and above (15.1 % of the population). This is projected to increase to 9.78 million by the year 2020 (17.4% of the population).<sup>68</sup> In some countries, the impact of this increased longevity are compounded by a falling birth rate so that there are relatively few young people developing to assist with and support their aging relatives. Good examples of this problem are found in China and Italy. These factors combine to result in a change in the structure of our population, which at one time was broadly pyramidal with large numbers of young people and a smaller elderly group. The structure is now more rectangular, with similar numbers of people in age groups up to the age of about 65 years old. Thereafter, the size of the groups begins to decline as the most common causes of mortality, which are associated with increasing age, begin to have an effect. These include cardiovascular disease, stroke, and cancer (Fig 15-1).<sup>63</sup>

The oral health of older people is also changing contemporaneously. Edentulism was a common feature of old age 30 to 40 years ago. This is no longer the case as increasing numbers of elderly

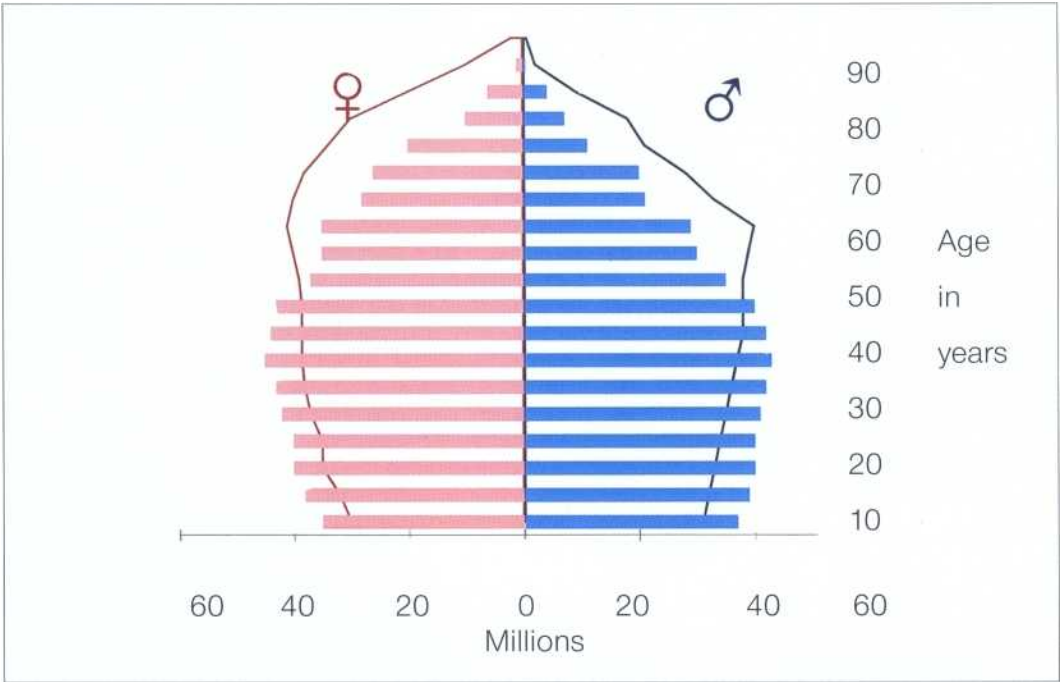


Fig 15-1 Population projections for the developed world. The solid bars represent the size of their respective age groups in 1998. The line is the outline of the structure in 2050. <sup>63</sup>

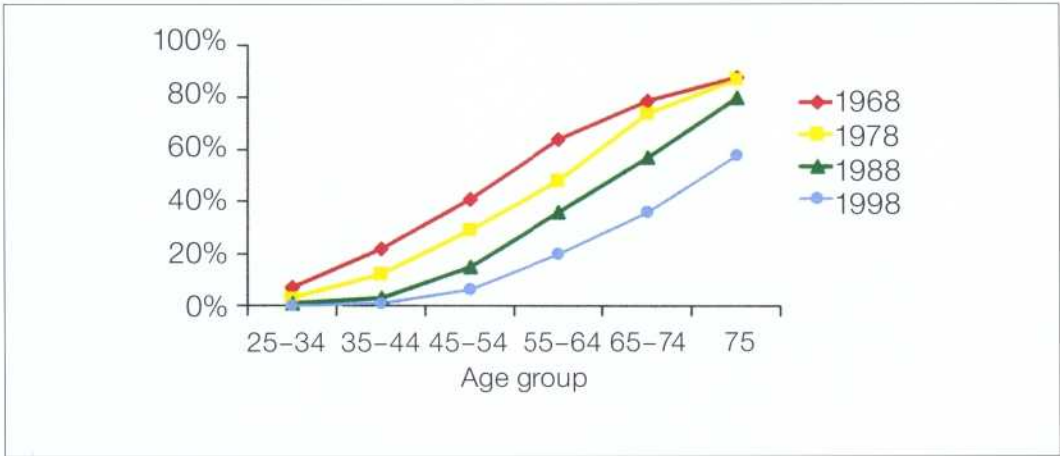


Fig 15-2 Proportion of the population of the UK that is edentulous by age group. <sup>23</sup>

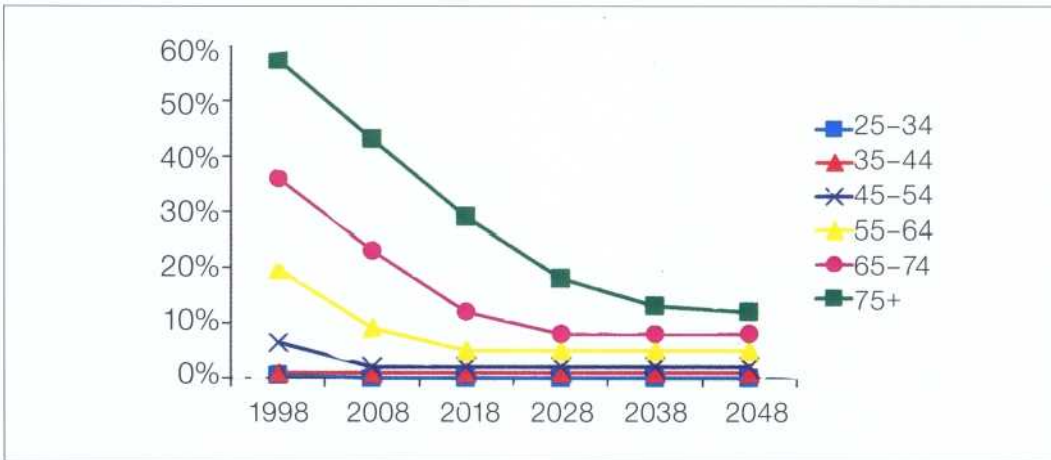


Fig 15-3 Projections for the fall in edentulousness over the next 50 years in the UK.<sup>23</sup>

people retain some or all of their natural teeth. This change is also occurring all over Europe, but has probably been best documented in the UK as a result of the decennial program of assessments of adult oral health (Fig 15-2). Population projections based on these data for the UK continue to show a decline in rates of edentulousness to levels of 8% for 65- to 74-year-olds in 2028 compared with 74% 50 years previously. The comparable figures for those older than 75 years are 18% compared with 87%. This reduction in edentulousness will have a profound impact on the oral health care needs and disease susceptibility of this age group, with an associated change in the patterns of oral health care that they require (Fig 15-3).<sup>23</sup>

## Aging

Increasing age has an inevitable, intrinsic, and irreversible effect on all tissues of the body that are also evident in changes to the oral and facial tissues.

## Oral Soft Tissues and Salivary Glands

Aging effects in these areas include changes in the submucosa, such as alteration in collagen structure and turnover, reduced elasticity of elastin, reduction in masticatory muscle bulk<sup>40,41</sup> and profound reductions in the numbers of secretory units in salivary glands.<sup>48</sup> Despite the marked histological changes in salivary gland structure seen in elderly people, there is little effect on salivary flow rates from the major salivary glands in this population group (Fig 15-4).<sup>4,5,36</sup> This is thought to be caused by a combination of adaptive capacity on the part of the gland and increased vagal neurological tone, which increases secretory activity and is often found in elderly people. Nevertheless, the salivary secretory reserve is perceived to be lower in elderly people. Hence, any challenges to salivary competence, including gland destruction by disease, radiotherapy, or the side effects of drugs<sup>55,64</sup> will be more likely to produce xerostomia in this age group. There are



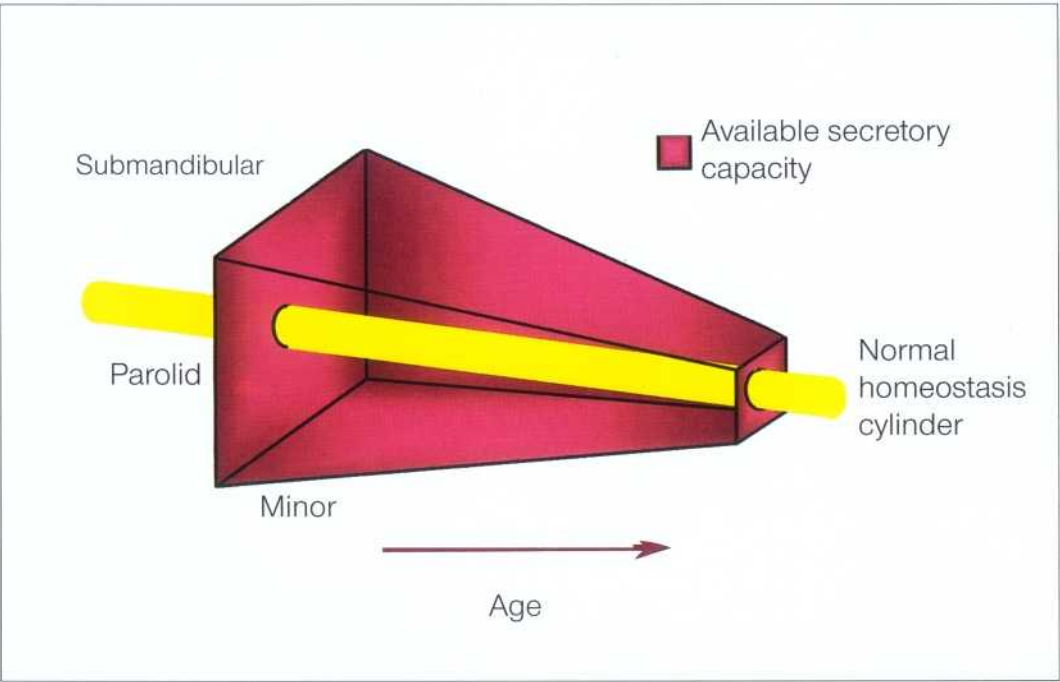


Fig 15-4 Schematic diagram illustrating the changes in salivary secretory capacity compared with the need for saliva to maintain health. The reserve (the difference between capacity and need) is much reduced in elderly people . 4

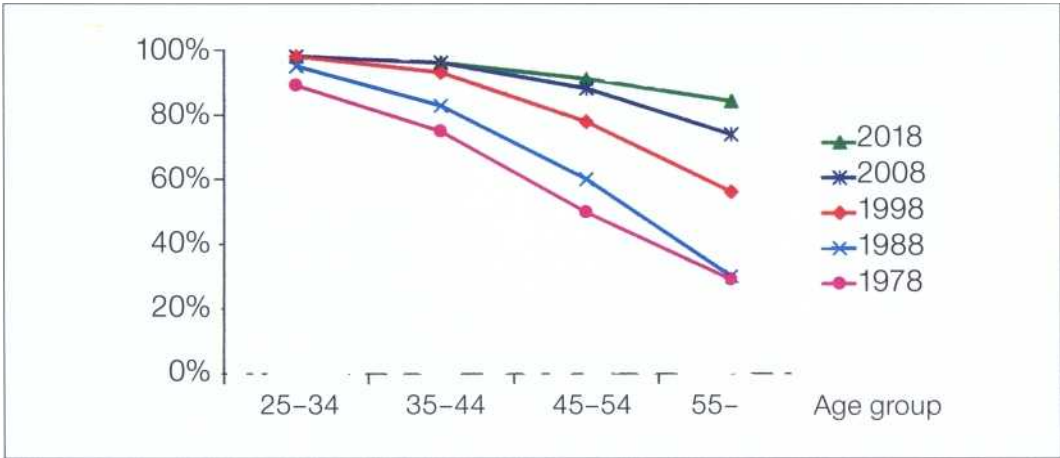


Fig 15-5 Projections for the proportion of the UK population with 20 or more natural teeth .23

also some suggestions in the literature that minor salivary gland function is diminished with age.<sup>12,53</sup>

There is an impression that the oral mucosa becomes thinned and more fragile with increasing age, but there are few data to support this. One report concerning the lateral border of the tongue showed reduced epithelial thickness and a reduction in the complexity of the rete peg apparatus.<sup>51</sup> These alterations mirror the profound changes seen in skin with the epithelial atrophy, increase in carbohydrate content, and keratinization that occur with age.<sup>51,52</sup> Oral manifestations may also result from systemic age-related diseases, eg, atherosclerosis, which is more common in elderly people than in other age groups and may produce oral changes by a diminution in the blood supply leading to mucosal atrophy.<sup>50</sup>

## Taste

There is an ongoing debate concerning the effects of age on taste perception, particularly because change in taste perception may be associated with variations in nutrient intake.<sup>8</sup> The changes in olfactory senses associated with aging are well documented,<sup>8</sup> as are the associations between smell and taste. The reported relationships between aging and taste vary in both the taste qualities (sweet, salt, sour, and bitter) involved and whether the intensity of the taste is heightened or lessened.<sup>65</sup> Nevertheless, there are associations between increasing age and an increase in the threshold for detection of sweet<sup>34</sup> and salt.<sup>3,15,60</sup> In addition, there is some evidence for greater confusion between salt and sour in older subjects.<sup>59</sup>

The quantity and quality of saliva affect taste. While there are no reported alterations in salivary flow levels associated with age, there are changes in both the ionic and mucin composition of saliva. It may be that these alterations influence the perceived flavor of food.

## Oral Health Status of Elderly People

### The Dentate

Among the dentate, there is a reduction in the number of teeth present and in the number of functional pairs of opposing teeth, both anterior and posterior, associated with increasing age. One measure of a functional dentition that has been suggested is the proportion of people who have 20 or more natural teeth. This is one of the World Health Organization's oral health targets.<sup>66</sup> Currently, the average dentate person older than 65 years in the UK has about 15 teeth, while about 29% have 21 or more teeth. In people older than 85 years, these figures fall to an average of 10 teeth per person, with only 5% having 21 or more teeth. However, the proportion of people with 21 or more teeth is also likely to rise over the next 20 years in association with the projected improvements in oral health status (Fig 15-5).

Nevertheless, elderly people will still have fewer teeth than the young and will be more likely to be reliant on a prosthesis of some sort for function. About 26% of dentate subjects older than 65 years have no teeth in one dental arch, ie, a complete denture in one jaw is opposed by natural teeth in the other. This pattern of dental health can be particularly limiting because the relatively high functional forces that

can be applied to the complete denture by the opposing teeth often impair the stability of the denture.<sup>57</sup>

## Caries

Recent data have confirmed that caries is the most important reason for tooth loss in an aging population.<sup>42</sup> Also, there is more untreated decay in elderly people on a population basis.<sup>43,57</sup> This is particularly apparent with trends in root caries, which increases with age and is more prevalent in men, in people from lower socioeconomic groups, and in those who are habitual nonattenders.<sup>11</sup> The crowns of teeth are susceptible to decay throughout the life of the tooth. Conversely, the roots of teeth become exposed with increasing frequency in elderly patients because of gingival recession caused by periodontal disease. This results in new surfaces being exposed and therefore becoming susceptible to decay in elderly patients.

The current group of dentate elderly people belong to a generation that has had varying extents of restorative dental care in youth. The legacy of this is a large number of retained heavily filled teeth. Consequently, it is difficult to assess caries activity in the crowns of teeth because it tends to take the form of recurrent and secondary caries in relation to existing restorations. The limited data available on caries in crowns of teeth in elderly subjects suggests an increasing frequency of caries with increasing age.<sup>2,19,57,67</sup> This apparent increase in caries activity may be due to increasing disease activity or to reduced dental attendance resulting in more caries surfaces being apparent during epidemiological studies of oral health for this age group.

Conversely, root caries has been more extensively studied because it is of increased relevance in elderly people. Prevalence rates between 60% and 90% have been demonstrated for aging population groups.<sup>11</sup> The susceptible sites (the root surfaces of teeth) are exposed almost universally with increased age and hence there is greater risk of caries activity. Recent data have also confirmed the association between root caries activity and frequency of dietary sugar intake, as well as quality of oral hygiene and the wearing of partial dentures.<sup>11,57</sup> Men tend to have more frequent sugar intakes. The frequency of such intakes was also much greater in a sample drawn from people living in long-stay care institutions.

Active root caries is a condition concentrated within a small proportion of the population (80% of root caries lesions are present in about 20% of the population<sup>60</sup>). Again, the older the subject, the more likely he or she is to have experienced root caries and to have current untreated root caries.

## Periodontal Disease

The effects of periodontal destruction are more severe in elderly people.<sup>32,43,62</sup> In some patients, this includes marked gingival recession in the absence of overt disease.<sup>50</sup> The pattern of periodontal destruction seen in elderly people appears to be different from that of the young. Shallow periodontal pockets are less likely to progress than deep pockets in an elderly patient. This is probably a consequence of two factors. First, there is a survivor effect in that those people who have teeth when they are 65 years of age are not likely to be among the groups most susceptible to

periodontal breakdown. Second, there are alterations in the immune response with age that modify the pattern of disease activity.<sup>13,14,20</sup>

## Oral Health Behaviors

Oral health behaviors are influenced by dental status. Relatively few edentulous subjects attend the dentist for routine inspection when compared with the dentate (13% to 15% compared with 55% to 65%). Even among the dentate, the rates of service utilization fall with increasing age, despite reported satisfaction with oral health decreasing and complaints about oral health and dentures increasing.<sup>56,58</sup> This dichotomy is likely to be a manifestation of a general stoicism often found among the elderly: Things go wrong as people get older and not everything can be fixed. In addition, a person with serious health problems may regard minor oral health concerns as relatively trivial and become habituated to them.

There is also a decline in dental attendance among the dentate with increasing age. This decline is manifest more in men, which is of some concern because men tend to have more caries in retained teeth than do women.<sup>43,62</sup> MacEntee et al have tried to identify the reasons for this altered attitude toward oral health.<sup>33</sup> Two quotations from their paper illustrate these points.

*"I don't think I need to go to a dentist because my mouth is free of pain and chewing fairly well." "If your general health is good, you've got enough on the ball to look after your teeth. If your general health isn't good, maybe you haven't got enough energy to go out to the dentist."*

There are a number of variables that influence oral health behaviors.

There are very real financial constraints on the uptake of care in some parts of the world.<sup>46,54,58,61,62</sup>

Fear remains a factor, even in elderly people. The frequency of reported anxiety is lower in elderly patients compared with the young; nevertheless, 25% to 35% of elderly patients express high levels of anxiety in relation to oral health care.<sup>17</sup>

The habits of youth are perpetuated into old age.

If attendance at the dentist as a social activity is not a routine while people are young, it does not become so as they age without a significant effort in terms of behavioral modification. In order to modify an individual's behavior, one must first educate the person about the condition so that he or she recognizes that an undesirable change has taken place, rather than simply ignoring it. Individuals then have to be taught the appropriate priority for the change they have identified in terms of severity, novelty, or meaning before they are then equipped to respond in an appropriate manner to a sign or symptom.<sup>25-27,47,48</sup>

Some oral health behaviors are a routine part of life, for example, personal oral hygiene: *"The first thing you do in the morning is to brush your teeth and if you're a floss person you use dental floss. You don't want to go around breathing on people and knocking them over. Oh, disgusting thought."*

Other behaviors such as dental attendance are a consequence of problem solving on behalf of the individual. The need to attend is triggered by a physical or social stimulus; unfortunately, the significance of such stimuli reduce with increasing age.

We have already noted that personal oral hygiene is part of a social regimen and the majority of the older population report frequent oral hygiene practices (52% of the population older than 85 years report brushing their teeth twice daily or more).<sup>57</sup> Sadly, this personal oral hygiene is ineffective in the majority of people. In the same survey, many people had large quantities of plaque in many sites. Again, the problem is one of routine; the routine that was established when an individual was young is no longer satisfactory in older age. The oral architecture changes with gingival recession. People become less dexterous and less able to manipulate some oral hygiene aids. Consequently, there is a need for retraining among elderly people that is poorly recognised and for which the uptake is poor. Strategies that are associated with success in oral hygiene interventions for elderly subjects include involving the individuals in the education process. A simple strategy of telling people what to do is ineffective.<sup>21,26,31,47</sup> Furthermore, training the participants in techniques for self or peer monitoring of oral hygiene has a positive effect on the outcome of the intervention. One program that has delivered improvement in personal oral health care is PRECEDE (predisposing, reinforcing, and enabling courses in educational diagnosis and evaluation).<sup>29</sup> This program resulted in improved oral health status and a greater sense of control on behalf of the participants. The negative aspect of this program was its cost and that the sample was self-selected and hence may have had more motivation to succeed. Nevertheless, this intensive intervention gives some interesting directions for future developments.

## Masticatory Function

As a broad generalization, chewing ability declines with a reduction in the number of functional pairs of natural teeth. The impact of this reduction is limited when there are 21 or more teeth remaining, corresponding to the *shortened dental arch*.<sup>1,6,7,16,22,30,45</sup> However, where there are fewer than 21 teeth present, there is a need to rely increasingly on a partial denture as an adjunct to function,<sup>56</sup> and objectively measured masticatory efficiency is reduced with or without the use of partial dentures.<sup>16</sup>

Masticatory efficiency with dentures is poorer than that with natural teeth. The least effective combination, from a masticatory standpoint, appears to be a natural dentition in one jaw opposed by a complete denture in the opposing jaw.

## Oral Health and Nutrition

A logical extension of the previous discussion on masticatory efficiency would be that reduced chewing ability would influence nutritional status. This area of work has been somewhat neglected; however, there is some data available, most recently from the National Diet and Nutrition Survey (NDNS) for people 65 years and older in the UK.<sup>57</sup> A comparable study has been conducted in the USA<sup>58</sup>; unfortunately, as yet no analysis of the relationships between oral health and nutritional status have been conducted on these data. Farrell established some time ago that chewing was not necessarily required for digestion of a modern diet.<sup>9,10</sup> However, inefficient masticatory ability influences food choice, which in turn has an effect on both intake and nutritional status in



elderly subjects. People with reduced masticatory efficiency are less able to eat foods that require rigorous mastication, for example, apples, raw carrots, nuts, toast, tomatoes, crisps, and oranges. This relationship is valid for both those with reduced numbers of teeth in the natural dentition and those who are edentate.<sup>6,57</sup>

These variations in ability to eat food are also reflected in variations in nutrient intake in relation to intrinsic and milk sugars and nonstarch polysaccharide in dentate subjects. The greater the number of pairs of anterior and posterior occluding teeth present in older people, the more intrinsic and milk sugars and nonstarch polysaccharides they consume.<sup>44,57</sup> Protein, intrinsic and milk sugars, calcium, nonheme iron, niacin, and vitamin C intake are also reduced in the edentate compared with the dentate.<sup>18,35,57</sup>

Finally, hematologic and biochemical measures of nutritional status are also in-

fluenced by oral health status. Plasma ascorbate (vitamin C) is reduced in edentate subjects and in those with fewer pairs of opposing teeth. Plasma retinol (vitamin A) and (α-tocopherol (vitamin E) levels were also reduced in edentate subjects compared with the dentate.<sup>57</sup>

The impact of these nutritional deficiencies is unclear. It is worthy of note that in addition to the above data, some of the subgroups within the NDNS survey had particularly poor nutritional status for specific micronutrients. For example, the median plasma ascorbate level for edentate subjects living in an institution was 11.4 μmol l<sup>-1</sup>, which is at the extreme lower range of normal. By definition, 50% of this sample would have plasma ascorbate levels lower than this value. This is of particular concern when the associations between vitamin C and respiratory function, stroke, and cardiovascular disease are taken into consideration.<sup>910,18,24,28,35,37-39,44</sup>

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**Table 16-2** Antibacterial varnishes and adhesives for preventive local root caries treatment

Brand name	Antibacterial component	Manufacturer
Duraphat	2.25% F-	Colgate
Fluor Protector	0.1% F-	Vivadent
Cervitec	1% CHX / 1% thymol	Vivadent
EC 40	40% CHX	Explore
Seal & Protect	Triclosan, Cetylaminhydrofluoride	Dentsply

tion and color has been shown.<sup>12</sup> Therefore, clinical diagnosis must rely on the texture of the surface of the lesion and its location, as well as the extent of the defect.

It is advantageous to determine the amount of mutans streptococci in plaque covering root caries lesions to assist with clinical treatment decisions.<sup>13</sup> However, within infected dentin *Actinomyces* species bacteria, especially *A. naeslundii*, play a significant role.<sup>3</sup> The pathogenesis is not entirely understood because *Actinomyces* species bacteria do not cause relevant collagen degradation.<sup>5</sup>

The decision on the most appropriate treatment modality (restoration or chemotherapeutic control) needs to be based on an assessment of caries risk and the likelihood of lesion progression. Invasive restorative procedures are not always necessary unless major cavitation is clinically apparent.

### Noninvasive Therapy and Prevention

Although fluorides inhibit mineral loss during acid demineralization and enhance remineralization,<sup>7</sup> the therapeutic effect of fluorides in high-risk situations is limited.<sup>11</sup> Besides a preventive program focusing on oral hygiene measures and decreasing the frequency of sugar intake,<sup>16</sup> two options are discussed for arresting initial lesions and preventing progression:

1. Reduction or elimination of pathogens by means of antibacterial varnishes or gels
2. Increasing host resistance against acid attack by means of sealing root surfaces with adhesive

An overview of antimicrobial varnishes is given in Table 16-2. The varnish Cervitec has a low concentration of chlorhexidine with 1 % thymol (to improve its substantivity). It showed promising results in laboratory and clinical assessments.<sup>10</sup> However,

Fig 16-1 After scaling and sealing of the root caries lesion, further demineralization (laser fluorescence, Diagnodent) was prevented over 6 months, despite plaque accumulation.



clinical studies have failed to demonstrate a clinically relevant therapeutic effect.<sup>6</sup> In contrast, the highly concentrated chlorhexidine varnish EC 40 was found to effectively prevent root caries of abutment teeth.<sup>11</sup> Even a 20% chlorhexidine varnish suppressed mutans streptococci over a period of months when covered with a light-cured nonfunctional bonding resin.<sup>5</sup> Interestingly, treatment with resin alone was statistically less effective, but differences between the results were small.

As an alternative to an antimicrobial agent, attempts have been made to protect root surfaces by sealing with dentinal adhesives. In simulating caries demineralization in vitro, the preventive effect of sealing dentinal surfaces was demonstrated.<sup>9,18</sup> A new attempt was made to use a triclosan releasing resin as protection against root caries as well as cervical abrasion. Preliminary results showed that demineralization could be prevented by means of sealing root surfaces.<sup>19</sup> However, a reduction in pathogens was not observed. In some cases demineralization was prevent-

ed despite plaque accumulation on surfaces at risk, as shown in Fig 16-1.

Figure 16-2 summarizes the recommendations for the treatment of root caries lesions. In general, it can be recommended to remove superficial carious layers and to smooth root surfaces with a curette before the application of a sealant or antibacterial varnish, as shown in Fig 16-3.<sup>1,2</sup> Although there are some indications that sealing is more effective than chlorhexidine therapy, conclusive clinical studies are not yet available. In the event that root caries lesions are subgingival, access is often only possible by means of periodontal surgery.

If cavitation necessitates restoration of the defect, there is no need to extend preparation into sound dentin. Restoring and sealing can be combined, thereby limiting cavity preparation to the central caries defect, followed by sealing of the surrounding initial defect. Quite often this is the only way to manage circumferential root caries.

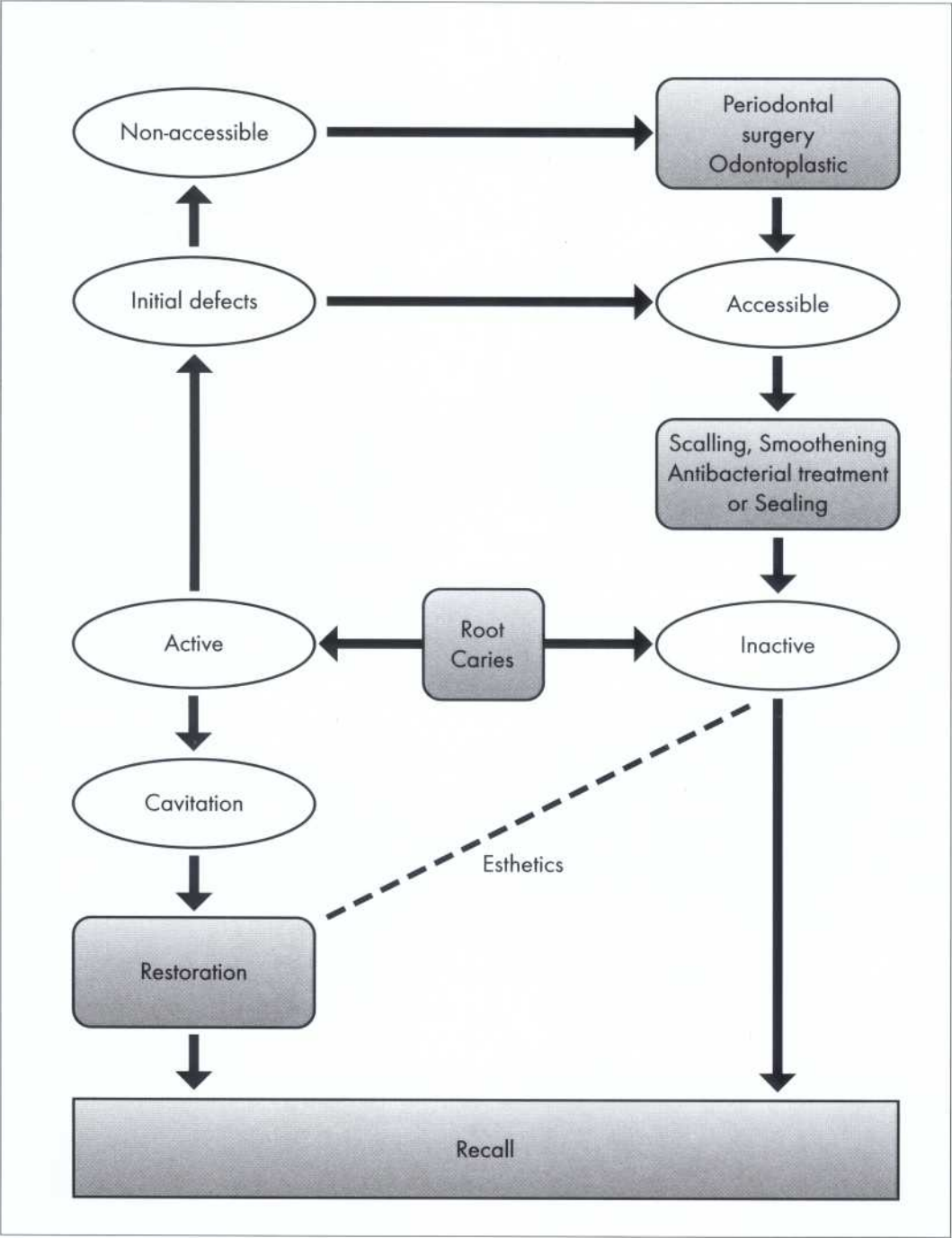


Fig 16-2 Treatment decisions for various stages of root caries.

Fig 16-3 Extensive restoration of initial root caries lesions is not required. Superficially infected and softened dentin can be smoothed and then sealed with a dentinal adhesive.



There are few data available to help the clinician choose the most appropriate restorative material. Composites and, in particular, flowable resins, compomers, and glass-ionomer cements, as well as resin-modified ionomers and amalgam, may be used.<sup>4</sup> Because tooth-colored materials can be combined with sealing techniques, they are probably more advantageous. However, in clinical situations the skill of the operator is more important to the survival of the restoration than the materials selected.

In addition, possible techniques to arrest root caries lesions by applying antibacterial varnishes and sealing dentinal surfaces have advantages in the preventive treatment of high-risk patients. Notwithstanding systemic factors and the patient's previous experience with coronal and root caries, prosthodontic treatment must be considered to be an independent risk factor.<sup>11,17</sup>

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# Adhesive Techniques for the Management of Fractured and Worn Teeth in Elderly Patients

Angus W.G. Walls

## Introduction

The advent of effective adhesive resins provides the opportunity to attach a variety of restorative materials in a predictable way to both enamel and dentin. There are, however, age-associated changes in the structure of both enamel and dentin that affect the ability to bond to these surfaces. This chapter reviews these changes and describes strategies for the use of adhesives during the management of fractured and worn teeth in elderly patients.

## Age Changes in Dental Tissues

### Age Changes in Enamel

The chemical structure of enamel changes little with age. However, there are changes to the surface layers of enamel that make orally exposed enamel resistant to demineralization. These changes are beneficial in helping to prevent caries but need to be taken into account when etching the enamel surface prior to bonding. The changes affect the surface enamel alone and do not affect freshly prepared enamel.

Whenever acid is present in the mouth, be it in the form of food, beverages, or regurgitated stomach acid, the surface of the enamel of the teeth will start to dissolve. Once the acid has been neutralized by the buffering and washing effects of saliva and to an extent through the dissolution of surface enamel, the opportunity is available for remineralization of the demineralized enamel surface. This remineralization takes place from saliva in the presence of calcium, hydroxyl, and phosphate ions. However, there are other ionic species present in saliva including fluoride, zinc, and manganese. Remineralization in such a mineral soup is not simply a matter of regeneration of hydroxyapatite. Ionic substitutions occur within the crystal lattice, including fluoride for hydroxyl and manganese and zinc for calcium. The physical chemistry of this process results in a crystal structure that is more stable than classical apatite. The surface is also, however, amorphous, without the characteristic organization of the enamel rods.

Reliance is placed upon the organization and orientation of the enamel rods to produce the irregular porous pattern associated with etched enamel. The more stable amorphous crystal structure found on the surface is less susceptible to etching

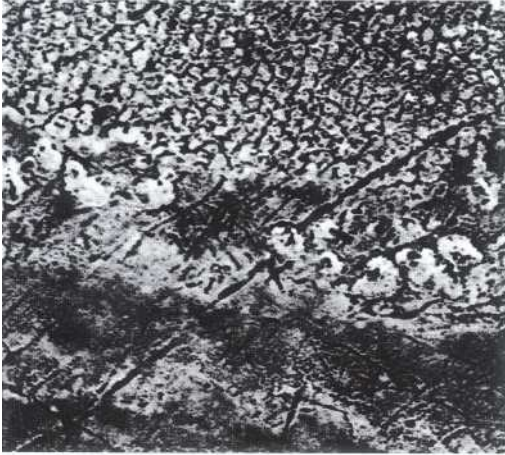


Fig 17-1 Scanning electron micrograph illustrating variations in etching patterns seen on unprepared enamel.

and is likely to be responsible for the wide variation in etch patterns seen on unprepared enamel surfaces (Fig 17-1). Attachment to such a surface is less predictable. The etching time should be increased on the surface of the enamel prepared to remove this layer. This is of significance when bonding structures to a previously orally exposed surface rather than a newly prepared surface.

### Age Changes in Dentin

Dentin undergoes age-associated change in two ways. When the dentin is exposed in the mouth, alterations similar to those that occur in enamel are evident in the dentinal surface. Consequently, previously orally exposed surfaces of dentin will have an altered surface structure when compared with a surface that has not been exposed to saliva. This may influence the quality of the attachment that can be achieved to noncarious cervical lesions, for example.

Dentin also undergoes alterations in its internal structure as a consequence of aging. The changes are more profound in areas where the surface of the dentin has been exposed in the mouth or where caries has extended to involve the dentin. The changes result in deposition of mineralized tissue within the dentinal tubules (peritubular dentin), causing a diminution of the diameter of the dentinal tubules. The extent of deposition of peritubular dentin is greater toward the periphery of the tubules.

The effect of this change varies with the proximity of the dentin to the pulp. The tubule density within dentin changes as the tubules radiate outward from the pulp toward the tooth surface. The diameter varies as described above. The combination of these effects results in marked variation in the proportion of tubules to mineralized tissue with the depth of the dentin relative to the pulp.

Penetration of resin into the dentinal tubules is responsible for between 25% and 40% of the attachment strength between composite resin and tooth. Obviously, the magnitude of this benefit depends on both the tubule density and, to an extent, the tubule diameter. Complete occlusion of the tubules, forming sclerotic dentin, does occur and results in a marked reduction in bond strength to levels at which there is substantial risk of failure of the bond under the forces of polymerization contraction. This phenomenon has been used to explain the relatively poor performance of certain adhesive resins when repairing noncarious cervical defects.<sup>1</sup>

## Comment

The benefit of an adhesive is the ability to bond materials or structures to tooth tissue. This can be used both to enhance retention in tooth preparations of limited height and to limit the extent of tooth reduction necessary for the mechanical retention of restorations. The extent to which these benefits can be relied on in aged teeth will be influenced by the extent of the age-related changes in the surfaces selected for bonding. The design of any restoration needs to take into account the potential for reduction in bond strength.

## Fractured teeth

Cuspal fracture is a problem associated with function of the teeth. It is more common in elderly people and in teeth that have been previously restored, particularly with intracoronar restorations of amalgam or gold (Fig 17-2a). The fractured cusp has traditionally been replaced using some form of mechanical accessory retention, commonly self-threading pins. Pins cause crazing within the dentin and weaken the amalgam restoration. Some would suggest that a tooth restored with a large pin-retained restoration subsequently should be crowned. This results in further loss of sound tooth tissue. The option of an adhesively retained restoration reduces the extent of tooth preparation required. The material used needs to be able to withstand the functional loads to which it may be subjected. There are concerns about the ability of composite resin to replace cusps because they tend to undergo significant levels of wear. The options would be a cast metal, porcelain-fused-to-metal (Figs 17-2b and 17-2c), or an all-porcelain restoration (Fig 17-3).

The fitting surface of these restorations needs to be treated to ensure an adequate level of bond strength to the adhesive being used. The nature of the surface treatment is also influenced to an extent by the adhesive that is to be used and its mechanisms of attachment to the metal or ceramic surface.

## Surface Treatments

### Cast Precious Metals

Some adhesives will bond effectively to a roughened gold surface. The surface of the restoration should be sandblasted with 40 mm of silica and then steam cleaned. The surface of gold restorations that contain more than 8% copper can also be heat treated to produce a stable copper oxide layer on the surface of the restoration. The restoration should be finished to a high shine on the functional surface. It should then be heated to about 400°C for 10 minutes in air. The surface of the casting will become black as a result of oxidation and should be returned to the clinician in this condition. Any attempt to polish the non-fitting surface of the tooth is likely to result in contamination of the oxidized gold fitting surface, which would reduce the attachment strength of the adhesive lute.

### Cast Nonprecious Metal

Nonprecious metals remain corrosion-free as a consequence of a stable oxide layer limiting the surface of the alloy. Adhesive luting agents can be bonded to such oxide layers. The surface treatment should optimize the production of the oxide layer



Fig 17-2a Fractured buccal cusp on a maxillary first premolar.



Fig 17-2b Porcelain fused to precious metal (PFM) addition made to replace the missing tooth structure.

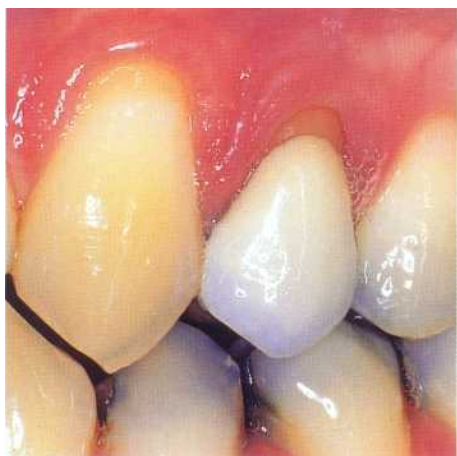


Fig 17-2c The PFM addition bonded in place using C&B Metabond. This restoration has functioned satisfactorily for 9 years.

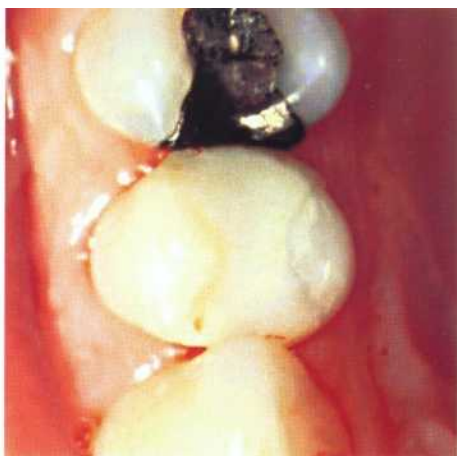


Fig 17-3 Buccal cusp replacement using an all-porcelain bonded addition. The restoration was bonded in place with a dentine-bonding agent (All-Bond) and a porcelain laminate veneer luting system.

by sandblasting the metal surface then steam cleaning.

## Porcelain Surfaces

Conventional dental porcelains can be etched with hydrofluoric acid to produce a microporous surface analogous to etched enamel. This surface should then be coated with a silane-coupling agent to maximize the attachment strength to the resin (Figs 17-4a to 17-4c).

Unfortunately, some of the recently developed high-strength materials cannot be etched in this way (eg, In-Ceram); consequently, they are not suitable for use when the adhesive is to be a major source of retention for the restoration.

## Tooth Wear

Tooth wear is a problem of increasing concern to the profession. Wear is normally related to oral function; however, in some patients wear occurs at an abnormal rate. Both normal and abnormal wear can cause esthetic and possibly functional problems in elderly dentate patients.

Adhesively retained restorations offer benefits in terms of increasing the attachment strength of restorations to teeth with short or convergent crown preparations and allow the clinician to add structures directly to worn tooth surfaces without preparation of the teeth, thus preserving sound tooth tissue.

A thorough assessment of the etiology of a wear problem is an essential precursor to its management. Whenever possible, the etiology should be identified and, if practical, controlled prior to commencing complex restorative care. This is of par-

ticular importance in erosive wear when ongoing erosive damage can threaten the longevity of restorations (Fig 17-5) and in attritive pattern wear when the final restoration is likely to be subjected to high functional loads if the patient continues to clench or grind his or her teeth (Fig 17-6).

## Composite Resin

Composite resin has relatively poor wear resistance. Consequently, it is not suitable as a long-term restorative material for the reconstruction of the functional surfaces of multiple teeth. However, it can be very useful as a durable, transitional restorative material during the management of a worn dentition, particularly when an increase in the occlusal vertical dimension is planned (Figs 17-7a to 17-7c). Also, it has been suggested that composite resin is an appropriate material for use in the medium-term management of patients with erosive tooth wear. The rationale for this approach is that composite resin can be added to or repaired. Hence, if there is any continuation of erosion that would result in loss of tooth structure around the margins of the restoration, further material can be added to reduce the possibility of caries occurring at the margins of the restoration.





Fig 17-4a Maxillary second premolar with fractured buccal and palatal cusps.



Fig 17-4b All-porcelain restoration to replace both cusps. The restoration was bonded in place with a dentin-bonding agent (GLUMA) and a porcelain laminate veneer luting system.



Fig 17-4c Restoration after 10 years of clinical services, showing some marginal staining.



**Fig 17-5** Ongoing erosive pattern tooth wear around the margins of adhesively retained additions to 25 and 26 in a patient with uncontrolled gastric reflux associated with a hiatus hernia.



**Fig 17-6** Fracture of porcelain from the occlusal surface of a porcelain-used-to-metal restoration in a patient with a bruxing and grinding habit. There was inadequate space within the occlusion for an adequately retentive preparation of both porcelain and metal in this case.



**Fig 17-7a** Mixed erosive and functional wear on the surfaces of 45 and 46 in a patient for whom the restorative process included an increase in the occlusal vertical dimension.

**Fig 17-7b** Laboratory-made composite resin onlays for 45 and 46 to restore occlusal form and function with ease of control of the occlusal morphology.



**Fig 17-7c** The restorations shown in Fig 17-7b luted in place using an adhesive technique onto the teeth shown in Fig 17-7a. Mirror occlusal adjustment only was required at this stage.



Fig 17-8a Worn occlusal surface in a molar tooth.



Fig 17-8b Oxidized precious metal casting prior to bonding to the tooth surface.



Fig 17-8c Occlusal spacer bonded in place using Panavia 21.



Fig 17-8d Metal spacer in place after occlusal adjustment and polishing.

## Laboratory-Made Restorations

Adhesive luting agents can be used to attach metal (Figs 17-8a to 17-8d), porcelain-fused-to-metal (Figs 17-9a to 17-9d), or porcelain additions to tooth structure (Figs 17-10a to 17-10d). The design of such restorations needs to be undertaken with the same level of care as is used for con-

ventional restorations, particularly when a reorganized occlusal scheme is planned. Mounted study casts and a diagnostic waxup are useful in guiding the clinician and the technician in the design of such restorations, particularly with regard to the pattern of dynamic tooth contacts that will be developed on the new restorations.

Figs 17-9a to 17-9d Reconstruction.

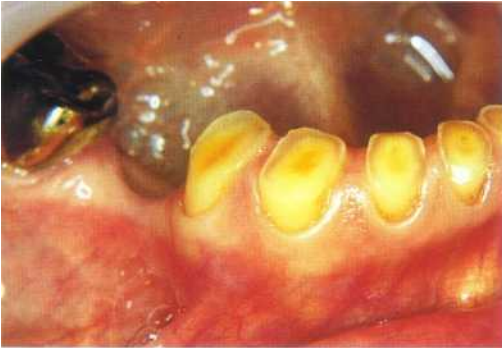


Fig 17-9a Extensive functional wear of the mandibular anterior teeth in a patient with a clenching/grinding habit.



Fig 17-9b Following reconstruction in the maxillary arch using porcelain-fused-to-metal crown and bridge work and adhesive porcelain additions in the mandibular arch.

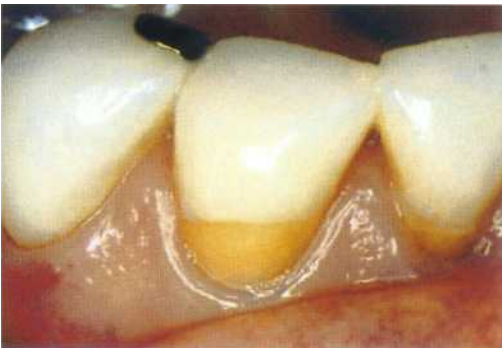


Fig 17-9c Ten years postrestoration. There has been considerable functional wear of the adhesive additions. The buccal extensions all fractured within 12 months of placement.



Fig 17-9d Functional wear on the palatal surface of the porcelain-fused-to-metal crowns in the opposing arch.



Fig 17-10a to 17-10d Anterior tooth wear.



Fig 17-10a Worn buccal and incisal surfaces in mandibular anterior teeth.



Fig 17-10b Porcelain additions to teeth 43, 31, 32, and 33 (41 is missing).



Fig 17-10c Porcelain addition to 43 eleven years after placement. There has been some wear or a small fracture at its mesial marginal edge, but otherwise the restoration continues to function. Note the change in color of the teeth compared with Fig 17-10b as a consequence of aging.



Fig 17-10d Porcelain restorations 11 years later, showing some marginal staining. These restorations were functioning against porcelain surfaces in the maxillary arch.

## Conclusions

The bond strength of resin to dentin and enamel may be affected adversely in elderly people as a consequence of age-associated change in the dental tissues. This can reduce the effectiveness of adhesive restorative materials in elderly people and needs to be taken into account when both planning treatment and designing restorations.

The use of adhesive resins offers the clinician a range of options when planning care for fractured and worn teeth. These techniques offer the opportunity to minimize preparation of otherwise sound residual tooth tissue. They may also make a restorative option practical on teeth with short clinical crowns.

## Reference

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has been introduced in several dental schools. A new concept developed in Sweden is Carisolv (Medi Team AB, Savedalen, Sweden), whereby caries is dissolved away with the aid of hand instruments rather than mechanically removed with a bur.

In the area of liners and bases a dramatic shift has occurred in the last decade. Until the 1990s zinc oxide-eugenol, calcium hydroxide, and zinc phosphate cements together with some varnishes (eg, Copalite) were the materials of choice. Then polycarboxylate and glass-ionomer cements became more dominant. Lately the need for any of these materials has been questioned, on the assumption that the most important protection when using composite filling materials is the sealing of the dentinal tubules to keep out any bacteria or other irritants. Thermal isolation is less important with the use of composites when compared with the use of metallic amalgam. It is of interest to share the opinions and policies of dental schools in Europe in this respect.

Undoubtedly, the most important development in recent times has been the introduction of adhesive techniques in combination with, in particular, composite filling materials. After the introduction of high-speed cavity preparation with diamond and tungsten carbide burs, adhesive technology and procedures were the most important evolutionary developments in conservative dentistry of the last century. We are now able to teach new generations of dentists to save tooth structure by removing decayed enamel and dentin only and reinforcing the weakened remaining hard tissues through the adhesive bonding of strong, wear-resistant, tooth-colored materials. The major prob-

lems of these materials in the 1980s were wear resistance and polymerization shrinkage. However, progress in the development of improved products has made available materials in which these two problems have been reduced to a clinically acceptable level.

We are in the process of making the change from Black's principles for cavity preparation for amalgam (Figs 18-1 a to 18-1d) to tooth-saving, adhesive restorative procedures using bonding agents and tooth-colored filling materials (Figs 18-2a to 18-2d). The extent to which this change is reflected in the programs of dental schools in Europe remains largely unknown. Recently, Wilson and Mjor<sup>5</sup> published the results of a descriptive study on the teaching of Class I and Class II direct composite restorations in European dental schools. Data from 104 dental schools out of a total of 185 schools were included in the study. All but 4 of the 104 participating schools were found to teach the use of composites in Class I and Class II, two-surface situations, at least in premolar teeth. The number of participating schools that considered premolar and permanent molar teeth suitable for restoration by means of Class I and two- and three-surface Class II composites is represented in Fig 18-3. There was almost full agreement with respect to the suitability of premolar teeth for restoration by means of posterior composites and in relation to permanent molars for restoration by means of Class I posterior composites. In contrast, less agreement was found in relation to the suitability of permanent molars to receive two- and especially three-surface composites. The suitability of premolars for three-surface composites was found to be similar to the suitability of permanent molars for two-

Figs 18-1a to 18-1d An amalgam restoration in a Class II cavity preparation according to G.V. Black's classification.



Fig 18-1a Occlusal cavity preparation.

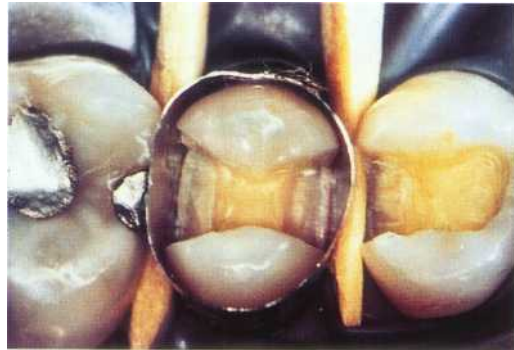


Fig 18-1b Cavity preparation with matrix and wedges.



Fig 18-1c Carved amalgam restoration.



Fig 18-1d Final polished amalgam restorations.

surface composites. Similar findings were obtained for the four geographic regions of Northern and Central Europe, Scandinavia, Southern Europe, and Eastern Europe (Table 18-1). As to the occlusal width of the preparation for Class I and Class II composite restorations, most schools considered  $< 1/3$  of the occlusal width as acceptable in both premolar and permanent molar teeth (Fig 18-4). Limitations in relation to the use of composites in posterior teeth were most

common in respect of the gingival margin being apical to the cemento-enamel junction. In contrast, relatively few schools indicated any limitation in terms of the buccolingual width and axial depth of proximal boxes (Fig 18-5). It should be noted that among European dental schools, there was almost full agreement on an anticipated increase in the proportion of the dental curriculum in operative/conservative dentistry to be devoted to the use of resin-based materials in posterior teeth.

Figs 18-2a to 18-2d A modern hard tissue-saving cavity preparation restored with composite filling material using an acid-etch adhesive technique (courtesy of Dr. J. Roeters).



Fig 18-2a Decayed first molar.



Fig 18-2b Initial tooth-saving cavity preparation.

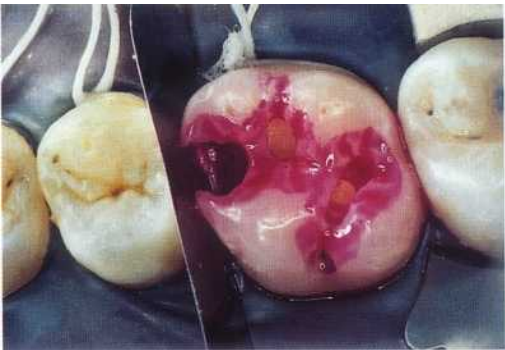


Fig 18-2c Disclosing solution applied.



Fig 18-2d Final composite restoration.

Table 18-1 Teaching of Class I and Class II composites according to geographic regions

Region of Europe	No. of schools (%)			
	Not taught	Class I	Class II (2-surface)	Class II (3-surface)
Northern & Central	1 (2)	18 (98)	45 (92)	41 (84)
Scandinavia	0 (0)	12 (100)	12 (100)	10 (83)
Southern	1 (4)	22 (96)	19 (83)	14 (61)
Eastern	2 (10)	18 (90)	18 (90)	14 (70)
Total	4 (4)	100 (96)	94 (90)	79 (76)

Fig 18-3 Number of schools (N=100) that considered premolar and permanent molar teeth suitable for restoration by means of Class I and two- and three-surface Class II composites . 5

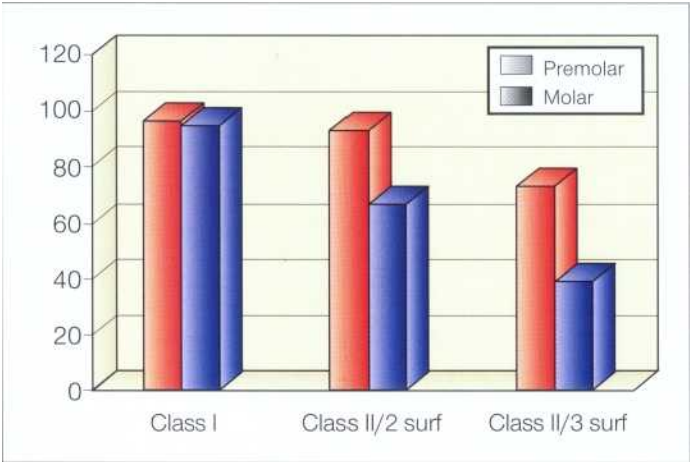


Fig 18-4 Number of schools (N=100) indicating limitations for direct composites in premolar and permanent molar teeth in terms of the extent of the occlusal width of the preparation . 5

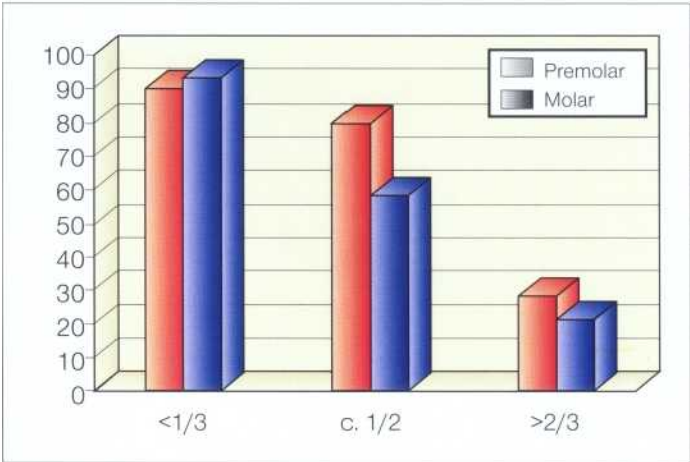
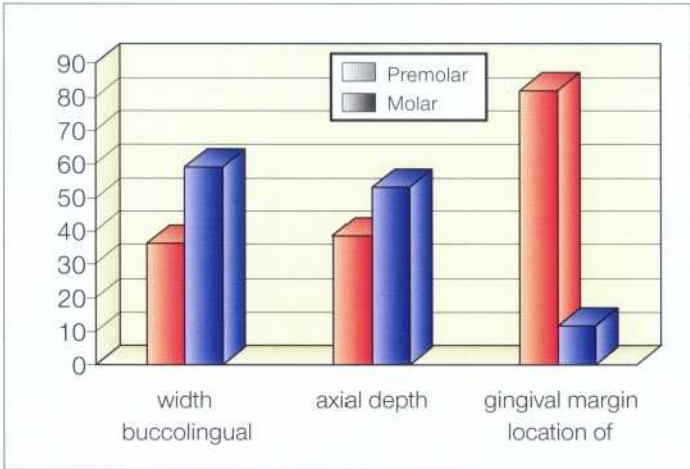


Fig 18-5 Number of schools (N=100) indicating limitations on the size of the proximal box in Class II preparations to be restored with a composite, 5





## Education in Conservative Dentistry

The combination of two major developments, one in learning in general and the other in the teaching of conservative dentistry will have a definite impact. These developments are the introduction of problem-based learning by educational psychologists, and the explosion in the availability of information computer technology. Problem-based learning does not emphasize the reproduction of facts and figures, but is more directed toward having students solve dental problems in patients by searching for what is known about the problem through evidence-based dentistry. All information available in the scientific literature on a specific subject is accessible in a structured way through practice guidelines in which both practical clinical evidence and scientific evidence is combined and adjusted to the specific problem to be solved. Secondly, the explosion in information computer technology is leading to a new era in teaching and learning. Large amounts of information in the form of text and images are already available through the Internet at any time and any place where dental students have access to an Internet-linked computer.

In both the theoretical and practical training of conservative dentistry, these innovations are already becoming increasingly visible. Digital lectures and databases of educational materials are being put on the Internet at a rapidly growing rate (Fig 18-6). Computer-based learning programs have been developed whereby students receive feedback on their progress in learning. It is assumed that in the coming years it will be normal for every student to have access to an Internet-linked com-

puter and to use it in combination with CD-ROM packages. In this way all theoretical information will be accessible to all students at any place where study is convenient (Fig 18-7). For teachers this requires a shift in activities from presenting information through lectures to formulating learning objectives, selecting learning materials (books, Internet, etc), guiding students, giving seminars, and developing feedback and examination tests. The role of the teacher should therefore be to stimulate students in scientific and creative thinking in order to develop a questioning and searching mind.

Teaching and learning of practical psychomotor skills in conservative dentistry is complex and demanding of curriculum time if it is done to an advanced level. New techniques do not always replace older ones; therefore, the number of treatment options is always increasing. This means that in many programs both amalgam and composite restoration procedures are being taught, together with indirect restorative techniques (eg, gold and ceramic inlays for the restoration of posterior teeth).

It is interesting to observe the developments in the teaching of skills in laboratory facilities. A good example is the DentSim dental unit, also described as the virtual reality dental training simulator (Fig 18-8). The functions of this system are to provide individual interactive training in cavity preparation skills on a phantom head, related theory and examples, and management information for the course director. The system's integral computer stores an on-line textbook, patient history data, diagnostic data, and principles of preparation and criteria for optimal performance. It includes three-dimensional tooth models and provides hyperlinks to a professional



Fig 16-6 Students are increasingly learning more through digital lectures and databases of educational material available on the Internet rather than through the reading of textbooks.



Fig 18-7 Dental schools are making available computer facilities to students for learning and communication through e-mail, the Internet, and local learning programs.



Fig 18-8 The DentSim dental unit, described as a virtual reality dental training simulator, provides individual interactive training in cavity preparation skills on a phantom head, combined with related theory and examples and management information for a course director

terminal. A number of advantages are being claimed. Round-the-clock, unlimited practice is possible. The clinical environment is simulated and evaluation of skills is standardized, objective, and immediate. Training data are stored and can be used to communicate with a teacher. DentSim claims to be highly effective in self-learning, to provide high-quality training, and to be instrumental in improving communication within and between dental schools. With such technology, the role of the clinical instructor may shift from giving live demonstrations and feedback to the development of programs and monitoring the progress of students. Time will show how important these developments will be in shaping education in conservative dentistry in Europe.

To gain sufficient clinical experience that will enable the new dental graduates to practice effectively in general dental practice, many schools now commence preclinical "phantom head" courses in the first or second year of their program. The first patients tend to be seen in the second or third year of a five-year course. Prevention, diagnosis, and treatment planning receive increasing attention as integral elements of practical training.

## European Developments in Conservative Dentistry

The training of dentists in Europe still reflects the two traditional methods—the southern and the northern approaches. The southern approach comprises medical training in the first years of dental education, followed by a dental program of 1 to 2 years only. In contrast, the northern European countries use the Anglo-Amer-

ican model in which students enter university from high school to join an integrated course of dentistry and medicine from the outset. To harmonize European dental education programs, the European Economic Community (EEC) in 1978 identified the profile of the dentist and listed the subjects to be studied as minimum requirements in European dental schools.<sup>1</sup>

In November 1995 the European Commission of the European Union adopted the report and recommendation concerning clinical proficiencies required for the practice of dentistry in the European Union.<sup>2</sup> As to the clinical proficiencies required in the field of conservative dentistry, the following item can be found in the report (Item 4.10): "The restoration to function of teeth utilising the full range of currently acceptable and available restorative materials with due consideration to the concept of oral health." As to the educational process, the report states: "The acquisition of clinical proficiency may be achieved through a diversity of educational and training programmes. These may be assessed and examined in different ways throughout the European Union. Nevertheless it is possible to agree on certain basic clinical proficiencies common to all member states of the EU." Such reference documentation allows dental schools to bring their programs into harmony within the European framework.

At the European level several initiatives have resulted in a strengthening of cohesion in dental education, principally through cooperative schemes between dental schools. These initiatives included:

1. The Association for Dental Education in Europe, founded in 1975 and now sup-

ported by the *European Journal of Dental Education*, which was launched in 1997.

2. The European Activity Scheme for the Mobility of University Students (ERASMUS), now expanded to include eastern Europe and renamed "Socrates." This program has stimulated exchange of teachers and students between a number of dental schools in Europe. One of the positive effects of this program is a better understanding and increased rate of change in dental education programs. Education and training in the area of conservative dentistry is considered to have gained considerably from these exchange programs.
3. The DentEd Consortium is a network of European dental schools established to build a system for quality assessment by site visitation throughout Europe. This European network has arranged an impressive number of site visits to help further harmonize dental education in Europe.

The objectives of the network are as follows:

- To establish a network of European institutions involved in dental education, with emphasis on undergraduate education
- To provide a database of information on dental educational institutions for mutual exploitation of available intellectual, technical, and clinical resources for the common good of European dentistry
- To promote an understanding of the educational systems in operation throughout Europe and provide an explanation of the logical and scientific

basis on which they have been developed

- To promote the development of a process of quality development through self-assessment combined with peer discussion in the dental schools of Europe
- To encourage the application of evidence-based competences in clinical dentistry in order to promote an objective self-assessment of the scientific evidence on which appropriate clinical procedures are taught to students
- To exchange teams of multinational visitors between institutions in order to review the different methods of education and training in the EU in the context of outcome, competences, and innovations

Presently, about 75 schools are involved in the network and the curricula of approximately 20 schools have been assessed in the past 18 months (Tables 18-2 and 18-3).

In the field of conservative dentistry there has been a recent initiative to create a European platform for university teachers and general practitioners. This platform—the Academy of Operative Dentistry, European Section (AODES)—was established in Riva del Garda, Italy, in 1998. Subsequently, annual meetings have been held in Munich, Germany (1999), and Bologna, Italy (2000). The objective of the AODES is to promote excellence in operative dentistry by exerting an influence on the clinical practice of dental health professionals, education in dental sciences, research, and in any other realm pertinent to conservative dentistry. It is hoped that many more European dentists will support and contribute to this new organization.

Table 18-2 Dental Schools in the European Union participating in DentEd (N=53)

Country	University	Country	University
Austria	Wien	Ireland	Dublin
Belgium	Bruxelles		Cork
	Liege		Belfast
	Leuven	Italy	Brescia
Denmark	Kobenhavn		Ferrara
	Aarhus		Firenze
Finland	Helsinki		Milano
	Oulun Yliopisto		Napoli
	Umea		Pavia
France	Montpellier I		Roma
	Rene Descartes (Paris V)		Sassari
	Denis Diderot (Paris 7)	Netherlands	Amsterdam
	Lyon		Nijmegen
	Nice-Sophia Antopolis	Portugal	Lisboa
	Rennes	Spain	Madrid
	Toulouse		San Sebastian
Germany	Auvergen-Clermont	Sweden	Stockholm
	Aachen		Malmo
	Dresden		Umea
	Freiburg	Un. Kingdom	Dundee
	Halle		Guy's London
	Köln		Kings College London
	Muenster		Liverpool
	Regensburg		The London Hospital
	Giessen		Manchester
	Witten/Herdecke		Cardiff
Greece	Athens		

Table 18-3 Dental schools outside of the European Union participating in DentEd (N=20)

Country	University	Country	University
Bulgaria	Sofia	Litowenia	Vilnius
Czech	Brno	Norway	Bergen
	Prague		Oslo
	Palacky	Poland	Lodz
Estonia	Tartu		Warsaw
Hungary	Budapest		Krakow
	Szeged	Romenia	Timisoara
Iceland	Reykjavik	Slovakia	Bratislava
Kroatie	Zagreb		Kosice
Latvia	Riga	Slovenia	Ljubljana

## **Conservative Dentistry Training in Europe**

Following are some details of programs in conservative dentistry in a number of dental schools in Europe. An attempt has been made to represent southern, northern, western, and eastern approaches to training in the field.

### **University of Madrid**

Prof. Javier Garcia Barbero, Spain

The teaching of conservative dentistry in Spain includes: dental pathology and dental therapeutics relevant to operative dentistry and endodontics, together with the study of all relevant dental materials science.

The general objectives are (1) to study all diseases affecting teeth with regard to etiology, pathogenesis, clinical manifestations, diagnosis, and prognosis, and (2) to accurately perform operative dentistry and endodontic treatments to the following levels: knowledge and handling of the necessary instruments, cavity preparation for amalgam and composite resins according to Black classification, cavity restoration with amalgam and composite resin, esthetic restorations, and the endodontic treatment of single- and multirooted teeth.

Minimum requirements are (1) preclinical-16 amalgam and 12 composite resin posterior restorations and 16 anterior composite resin restorations, and (2) clinical-12 amalgam and 25 composite resin restorations. Treatment distribution in clinical studies is variable depending on each patient's needs. Patients are allocated to students by a central, computerized reception service.

Curriculum time requirements are (1) preclinical-70 hours on typodont and extracted teeth, comprising 40 hours for operative dentistry and 30 hours for endodontics, and (2) clinical-100 hours, comprising 70 hours for operative dentistry and 30 hours for endodontics.

The student-to-professor ratio is 1:12 in preclinics and 1:6 in clinics. Following successful completion of this training, students enter integrated clinics in which restorations and endodontics are performed on patients as part of integrated care. Inlay/onlay treatments, porcelain veneers, post and core buildups, and complex endodontics, including endodontic surgery, are taught in the pregraduation practical course.

### **UK Dental Schools**

Prof. Nairn H. F. Wilson, Manchester

Traditionally, the teaching of conservative dentistry in the UK has included the teaching of operative dentistry, endodontology, and fixed prosthodontics. Subsequent to the regulatory recognition of dental specialties, including endodontics and fixed and removable prosthodontics in 1998, a number of dental schools have instituted, or at least planned, internal reconfigurations to give endodontology a separate academic identity and to integrate the teaching of fixed and removable prosthodontics. Long-established departments of conservative dentistry have, as a consequence, been fragmented and downsized to departments or academic units of operative dentistry, with a number of schools having given consideration to subsuming the residual elements of former



departments of conservative dentistry into departments of, for example, comprehensive patient care. Notwithstanding circumstances in which conservative dentistry continues to maintain separate curriculum provision, typically linked to the core teaching of dental biomaterials science, the future academic provision for operative, let alone conservative, dentistry as a separate discipline is increasingly unclear in certain UK schools.

Irrespective of recent and possible future changes in the provision for the teaching of conservative dentistry in UK dental schools, the teaching of the "drill and fill" philosophy is now being replaced with preservative approaches to patient care. As indicated by the findings of recent surveys of the teaching of different materials and techniques, students in UK dental schools may be taught the use of most modern materials and restorative techniques. Traditional forms of teaching, learning, and assessment in conservative dentistry in the UK may increasingly be found to be replaced by competence- and problem-based approaches to student progression. Initiatives in student pairing; skill-mix, involving, in particular, dental nurses and hygienists; and outreach longitudinal, comprehensive patient care programs are opening up new possibilities for the efficient, effective delivery of programs of education in conservative dentistry.

## Centre for Oral Health Sciences, Malmö

Dr. Katarina Wretling, Sweden

At the Centre for Oral Health Sciences in Malmö, cariology for the undergraduates is taught using the problem-based learn-

ing concept. This begins in the first semester and continues throughout the whole curriculum, including the last (10th) semester. Learning in context, early patient contact, and a commitment by the students to take responsibility for their own learning are central concepts.

According to the principles of problem-based learning, students acquire knowledge of the caries process and how to treat the disease by solving the problems of the study cases presented using specific guidelines. For example, during the third semester, students will be given a case, as follows: "One of your patients is worried about his front teeth. During the last year brownish stains, close to the margin of the gingiva, have appeared, and he thinks they have a negative impact on his appearance." After working with this case the students should be able to:

- Describe how the balance in the oral ecosystem can be disturbed and what this means for the surface of the tooth
- Describe the reaction of the tooth on a caries attack and on operative dentistry
- Understand how caries and its symptoms can be treated

During the third and fourth semesters, several other cases pertain to cariology and operative dentistry. Parallel to the theoretical studies, the students attend the laboratory during the third semester, then attend the clinic, treating their own patients, during the fourth and fifth semesters. Students face clinical tests in diagnostics and in performing different types of restorations. After the fifth semester, the basic course in cariology is completed, and the students continue to treat

patients presenting with caries at the Comprehensive Oral Health Care Clinic for adult patients and also later in the clinic for children and adolescents.

## Munich University

Prof. Dr. Reinhard Hickel, Germany

There are three different levels of regulations for dental education in Germany: (1) the federal regulations, (2) university regulations, and (3) the rules set by the chairmen of the department. This results, in some cases, in large differences across the 30 dental schools in Germany.

Conservative dentistry includes preventive and restorative dentistry, endodontics, pedodontics, and periodontology. For the purposes of the present comparison, only restorations are considered.

The teaching of direct fillings, including inlays and onlays, starts in the third year with the preclinical phantom course in conservative dentistry.

The principal teaching in restorative dentistry is in the fourth and fifth year of the curriculum in which two courses, each of which require 20 hours per week treating patients, have to be completed. In the second clinical course (fifth year), 30 surfaces for anterior fillings and 30 surfaces (mesio-occlusodistal = 3) of posterior restorations have to be completed, together with 30 surfaces of indirect restorations (inlays). In the first clinical course in conservative dentistry, 20 rather than 30 surfaces are required. The students have to treat patients requiring restorations as part of other treatment needs, including periodontal, endodontic, and preventive therapies.

Additionally, the students have to participate in two 10- to 12-week semesters of

lectures on conservative dentistry, including endodontics and prevention (3 to 4 hours), pedodontics (1 hour), and periodontics (1 to 2 hours). In the third year (phantom course), the students have special weekly lectures (2 hours) and seminars in all aspects of conservative dentistry, including dental restorative materials.

## Italian Dental Schools

Prof. Dr. Sandro Rengo, Naples

In Italy, the teaching of operative dentistry is organized as a 3-year course. One year concerns endodontics and 2 years address restorative techniques. The main aims of the course are:

1. To provide the students with a theoretical knowledge of craniofacial anatomy, physiology, and the basic techniques and materials used in operative dentistry
2. To have the students acquire an understanding of and basic skills in the handling of instruments and materials, together with knowledge of guidelines for ergonomic work organization prior to treating patients.

In each year the teaching consists of traditional lectures ex cathedra and seminars with an emphasis on new materials, instruments, and clinical procedures. This training consists of cavity preparations for amalgam, direct and indirect composites, and endodontic therapy, first on simulators and extracted teeth and subsequently in patients (while under supervision). At the end of the course, the students have to take an examination that consists of a written paper, a clinical test, and an oral examination.

## Nijmegen University

Prof. Dr. Alphons J. M. Plasschaert, The Netherlands

The dental curriculum at Nijmegen University is a 5-year program. Conservative dentistry (defined here as operative dentistry limited to the techniques and theory to restore teeth with plastic filling materials) is taught in each consecutive year. The curriculum is programmed to a total study load (SL) of 1680 hours (contact time and self-study time) per year. In the first year there is a course entitled "Restoration of Teeth" with an SL of 320 hours (142 hours contact time: 126 hours practice and 16 hours theory). The objective of this course is to complete simple preparations and restorations. The course entitled "Teeth" has for conservative dentistry a 24-hour SL, of which 4 hours is contact time. In the second year there is a 240-hour SL in the course "Restoration of Teeth II" (203 hours contact time: 190 hours practicals and 13 hours theory).

In the third, fourth, and fifth year, conservative dentistry is integrated with other clinical activities, including periodontics, endodontics, crown and bridge work, and applied preventive dentistry. The three integrated clinical courses have SLs of 160, 160, and 800 hours. In addition, there is an elective course in the fifth year on adhesive/cosmetic dentistry comprising 160 hours. The minimal requirements in terms of numbers of surfaces to be completed are: second year, 11; third year, 36; fourth year, 60. There is no quantitative requirement in the fifth year. Students have to complete several patient cases in which conservative procedures are part of the treatment plan.

## Discussion

The present is the result of the past, and the future lies in today. It is obvious from the data presented here that there are marked differences among dental schools in Europe in relation to the teaching of conservative dentistry as part of the dental curriculum. It is promising, however, that in recent times information exchange and student and staff mobility schemes have contributed to some harmonization of the teaching of conservative dentistry across Europe. The DentEd site visitation program is unique and will certainly contribute to a greater commonality in approach and quality.

We are at the beginning of a new century and millennium. If progress continues at the pace seen in the last century, it is hard to envisage what innovations in computer science and technology alone will do for data processing and communications. Flexibility and a readiness to change is essential in having dentists become life-long learners, giving the best they can to serve their patients. A challenge will be the sharing of creativity and the pooling of resources in a combined effort to develop CD-ROM educational programs for conservative dentistry at the European level. It is, therefore, essential to first agree on pan-European learning objectives for conservative dentistry. Questions as to what kind of professionals we need in dentistry in the future, the changing role of the practitioner, and the impact dental auxiliaries will have on the future delivery of operative dental care are to be researched and debated. In this way, it is hoped that a better understanding will be promoted among teachers of conservative dentistry across Europe. Organizations, including

the AODES, will hopefully provide a forum for future collaborations and cooperation.

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# Index

Page numbers followed by 'f' indicate figures;  
those followed by 't' indicate tables.

## A

Academy of Operative Dentistry, European  
Section, 249

Acid etching

- dentin, 28, 30f, 73, 75f-76f
- enamel, 73, 75f, 147, 165, 177, 180f, 230f
- porcelain, 233
- smear layer, 73, 75f-76f, 88

Acrylic mock-up, 140, 141f, 142

Adhesive cements and systems

- advancements in, 61
- benefits of, 242
- caries prevention using, 225
- dentinal bonding, 30f-31f
- evaluation of, 33
- indirect restorations, 96-97, 103, 104f-105f
- properties of, 97t
- resins. *See* Composite resins.
- self-etching, 29, 32-33, 32f
- tooth preservation benefits of, 79
- types of, 97t

Aging. *See* Elderly.

Amalgam restorations

- Black's technique, 242, 243f
- degradation of, 197
- properties of, 73

Anterior restorations

- case study examples of, 57, 58f-60f, 69f-70f
- color matching, 61, 62f-70f
- esthetic principles for, 61-62, 62f-70f
- layering technique for, 64f-67f
- margin placement, 110, 111f
- materials development, 57, 61
- retraction cord placement, 126f, 129
- tooth preparations
  - errors in, 109-110
  - extent of, 121
  - taper of, 110, 111f
- tooth reduction assessments
  - depth cuts, 112, 112f
  - matrices, 112, 112f

provisional crown, 112-113, 113f

worn teeth

- axial movement, 115-116, 117f
- changes resulting from, 113-114
- composite resin restorations of, 116, 117f
- crown lengthening, 114-115
- description of, 113
- illustration of, 123f
- occlusal adjustments for, 114
- space creation methods for, 114-116
- vertical dimension of occlusion increases, 115

Anterior teeth

- axial movement of, 115-116, 117f
- color of, 62f
- coronal and radicular dentin, 193
- curvature of, 110
- endodontically treated, bonded partial restorations  
for, 199, 200f-201f
- extrusion of, 120
- facial aspects of, 110
- preparations of
  - diagnostic waxup, 140, 142
  - errors in, 109-110
  - extent of, 121
  - importance, 135
  - taper of, 110, 111f
- restorations of. *See* Anterior restorations.
- rubber dam placement, 44
- wear of. *See* Anterior restorations, worn teeth.

Antimicrobial varnishes, 224, 224t

Axial movement of anterior teeth, 115-116, 117f

## B

Bacteria

- removal of, 17-18, 18t
  - root surface caries caused by, 223t, 223-224
- Bevel, esthetic uses of, 61, 68f

Biologic width

- crown-lengthening surgery, 52, 53f-54f
- indirect restorations, 119

Biomimetics, 135-136

Bonded partial restorations, for endodontically  
treated teeth  
advantages of, 193-197

- anterior teeth, 199, 200f-201f
- biomechanical properties of, 195, 197
- definition of, 191
- fracture resistance benefits, 197
- full-coverage restorations vs., 195
- in immature teeth, 195
- immediate placement of, 196f
- indications, 197-199
- posterior teeth, 199, 202f-206f, 203
- transitional, 195
- Bonding**
  - adhesive systems, 29, 32-33, 32f
  - cementum, 98
  - ceramics, 165-166
  - chemical irritation during, 29
  - composite resins, 166
  - dentin. *See* Dentin.
  - enamel, 98
  - etching benefits for, 73. *See also* Acid etching.
  - evaluations of, 29
  - micromechanical, 73, 77f
  - substrates for, 98-100, 99f-101f
- Bonding agents and systems**
  - color of, 63
  - dentinal damage reduced using, 18t
  - esthetic principles for applying, 63
  - etching benefits of, 73, 75f
  - pulpal damage prevented using, 25
  - resin. *See* Composite resins.
  - restoration protection using, 20t
- Burs, 143f, 144**
- C**
- CAD/CAM system**
  - Cerec 3. *See* Cerec 3 CAD/CAM system.
  - description of, 102-103
- Calcium-hydroxide cements, 18t**
- Caries**
  - age-related increases in, 216
  - crown margin placement and, 50
  - in elderly, 216
  - root
    - antimicrobial varnishes, 224, 224t
    - bacterial pathogens associated with, 223t, 223-224
    - noninvasive therapy, 224-227
    - prevention of, 224-227
    - restorative materials for, 227
    - treatment planning algorithm, 226f
    - tissue loss secondary to, 191
- Caries detector, 79, 81f**
- Cementation, temporary, 145**
- Cemento-enamel junction, 98, 101f-102f**
- Cements**
  - calcium-hydroxide, 18t
  - glass-ionomer. *See* Glass-ionomer cements.
  - luting. *See* Luting cement.
  - nonadhesive, 98, 98t
- Cementum bonding, 98**
- Ceramic restorations**
  - acrylic mockup, 140, 141f, 142
  - bonding, 165-166
  - case study example of, 149, 150f
  - casting of, 102
  - description of, 135
  - indications, 136, 137f-138f
  - milling of, 102
  - properties of, 96, 145-146
  - provisional restoration, 142, 144
  - tooth preparations, 142, 143f, 144, 147
  - tooth structure losses, 142
  - waxups, 140f, 140, 142
- Ceramic veneer**
  - bonding of, 148-149
  - case study example of, 149, 150f
  - Cerec 3 CAD/CAM system design of. *See* Cerec 3 CAD/CAM system.
  - chip fractures of, 146
  - delamination of, 146
  - enamel and, similarities between, 145-146
  - failure of, 146
  - indications, 136, 137f-139f
  - occlusal adjustments, 149
  - placement of, 148-149
  - production of, 146
  - surface conditioning, 147, 148f, 166
  - tooth preparations for bonding, 147
  - try-in, 146-147
- Cerec 3 CAD/CAM system**
  - background, 154
  - clinical preparations
    - impressions, 155
    - provisional restoration, 155
    - tooth preparations, 155, 156f
  - shade selection, 154
  - system description, 153
  - veneer
    - adhesive placement of, 162, 163f
    - CAD design of, 156f-159f, 156-159
    - cast try-on, 159, 161f
    - esthetic buildup, 159, 159f-161f
- Cervical chamfer, 142, 155, 156f**



- Chip fractures, 146
  - Chlorhexidine, 225
  - Clamps, rubber dam, 40t, 40-41, 41f-43f
  - Collagen fiber network, 77f
  - Compomers
    - advantages of, 97t
    - disadvantages of, 97t
    - hydrophilicity of, 35
    - margin protection, 19t
    - rubber dam use, 35
  - Composite resins
    - advancements in, 73, 96
    - advantages of, 97t
    - adverse reactions, 79
    - bonding to, 166
    - color of, 61
    - dentin interface with, 73, 77f-78f
    - disadvantages of, 73, 74f, 97t
    - hybrid layer, 73, 77f, 88
    - light curing of, 79, 81, 82f-83f, 146
    - opacities of, 61
    - polymerization shrinkage, 79, 89-90
    - posterior teeth placement. *See* Composite-up technique.
    - prevalence of use, 242-243, 244t
    - properties of, 97t, 146
    - self-curing, 89, 92
    - tags, 78f, 100
  - Composite-up technique, for direct posterior restorations
    - adhesion procedures, 88-89
    - biocompatibility, 88-89
    - cavity preparation, 88
    - finishing of, 91f, 92
    - indications, 88
    - occlusal surface, 90f-91f, 92
    - polymerization shrinkage considerations, 89, 92
    - proximal surface reconstruction, 89, 89f
  - Conservative dentistry
    - adhesive techniques, 242
    - composite restorations, 242-243, 244f
    - content changes in, 241-243
    - disclosing solutions, 241-243
    - education in, 246-249, 250t
    - European developments in, 248-249, 250t
    - future of, 254-255
    - occlusal width, 243, 245f
    - training programs, 251-254
  - Crown lengthening
    - biologic width after, 52, 53f-54f
    - cosmetic effects of, 115, 116f
    - indications, 120
    - partial-thickness flap, 52f-53f
    - subgingival caries, 50
    - technique for, 50, 52, 52f, 123f
    - worn teeth, 114-115
  - Crown margins
    - caries incidence, 50
    - description of, 49
    - periodontal support loss, 49-50
    - subgingival vs supragingival placement, 49-50
- ## D
- Dam. *See* Rubber dam.
  - Delamination, of ceramic veneers, 146
  - Dental apoptosis cycle, 193
  - DentEd Consortium, 249, 250t
  - Dentin
    - adhesive bonding to, 29, 30f-32f
    - age-related changes in, 230
    - anatomy of, 27-28
    - bacteria removal from, 17-18, 18t
    - bonding agents, 145, 165
    - caries preparation effects, 28
    - composite resin interface with, 73, 77f-78f
    - coronal and radicular, in anterior vs posterior teeth, 193
    - damage to, 17-19
    - definition of, 17
    - demineralization of, 25, 225
    - disinfection of, 17, 18t
    - enamel and, relationship between, 135-136
    - etching of, 28, 30f, 73, 75f-76f
    - fractured, 76f-77f
    - hybridization of, 28, 29, 98, 100f
    - hybrid layer, 73, 77f, 88
    - permeability of, 18, 28, 33
    - properties of, 28
    - sclerotic, 230
    - smear layer removal, 73, 75f-76f, 88
    - types of, 98, 99f
      - in vital vs nonvital teeth, 195
  - Dentinal tubules
    - description of, 27-28
    - illustration of, 74f
    - resin penetration into, 230
  - Dentin-enamel bonding systems
    - dentinal damage reduced using, 18t
    - pulpal damage prevented using, 25
    - restoration protection using, 20t
  - Dentition. *See* Teeth.
  - Depth cuts, 112

Diagnostic waxup. See Waxup.  
 Diastema, 145  
 Direct restorations  
     composite-up technique. See Composite-up technique.  
     indirect vs, 95  
     posterior teeth. See Posterior teeth restorations.  
 Disclosing solutions, 241-243

## E

Elderly  
     caries, 216, 223-227  
     dental attendance visits by, 217-218  
     dentinal changes, 230  
     enamel changes, 229-230  
     fractured teeth, management options for  
         all-porcelain restoration, 231, 232f  
         cast metal restoration, 231, 232f  
         description of, 231  
         porcelain-fused-to-metal restoration, 231, 232f  
         surface treatments, 231, 233, 234f  
     masticatory reductions in, 218-219  
     nutrition, 218-219  
     oral anatomy changes in  
         salivary glands, 213-215, 214f  
         soft tissue, 213, 215  
     oral health of  
         behaviors associated with, 217-218  
         contemporary changes in, 211, 213  
         dentate, 214f, 215-216  
     oral hygiene practices, 218  
     periodontal disease, 216-217  
     population projections for, 211-213, 212f, 214f  
     stereotypes, 211  
     taste perception changes, 215  
     tooth wear. See Worn teeth.

## Enamel

    age-related changes in, 229-230  
     bonding to, 98  
     dentin and, relationship between, 135-136  
     etching of, 73, 75f, 147, 165, 177, 180f, 230f  
     residual, effect on restoration margin, 103  
     waxups for preserving, 144

## Enamel margin

    alteration prevention methods, 21, 22f-23f  
     beveling of, 61, 68f  
     cemento-enamel junction, 98, 101f-102f  
     preservation of, 61

## Endodontically treated teeth

    bonded partial restorations  
     advantages of, 193-197

    anterior teeth, 199, 200f-201 f  
     biomechanical properties of, 195, 197  
     definition of, 191  
     fracture resistance benefits, 197  
     full-coverage restorations vs, 195  
     in immature teeth, 195  
     immediate placement of, 196f  
     indications, 197-199  
     posterior teeth, 199, 202f-206f, 203  
     transitional, 195  
     description of, 191  
     failure of restorations, 195  
     fragility of, 191  
     post and core restorations for, 191-193, 192f  
     treatment planning considerations, 191  
 Etching. See Acid etching.

## F

Forceps, rubber dam, 39-40, 40f  
 Fractured teeth, management options for  
     all-porcelain restoration, 231, 232f  
     cast metal restoration, 231, 232f  
     description of, 231  
     porcelain-fused-to-metal restoration, 231, 232f  
     surface treatments, 231, 233, 234f

## G

### Gingiva

    contours of, 120  
     retraction cord for crevice dilation, 126f, 129, 176f

### Gingival index, 49

### Glass, 96

### Glass-ionomer cements

    advantages of, 97t  
     antibacterial benefits of, 24-25  
     disadvantages of, 97t  
     fluoride-releasing benefits of, 21  
     margin protection, 19t-20t, 21  
     resin-modified, 97t

## Indirect inlays, 170, 170f-173f

## Indirect restorations

    anterior teeth  
         adhesive technique, 103, 104f-105f  
         biologic width, 119  
         bonding, 98-100, 99f-102f, 121-122  
         case study example of, 122-131  
         cementing materials for, 96-98, 97t-98t  
         construction techniques, 100-103  
         dentoperiodontal relationships in, 119-131

direct restorations vs, 95  
 esthetic materials for, 95-96  
 patient management, 119, 120f  
 periodontal treatment and, 119-121  
 quality of, 103  
 posterior teeth  
   inlays. *See* Inlays.  
   longevity of, 185, 186t  
   onlays. *See* Onlays.  
   rationale for, 166  
   technique for, 174-185, 175f-185f  
 Inlays  
   chairside, 167-170  
   direct composite, 167  
   extraoral composite, 167-170  
   indirect, 170, 170f-173f  
   longevity of, 185, 186t  
   provisional, 174, 177, 178f  
   semidirect technique for, 166-167  
   technique for, 174-185, 175f-185f  
 Intercuspal position, 114

**L**

Light curing, of composite resins, 79, 81, 82f-83f, 146, 182f  
 Luting cement  
   inlays, 177, 181f  
   restoration seating, 97  
   temporary, for provisional restorations, 145

**M**

Mandibular molars, 81, 83, 83f-84f  
 Margin of restoration  
   alterations prevention, 24-25  
   chemical degradation of, 20  
   gaps, 18-19, 22f  
   hybrid layer, 22f-23f  
   microleakage, 20-21, 74f, 95, 103, 195  
 Masticatory function, in elderly  
   nutrition and, 218-219  
   reductions in, 218  
 Materials. *See* specific material.  
 Matrices, for tooth reduction assessments, 112, 112f  
 Metal matrix, 89  
 Microleakage, 20-21, 74f, 95, 103, 195  
 Moisture management  
   description of, 35  
   rubber dam. *See* Rubber dam.  
 Mutans streptococci, 223t, 224

## N

Natural inlay, 96  
 Nonadhesive cements, 98, 98t

## Occlusion

adjustments  
   ceramic veneer placement, 149  
   inlay placement, 177, 182f-183f  
   space for anterior restorations, 115  
 vertical dimension of, 115, 233, 235f

## Onlays

indirect, 170, 170f-173f  
 longevity of, 185, 186t  
 technique for, 174-185, 175f-185f

Oral mucosa, age-related changes in, 215

## P

Partial restorations, for endodontically treated teeth

advantages of, 193-197  
 anterior teeth, 199, 200f-201f  
 biomechanical properties of, 195, 197  
 definition of, 191  
 fracture resistance benefits, 197  
 full-coverage restorations vs, 195  
 in immature teeth, 195  
 immediate placement of, 196f  
 indications, 197-199  
 posterior teeth, 199, 202f-206f, 203  
 transitional, 195

Periodontal disease, 216-217

## Periodontal tissue

atraumatic manipulation of, 49, 51f  
 in elderly, 216-217  
 restoration-induced trauma, 49, 50f

Polishing, 184f-185f

Polymerization shrinkage, 73, 74f, 79, 89

## Porcelain

acid etching of, 233  
 anterior tooth wear restored using, 237, 238f  
 characteristics of, 95-96

## Porcelain-fused-to-metal restoration

for fractured teeth, 231, 232f  
 for tooth wear, 236, 237f

Porcelain veneer. *See also* Ceramic veneer.

composite accumulation under, 142  
 illustration of, 138f

Post and core restorations, 191-193, 192f

## Posterior teeth restorations

- adhesion procedures, 88-89
- biocompatibility, 88-89
- bonded partial restorations, for endodontically treated teeth, 199, 202f-206f, 203
- bonding
  - restorative materials, 165-166
  - tooth substrates, 165
- cavity preparation, 88
- coronal and radicular dentin considerations, 193
- finishing of, 91f, 92
- indications, 88
- indirect
  - inlays. See Inlays.
  - longevity of, 185, 186t
  - onlays. See Onlays.
  - rationale for, 166
  - technique for, 174-185, 175f-185f
- mandibularfirst molar, 81, 83, 83f-84f
- occlusal surface, 90f-91f, 92
- phases of, 87
- polymerization shrinkage considerations, 89, 92
- proximal surface reconstruction, 89, 89f
- technique for, 79, 81, 83, 80f-84f

## Provisional restoration

- case study use of, 122, 125f
- inlays, 174, 177, 178f
- layering techniques for, 145
- leakage of, 195
- principles of, 142, 144
- production of, 145
- tooth reduction assessments using, 112-113, 113f

## Pulp

- anatomy of, 27-28
- damage, 24-25
- vascular supply, 28

## Pulp-dentin complex

- adhesive systems, 29, 30f-32f
- immediate dentinal bonding for preservation of, 145
- protection of, 28-37

## R

Resin composites. See Composite resins.

Resin tags, 78f, 100

## Restorations

- amalgam. See Amalgam restorations.
- anterior teeth. See Anterior restorations.
- ceramic. See Ceramic restorations.

- external protection of, 19, 19t
- internal protection of, 19-21
- margin. See Margin of restoration.
- marginal gaps, 19-21, 22f
- partial. See Bonded partial restorations.
- periodontal tissue trauma caused by, 49, 50f
- post and core, 191-193, 192f
- posterior teeth. See Posterior teeth restorations.
- provisional. See Provisional restoration.
- resin luting cement for seating of, 97

## Retraction cord

- cervical chamfer created using, 142
- gingival crevice dilation using, 126f, 129, 176f

## Retruded axis, 114

## Rubber dam

- advantages of, 36t
- adverse reactions to, 37
- anterior teeth use, 44
- application technique, 44-45, 45f-46f
- clamps, 40t, 40-41, 41f-43f
- colors of, 36-37
- forceps, 39-40, 40f
- frame, 37, 38f
- history of, 35
- placement of, 44-45, 45f-46f
- posterior teeth use, 44
- powder-free, 37
- preparations for application, 41, 44
- prerequisites for using, 36
- punch, 37-39, 38f-39f
- removal of, 47f
- summary overview of, 48
- thickness of, 36, 36t

Salivary glands, age-related changes in, 213-215, 214f

Sealers, 19t

Self-etching adhesive systems, for dentinal bonding, 29, 32-33, 32f

Silane, 177

Silanization, 165

Smear layer, 73, 75f-76f, 88

## T

## Teeth

- cracks in, 197
- in elderly, 214f, 215-216
- fractured. See Fractured teeth.
- preparing of. See Tooth preparations.

structure loss  
     bonded partial restoration indications,  
       198-199,203  
     ceramic restorations, 142  
     effects of, 195

Toothpastes, 19t

Tooth preparations  
     diagnostic waxup, 140, 142  
     errors in, 109-110  
     extent of, 121  
     illustration of, 143f  
     importance, 135  
     principles of, 142, 143f, 144  
     taper of, 110, 111f

Tooth wear. See Worn teeth.

## V

Veneers

    ceramic. See Ceramic veneer.  
     Cerec 3 CAD/CAM design of, 156f-159f,  
       156-159

Vertical dimension of occlusion, 115, 233, 235f

## W

Waxup

    additive, 140, 140f, 142  
     ceramic restorations, 140, 142  
     enamel preservation, 144  
     indirect restorations, 122, 124f

Worn teeth

    anterior

        axial movement, 115-116, 117f  
         changes resulting from, 113-114  
         composite resin restorations of, 116, 117f  
         crown lengthening, 114-115  
         description of, 113  
         illustration of, 123f  
         occlusal adjustments for, 114  
         porcelain additions, 236, 238f  
         porcelain-fused-to-metal restoration for, 236,  
           237f  
         space creation methods for, 114-116  
         vertical dimension of occlusion increases, 115  
 attritive pattern, 233, 235f  
 causes of, 233  
 composite resins for  
     indications, 233  
     laboratory-made restorations utilizing, 236,  
       236f-238f  
 erosive, 233, 235f

## X

Xerostomia, 213, 215