Irena Sailer | Vincent Fehmer | Bjarni Pjetursson

FIXED RESTORATIONS

A CLINICAL GUIDE TO THE SELECTION OF MATERIALS AND FABRICATION TECHNOLOGY

QUINTESSENCE PUBLISHING

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Dedication

"To our families and mentors who inspired us"

Irena, Vincent, and Bjarni

Forewords

I must admit that the request from Irena Sailer, Vincent Fehmer, and Bjarni Pjetursson to write a foreword for their new book entitled “Fixed Restorations” surprised me. My first thought was: Do we need a book about fixed restorations in this day and age?

On second thoughts, I rapidly changed my mind. They are right. It is necessary and even urgent to publish such a book at this juncture. In many discussions with colleagues, I have noticed how little we know about the incredible product developments in fixed restorations in recent years, and the controversies surrounding the issue. Many protocols and elements have changed in this area of dentistry. It seems essential that the dental community have an overview and guidelines of the current state of the art. A multitude of different materials is available in fixed restorations. Also, the manufacturing techniques for fixed restorations have made fundamental developmental changes, which need to be fully understood.

The practicing clinician should also have a strong foundational knowledge of all the various materials and manufacturing techniques in fixed restorations. But, hand on heart, is this requirement possible? Only during their formal education years do clinicians learn the ability to obtain profound knowledge of the composition and availability of the different materials in fixed restorations; their advantages and disadvantages; their various fields of application; and the various manufacturing techniques. The combined elements of official tutoring, available literature, communication, and controlled hands-on experience allow the clinician to formulate opinions about the gold standards of restorative treatment. Considering the last decades of dentistry, it is apparent that a clinician will never be in the position of always being up to date in the fields of new materials and new manufacturing techniques of fixed restorations. During a clinician's entire professional life, development of these new techniques and materials is too rapid and intensive to remain fully informed.

Therefore, nowadays, more than ever, the clinician must build a team with his or her laboratory technician. The laboratory technician is the individual who works with dental components daily, gaining a deep understanding of the advantages and disadvantages of different materials. Laboratory technicians hold casts in their hand or look at models on the screen daily; they see the chipping, the fractures, and the problems of the different materials used for fixed restorations as they are utilized and produced. They can formulate opinions on suitability and functionality better than anyone else. The wise and ethically motivated dental clinician and researcher needs to lend an ear to the incredible experience and understanding of laboratory technicians.

Irena Sailer, Vincent Fehmer, and Bjarni Pjetursson choose this innovative approach in their book by selecting authors with different backgrounds. Irena Sailer and Bjarni Pjetursson are both incredible clinicians and researchers. Still, they knew and understood that for such a book project to succeed an exceptional laboratory technician's contribution and input would be required. They found it in Vincent Fehmer. They together have the complete knowledge and experience to create such a mammoth undertaking. I can see with my own eyes what thorough and intense discussion they must have had during the writing of this book. They knew that one of them would never be able to finish such a project. The only way to succeed was to form a team with three exceptional characters.

In the fall of 2019, I had the pleasure to be invited to the wedding of Irena and Vincent. Bjarni was the chosen best man. At the fantastic evening party, all attendees could feel the unique energy between the three of them. They have more than just friendship. There is energy, emotion, and pleasure between them. These characteristics are necessary to build an incredible team to create a unique project like this book.

Dear lovely readers, you now have this book in your hands. I am convinced that you will feel the energy and the enthusiasm of the team behind it while reading. The sparks of fixed restoration will also fly in your mind.

Prof Dr Markus Hürzeler

Today's progress in dentistry is extremely rapid regarding the development of new materials and techniques for treating patients in need of fixed restorations. It is easy for clinicians to lose oversight of the myriad of materials available and the technical methods to process them and thus to feel left behind this rapid but fascinating progress. In addition, scientific journals in the field are filled with articles on new material categories, new material compositions, and new techniques and methods for material processing. It is becoming increasingly difficult for clinicians to master the problem of which material is best for which indication in clinical practice. With this book, the authors Irena Sailer, Vincent Fehmer, and Bjarni Pjetursson have compiled clinically relevant and useful recommendations on where and how to apply the optimal dental materials in a given clinical situation. It clearly represents the current best practice for decision making regarding material selection in patients in need of fixed restorations. I expect this book to help seasoned clinicians, trainees in dental schools, as well as students in postgraduate programs to provide better care for their patients.

Divided into four parts, the book covers basic information regarding materials and the overall production processes in the first part, and the clinical procedures step-by-step in the second part. The broad illustration with excellent pictures helps the reader to understand the connection between the initial diagnosis, the patient's needs, the careful identification of indications, and the optimal choice of the best suitable materials, coupled with the state-of-the-art manufacturing technique. The discussion of the clinical challenges occurring around dental restorations would not be complete without the third Part detailing the important issues of long-term outcomes, and the final Part describing the management of complications. Thanks to their years of experience in clinical dentistry and their careers as clinical researchers, the authors excellently combine clinical judgment with the scientific evidence for the recommendations on best practice for fixed restorations. In the light of today's important role of dental implants to support and improve the desired clinical outcomes, this book deals with materials to restore natural teeth as well as dental implants.

In summary, the authors are to be congratulated for having compiled a guide for the dental community to enable better health care in this era of rapid technical and scientific development in the field of dental restorative materials and their application in clinical practice.

Prof Dr Dr h c Christoph Hämmerle

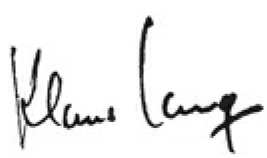
For decades, restorative dentistry has been dominated by mechanistic therapeutic concepts and simple material sciences aspects. However, in more recent years, these concepts were severely challenged and replaced by biologically oriented treatment concepts. “To maintain, rather than to extract a tooth” became the paradigm for restorative dentistry. In this respect, the placement of implants became a concept to replace missing teeth rather than to replace teeth. The teeth experienced a renaissance in their significance and priority in the concept of total patient care and maintaining the dentition for a lifetime.

The periodontal aspects of abutment teeth and final restorations receive great attention when restoring a mutilated dentition. It was realized that oral diseases, with the exception of trauma and malignancies, represent opportunistic infections that have to be successfully treated before restorations can be incorporated. The principle of “never building a house on sand, but rather on a solid foundation” was introduced and consequently implemented in restorative dentistry. This, in turn, meant that periodontal and endodontic treatment had to be successfully completed prior to prosthetic rehabilitation.

At the same time, tremendous progress was made in developing dental materials that were able to mimic the natural dentition in terms of esthetics and function. These techniques require highly skilled laboratory technicians and profound knowledge of dental materials in order to be applied in clinical work.

It is evident that a modern textbook on restorative dentistry has to be based on the biologic principles discussed above. While a plethora of texts address single aspects of prosthetic restorations, there are only a few textbooks that present a comprehensive view on the entire field of oral rehabilitation. Moreover, only occasionally do we encounter a textbook with a clear biologic background. The present text is such an exceptionally rare documentation of a biologically based treatment philosophy. The numerous case documentations are testament to the feasibility of individually optimal restorations centering on the patient’s needs rather than on idealistic and hardly affordable concepts.

Irena Sailer, Vincent Fehmer, and Bjarni Pjetursson are a trio that has successfully established international recognition in the field of oral rehabilitation. They have worked together for over 10 years and are well known from their annual Icelandic Education Weeks. These have been very successful 1-week events with an international attendance of enthusiastic participants. Both Irena Sailer and Bjarni Pjetursson are clinically highly competent and skilled clinicians. They unite the fields of Periodontology and Restorative Dentistry in a unique way. Vincent Fehmer is a well-known master dental technician who completes the trio and contributes to the technical aspects of restorative dentistry. It is fortunate indeed that this trio has taken the time to provide the profession with such a unique textbook on all modern aspects of restorative dentistry.



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Prof Dr Irena Sailer received her Dr med dent degree from the University of Tübingen, Germany (1997/1998). She received an Assistant Professorship at the Clinic of Fixed and Removable Prosthodontics and Dental Material Sciences, Zurich, Switzerland (2003), where from 2010 she was an Associate Professor. In 2007, Prof Dr Sailer was a Visiting Scholar at the Department of iomaterials and Biomimetics, Dental College, New York University, NY, USA. Since 2009 she has held an Adjunct Associate Professorship at the Department of Preventive and Restorative Sciences, Robert Schattner Center, University of Pennsylvania, PA, USA (Head: Prof Dr MB Blatz).

Prof Dr Sailer is Head of the Division of Fixed Prosthodontics and Biomaterials at the University of Geneva, Switzerland. In 2019, she received an Honorary Skou Professorship at Aarhus University, Denmark. She is a Specialist for Prosthodontics (Swiss Society for Reconstructive Dentistry), and holds a Certificate of focused activities in Dental Implantology (WBA) of the Swiss Society for Dentistry. She is a member of the Board of Directors of the European Association of Osseointegration (EAO), Vice President of the European Academy of Esthetic Dentistry (EAED), member of the Swiss Society of Reconstructive Dentistry, the Education Committee of the International Team for Implantology (ITI), and the Greater New York Academy of Prosthodontics (GNYAP), and Editor-in-Chief of the International Journal of Prosthodontics. She is widely published and holds several patents on esthetic coatings of dental/medical devices, and on a digital dental splint.

MDT Vincent Fehmer

MDT Vincent Fehmer received his dental technical education and degree in Stuttgart, Germany, in 2002. From 2002 to 2003 he performed fellowships in the UK and the USA in Oral Design certified dental technical laboratories. From 2003 to 2009 he worked at an Oral Design certified laboratory in Berlin, Germany, at Zahntechnik Mehrhof. In 2009 he received his MDT qualification in Germany. From 2009 to 2014 he was the chief dental technician at the Clinic for Fixed and Removable Prosthodontics in Zurich, Switzerland. Since 2015 he has been dental technician at the Clinic for Fixed Prothodontics and Biomaterials in Geneva, Switzerland, and runs his own laboratory in Lausanne, Switzerland.

MDT Fehmer is a Fellow of the International Team for Implantology, an Active member of the European Academy of Esthetic Dentistry (EAED), and a member of the Oral Design group, the

European Association of Dental Technology (EADT), and German Society of Esthetic Dentistry (Deutsche Gesellschaft für Ästhetische Zahnheilkunde, DGÄZ). He is active as a speaker at a national and international Level. MDT Fehmer has received honors including the prize for the Best Master Program of the Year (Berlin, Germany). He has published numerous articles within the field of fixed prothodontics and digital dental technology. He also serves as reviewer for several international journals and is a section editor for the International Journal of Prosthodontics.

Prof Dr Bjarni E Pjetursson, DDS, MAS Perio, PhD

Prof Dr Bjarni Pjetursson received his DDS from the University of Iceland in 1990. From 1990 to 2000 he worked as a general dentist in his private clinic in Iceland. In 2000 he started his postgraduate training in Periodontology and Implant Dentistry at the University of Bern, Switzerland. He received his specialist certificate (EFP & SSP) and Masters of Advanced Studies in Periodontology and Doctorate in Dentistry from the Faculty of Medicine, University of Bern. From 2003 to 2005 he did his postgraduate training in Prosthodontics at the University of Bern. From 2005 he was Assistant Professor and Senior Lecturer at the Department of Periodontology and Fixed Prosthodontics, University of Bern, and from 2009 to 2014 the Dean of the Faculty of Odontology, University of Iceland.

Presently he is a Professor and Chairman of the Department of Reconstructive Dentistry, University of Iceland, and a Titular Professor at the Division of Fixed Prosthodontics and Biomaterials at the University of Geneva, Switzerland. Prof Dr Pjetursson is a board member of EAO, an ITI Fellow, Associate Editor of the International Journal of Prosthodontics, and member of the editorial board of Clinical Oral Implants Research. He has published extensively in and given over 700 lectures in 50 countries around the world. His research interests are clinical studies in implant dentistry and evidenced-based evaluation of different treatment modalities in implant and prosthetic dentistry.

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PART I
BASICS

CHAPTER 1

Current restorative materials

Jens Fischer

1.1.1 Introduction

In this chapter:

- Requirements for restorative materials
- Overview of current materials for fixed restorations
- Conclusions

In the past, material selection in fixed prosthodontics was mainly based on metal-ceramics and on a few all-ceramic alternatives. Metal-ceramic restorations were selected in clinical situations with need for high stability (eg, in the posterior region or in the case of multiple-unit fixed dental prostheses), whereas all-ceramic restorations were recommended in single tooth replacement with high esthetic demands, especially in the anterior region. These materials were traditionally processed by manual fabrication technologies such as casting, pressing, or layering[1,2]. Restorative dentistry with all-ceramic restorations has suffered from a prolonged learning curve. Several of the early systems disappeared shortly after being introduced due to an unacceptable number of mechanical failures[3].

Nowadays, clinicians and technicians can choose from a wide range of reliable materials. Digital technologies such as intraoral optical scans and computer-aided design/computer-aided manufacturing (CAD/CAM) procedures have opened up new treatment pathways in fixed prosthodontics. New digital fabrication workflows were defined and in parallel advanced materials were developed and adjusted to the specific requirements of numerically controlled processing such as high-strength ceramics and composites. In these digital workflows, the restorations are fabricated by means of computer-aided milling from prefabricated blanks, increasingly replacing conventional manual processing.

The different materials available today exhibit differences in properties, influencing the esthetics and the long-term performance of the restorations. As multiple alternatives exist for each clinical situation, it is more difficult to select the most appropriate material for the respective clinical situation today than in the past[4–6]. As a consequence of the transformation in present technology, selection of the restorative material requires understanding of the interaction between material properties and clinical performance[7].

After an introduction to the requirements for restorative materials and the behavior of the different material classes used in dentistry, this Chapter will provide an overview of the current material options for fixed restorations and their clinically relevant properties, indications, and limitations.

1.1.2 Requirements for restorative materials

In the oral cavity, restorative materials have to meet three requirements: *biocompatibility, longevity,* and *esthetics*.

Biocompatibility

The term biocompatibility implies that the material shall do no harm to the living tissues, achieved through chemical and biological inertness[8]. As every material potentially dilutes or degrades depending on the environment, the extent of decomposition, and the quality and amount of released substances determine the degree of biological complications. A possible host response might be localized or systemic toxicity, hypersensitivity, or genotoxicity[9]. The restriction to biocompatible components strongly limits the room for the development of new materials.

Due to the strict regulations for medical devices, manufacturers have to prove biocompatibility of their materials. International standards help the choosing of the appropriate tests and in interpreting the results. Tests must be done with every novel material prior to approval. Biological tests are employed in a sequence, ending up with animal tests[9]. Furthermore, manufacturers of medical devices are forced by law to perform a systematic post market surveillance of the materials and devices. Measures have to be taken to minimize risk and unexpected side effects must be notified to the authorities. Fortunately, it can be concluded that biological and immunological adverse reactions attributed to dental materials are rare and the reported adverse effects are acceptable[9].

On the other hand it is unrealistic to assume that absolute material inertness is attainable and biological behavior is definitely predictable by means of biological tests[10]. Hence, the biocompatibility of dental materials must always be weighed against their benefit[11]. Controlled clinical trials are currently still the best way to assess the clinical response to materials. But even these tests have significant limitations. Therefore, practice-based research networks and practitioner databases are increasingly considered as a valuable alternative[10].

Longevity

The long-term success of a restoration mainly depends on its mechanical performance. From the technical side the success of a restoration can be controlled by the durability of the *material*, the nature of the *design*, the quality of the *processing*, and the effectiveness of the *finishing*.

Material

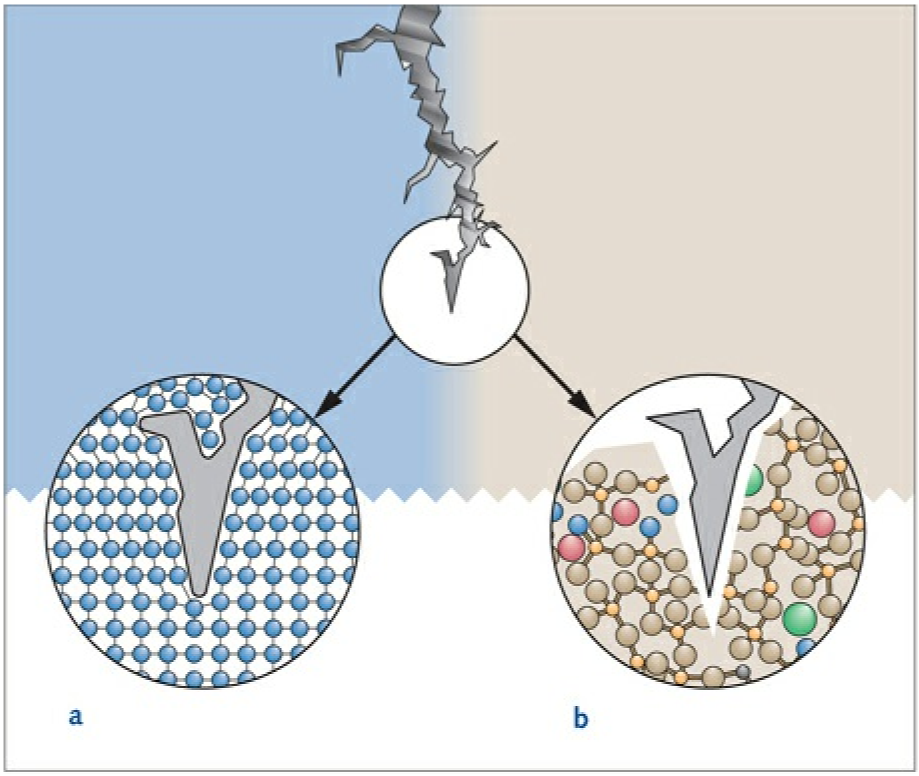
The mechanical behavior of dental materials is mainly characterized by elasticity, flexural strength, fracture toughness, and hardness. These properties are basically given by the type and strength of the bondings between the atoms.

Elasticity is the ability of the material to resume its initial shape after loading, measured in GPa (= 10^3 N/mm^2). Stressing a material beyond its limit of elasticity leads to plastic deformation, a permanent distortion. Brittle materials such as ceramics only show minimal or no plasticity, which means they fracture very soon after reaching the limit of elasticity. The stress where fracture occurs is the flexural strength, measured in MPa (= N/mm^2). The resistance against crack growth is called fracture toughness, measured in MPa√m.

Elasticity, flexural strength, and fracture toughness are bulk properties. Hardness in contrast is a surface property, which is defined as the resistance to localized deformation induced by mechanical indentation or abrasion. Harder materials therefore show less risk of surface damage. Flexural strength and hardness are correlated to a certain extent.

The main risk for mechanical failure of restorations are flaws at the surface, which might act as a starting point for microcracks. In case of tensile loading, a microcrack opens and stress develops at the tip of the crack. Stress which exceeds the strength of the material leads to crack propagation. Under cyclic loading − such as mastication − crack growth happens in a micrometer scale. But over time the crack grows significantly. Finally, catastrophic failure occurs when the residual cross-section is too small to withstand the load.

It is important to understand the fracture mechanisms of the different materials. In metals the crack tip is rounded out by plastic flow and thus the risk of fracture is significantly reduced (Fig 1-1-1). In ceramics plastic flow is not possible due to the covalent bonds. The crack tip remains sharp and crack growth is a significantly higher risk than in metals. That is the reason for the well-known brittle behavior of ceramics. To increase strength and in particular toughness, strengthening mechanisms on the microscopic level to impede crack propagation are employed. In brittle materials this might be achieved by internal compression or by particles, which act as obstacles against crack growth (Fig 1-1-2). The objective of such strengthening mechanisms is to stop crack growth or at least to hamper it, like a hurdler who is not as fast as a sprinter.



Figs 1-1-1 Schematic representation of crack propagation in materials. **(a)** Plastic material (eg, metals). **(b)** Brittle material (eg, ceramics).

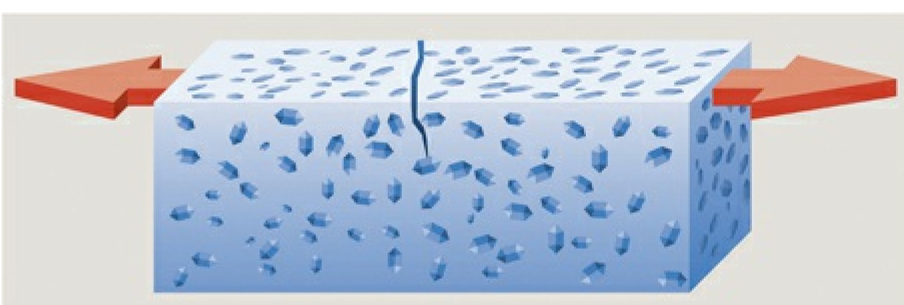


Fig 1-1-2 Schematic representation of crack propagation in particle-reinforced materials under tensile stress (red arrows). When the crack

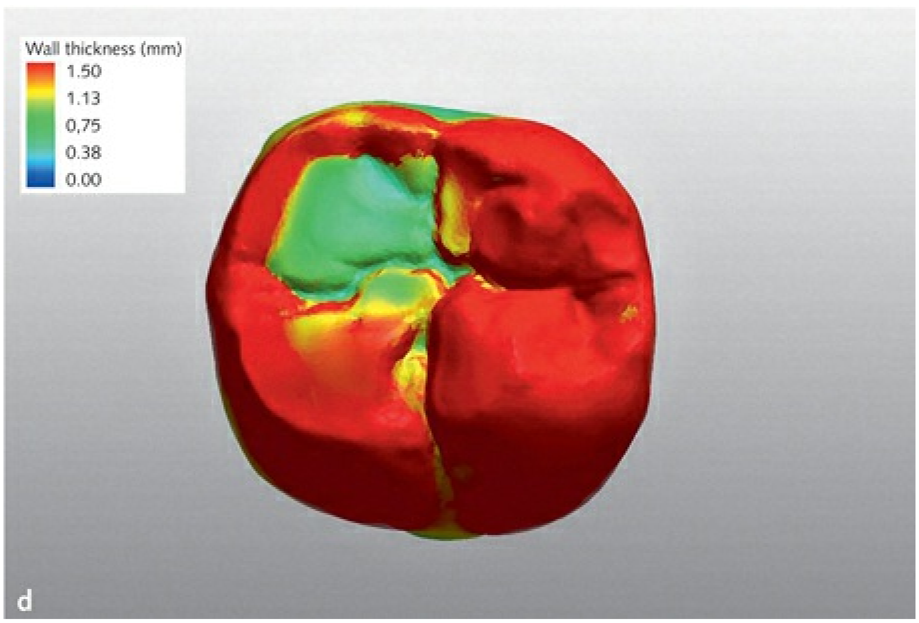
tip strikes a particle, crack propagation is impeded, or at least decelerated.

The term *durability* includes not only the mechanical characteristics specified above but resistance to wear and aging as well. The degradation of the materials by wear and aging depends on the mechanical properties and also on the susceptibility to the oral environment including humidity, temperature, and loading characteristics. Water for instance may attack the material's bonds especially at phase boundaries or microcracks, thus promoting degradation.

Design

Several mistakes can be made when designing a restoration. Insufficient dimensioning in crown walls or connectors of fixed dental prostheses is one reason for failures. Instructions of the manufacturers have to be strictly followed. Further, sharp edges increase the risk of failure due to an uncontrolled stress development (Fig 1-1-3). And finally, restorations made by materials, which require a thermal treatment should be designed with an even wall thickness as far as possible to get a homogeneous stress distribution during cooling. That applies especially for veneering ceramics, which must be layered in a uniform thickness and adequately supported by the framework both for metal-ceramic and all-ceramic bilayers.

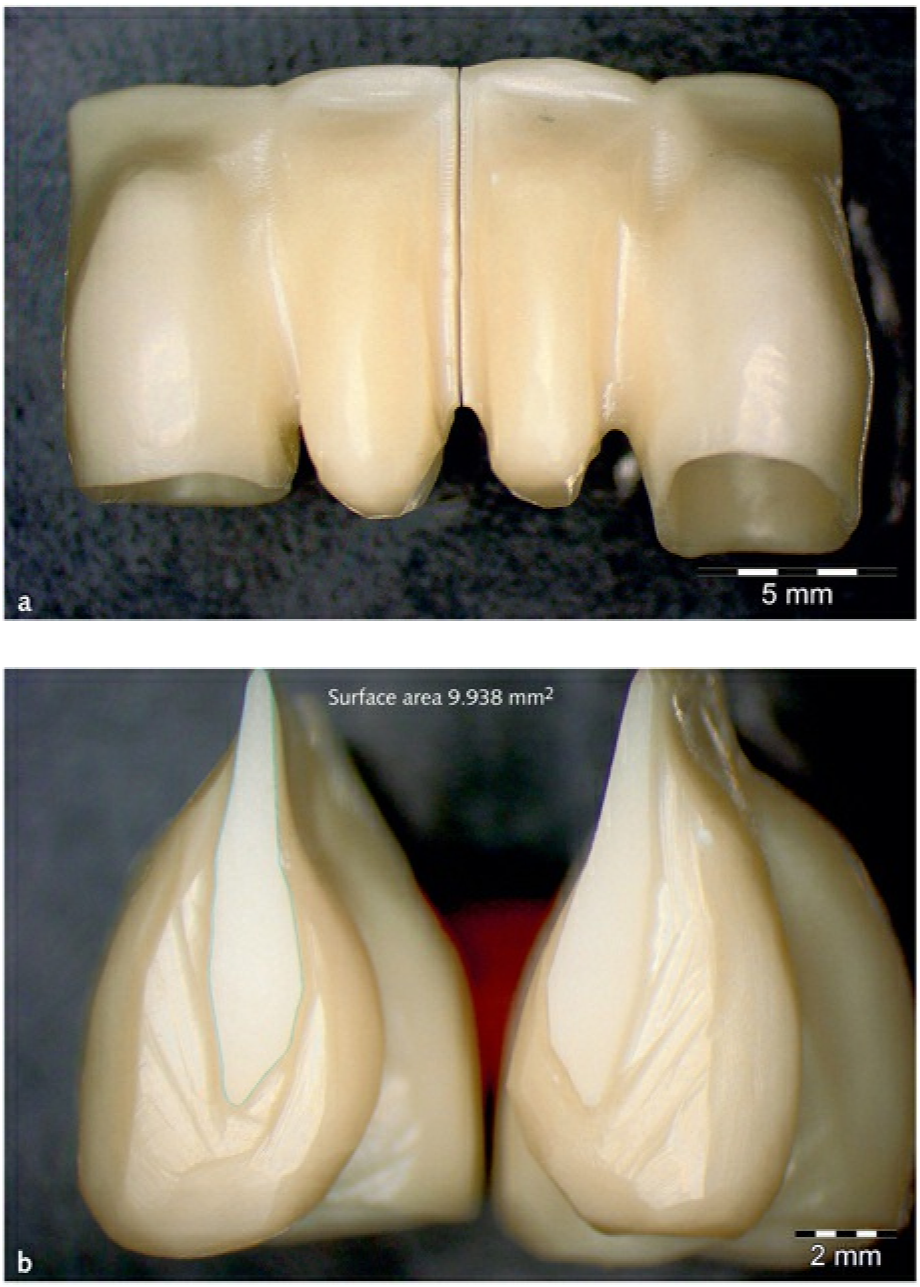

a
b

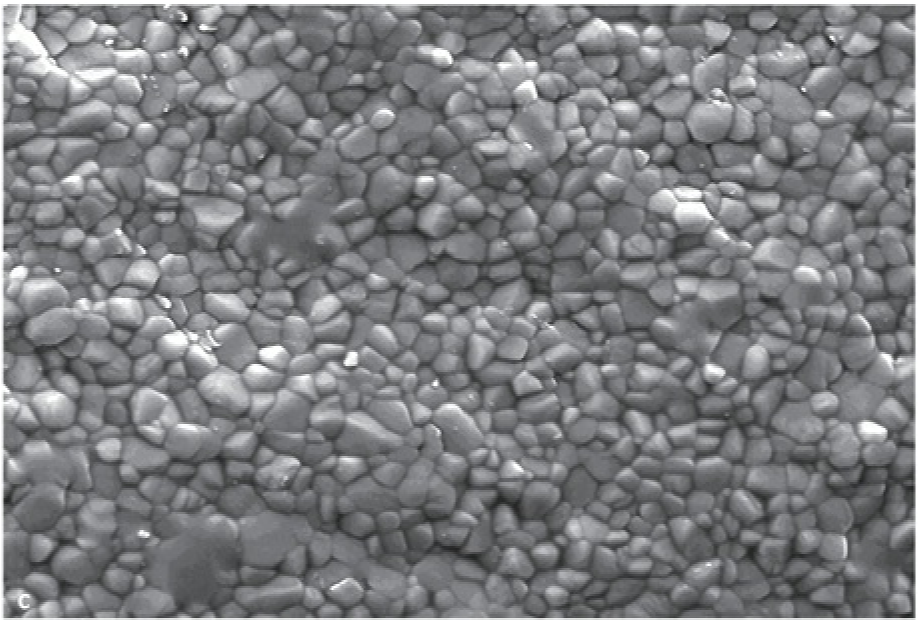


Figs 1-1-3a to 1-1-3d Insufficient thickness of the crown and sharp edges of the preparation caused fracture of the restoration. **(a)** Restoration on tooth 47 after cementation. **(b)** Radiograph after cementation. The insufficient occlusal thickness of the restoration and the sharp edge of the distal preparation are obvious. **(c)** Fracture of the restoration after 1 year in function. **(d)** Analysis of wall thickness on the basis of the CAD design.

Processing

A shaping process always requires machining, a thermal treatment such as sintering or pressing or a polymerization process. If not processed properly, defects might be created in the material, thus reducing the strength of the restoration (Fig 1-1-4). The manufacturer’s instructions must be meticulously followed.





Figs 1-1-4a to 1-1-4c Fractured zirconia framework 42 x x 32. **(a)** Framework after sintering, fracture occurred between 41 and 31. **(b)** Light microscopy image of the fractured area. The area was cut in the white state in order to separate the two pontics. Thus a crack was initiated, which was not sealed during sintering. **(c)** Scanning electron microscopy (SEM) of the fractured surface after sintering. The formation of grains at the surface indicates that the fracture occurred before sintering.

Finishing

Materials, if machined, sintered, pressed, or polymerized, must be finished with material specific tools and appropriate speed, feed, and pressure of the tools to avoid damage at the surface. For ceramics, as an alternative a glaze firing (a heat treatment without additional application of glaze) or glazing (a heat treatment with additional application of glaze) can be performed (Fig 1-1-5). However, if the restoration is not handled in a way appropriate to the material, it might occur that subsurface damage is not sufficiently eliminated by the finishing procedure and residual flaws potentially act as an origin for microcracks.