Matthias Kern

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Resin-Bonded Fixed Dental Prostheses

Minimally invasive – esthetic – reliable

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For our patients,
to whom minimally invasive RBFDPs
restore a high degree of quality of life

Preface

More than 25 years after our first description of all-ceramic resin-bonded fixed dental prostheses (RBFDPs), a former experimental method has turned into a very reliable treatment modality.

Excellent clinical data confirms their longevity. These RBFDPs were fabricated in 1990 from alumina ceramic for anterior single tooth replacement[2] using a two-retainer design. About 5 years later the single-retainer design for all-ceramic RBFDPs was introduced[3] and yielded even better success.

With caries-free abutment teeth and adequate indication, anterior tooth replacement with single-retainer metal- and all-ceramic RBFDPs provides a minimally invasive alternative to single implants or other conventional treatment methods. Why, however, do we only now have a book about this actually rather old dental treatment method?

In February 2016, it was decided by the responsible German federal agency that in Germany as of July 2016, single-retainer metal-ceramic RBFDPs might be used to replace missing incisors. This use is independent of the patient's age within the German social health insurance system[1]. Single-retainer all-ceramic RBFDPs can be applied as an equivalent treatment option, rendering the patient a cost subsidy to be paid by his or her insurance.

Thus, in Germany a great obstacle to the spread of this minimally invasive treatment option has been removed. Despite its simplicity and its multiple advantages, this treatment modality was never established widely in general dental practice. This book aims to promote this extremely reliable minimally invasive treatment option in order to establish the method in general dental practice. It attempts to remove the remaining skepticism in the dental community.

This book presents concisely and exactly what should be followed to be successful with single-retainer cantilever RBFDPs when replacing incisors. Although this method is technique sensitive, it is actually simple and extremely reliable when adequate clinical and laboratory protocols are followed. Indeed, minor (avoidable!) errors in the protocol are likely to result in a clinically failing RBFDP. As our surveys over the past years have revealed, in the dental community there is still great uncertainty over the use of adhesive technologies, in particular when it comes to the bonding of zirconia ceramic restorations[4]. Unfortunately, quite often unfavorable or even wrong methods are preferred. With such methods, bonded all-ceramic RBFDPs will not be able to function in the longer term.

This book shows how it works, and also depicts what must be avoided, when single-retainer metal- and all-ceramic RBFDPs are to be used successfully. The main focus is on the use of zirconia ceramics as a framework material that combines best stability and esthetics. This book is explicitly not a textbook that considers dental materials, or alternative bonding procedures, or treatment methods comprehensively. Instead, it shows in detail how single-retainer cantilever RBFDPs can be applied clinically successfully. It also shows in which (rare) cases a single-retainer design should not be used and how instead a splinting of two retainers or two-retainer fixed-to-fixed RBFDPs might be successfully used.

Any dentist who is willing to follow the cookbook-like instructions will be successful with this method. Deviations from the described methods do not have to result in failure, but can easily do so. A perspective is given on the successful replacement

of canines and premolars with single-retainer RBFDPs, although here long-term data are missing.

I wish all readers around the dental world and their future patients a lot of joy with the application of this reliable treatment method. I also appreciate any feedback regarding clinical problems or suggestions for a possible revised edition.

Matthias Kern
Kiel, Germany, 28 September, 2017

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Acknowledgment for the English edition

When it was decided to publish an English edition of this book, I was pondering whether I should translate it myself or whether a professional translation service should do it. Finally, I did the translation myself, despite the fact that I was taught in high school much more Latin and ancient Greek than English. My English improved only a little after starting to read international literature published in English when starting to work scientifically, being already 30 years old.

However, visiting the University of Maryland, School of Dentistry, Baltimore from 1991-1993 on the basis of a grant from the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) helped tremendously to improve my weak English language skills. Van P. Thompson, father of the well-known "Maryland Bridge" and Professor at Maryland at that time, was very patient with my English that improved only gradually – Van, thank you for your patience during these two years!

During the time in Maryland I also attended a conference with Raymond (Ray) Bertolotti from California who called himself a "Bondodontist". Over the past 25 years the contact and friendship with Van and Ray flourished. When I started with the English translation of the book Ray agreed to go through every single chapter helping to improve clarity and English wording. Ray, thank you so much for your great support during the weeks of translating the book!

After completion of the translation I also asked Van to have a glance at the book. Van's additional suggestions and hints were also very appreciated, thank you for that. The third individual who had a significant influence on this book was Michael (Mike) Botelho, whose long-term experience with single-retainer metal-ceramic RBFDPs I followed over the past two decades and who also gave me significant advice. Mike, thanks for that!

Markus B. Blatz, a native German, now at the University of Pennsylvania, helped with the translation of some specific German words into English, as well as some other colleagues I ask from time to time for advice. Thank you all very much!

Special thanks again to my partner Karin Pohley, who helped a lot with correcting the manuscript and the proofs again before sending it to the publisher. In addition, many thanks to Natalie Ward (London) and Anita Hattenbach (Berlin), both editors at Quintessence Publishing Company, Avril du Plessis (London) for proofreading, and the staff of the publisher, who have again produced a book of high quality.

Acknowledgment for the German edition

I would like to take this opportunity to say thank you very much to my patients, who, by their readiness to be photographed, have made this book possible. Everyone who takes patient photographs knows that, especially intraoral photographs that require the aid of lip retractors and mirrors, are not exactly pleasant for the patient.

I would also like to thank the staff and colleagues who supported me in the treatment or provided me with photographs for this book. In particular, the dentists and dental technicians in my department, in particular Reinhard Busch, Raphael Gerhard, and Britta Schlüter, and in commercial laboratories, especially Jürgen Feddern, Rainer Gläser, Stefan Horn, Tomonari Okawa, and Wolf Woerner. Thanks and appreciation for their excellent work. I would like to thank my orthodontic colleagues for their cooperation in the pretreatment of many patients. And also to Bärbel Kahl-Nieke, from the University of Hamburg – thank you for your orthodontic advice regarding some interdisciplinary text passages.

I would like to thank Frank Lehmann for the preparation and scanning of some scanning electron micrographs and the elimination of computer-type obstacles over many years. Many thanks also to Detlef Gostomsky, who has been producing video films for many years with great dedication, from which individual screenshots have now been taken for the step-by-step presentation of treatment. He has lovingly edited the artwork.

I would like to thank my secretary, Susanne Riemer, for her many years of support and her great commitment to the discovery and recruitment of missing patients, without which some long-term documentation available in this book would not have been possible.

My former senior lecturer, Stephanie Eschbach, and my sister, Irene Kern-Krüger, thank you for the quick, yet very thorough, proofreading of the German book manuscript. A very special thanks to my partner Karin Pohley, who has not only read the manuscript proof, but has also given me great support during the writing phase. Her judgment as dental layperson was often very helpful to me.

To Anita Hattenbach, editor at Quintessence Publishing Company in Berlin, thanks for your dedication and thorough editing of the German book manuscript. Your professional input has been very helpful to me. I was very enthusiastic about the professional and speedy implementation of the book project. Last but not least, I would like to thank Quintessence Publishing Company's Publishing Director, Johannes Wolters, for his motivation to tackle the book project in the short term, and Quintessence Publisher, Horst-Wolfgang Haase, whose support has contributed to a record-breaking production time of the book. As a result, this book has an actuality that is not often found.

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Scientific interests: Adhesive prosthodontics, all-ceramic restorations, dental implantology, and dental materials.

Contents

Chapter 1

Why RBFDPs evolved to a single-retainer design

Buonocuore's[20] development of the acid-etch technique for enamel 60 years ago provided the basis to achieve high and durable enamel bonding using dental resins (Fig 1-1). In the 1970s, artificial teeth were initially bonded with composite resin to adjacent abutment teeth for anterior tooth replacement[37] using the acid-etch technique. However, the longevity of these purely resin-based restorations was rather limited.

Today, extracted natural or artificial teeth can still be adhesively bonded in the same way to serve as long-term provisional restorations, e.g. when inflamed tissues in the alveolar ridge need time to heal prior to the fabrication of the final prostheses. It requires no great effort to shorten an extracted tooth by cutting off its root and to bond it back adhesively. However, after removing the root the remaining crown should be sealed on its cervical end using a dentin adhesive, and by using a tooth-colored composite resin, an ovate pontic basis is formed. The ovate pontic should reach 2 to 3 mm into the extraction socket and support the marginal gingiva circumferentially (immediate pontic technique, compare with Fig 5-11). In this way, the blood coagulum in the extraction socket is also protected. In the presented case (Figs 1-2 to 1-9), the resin bonding of the extracted and shortened tooth was reinforced using

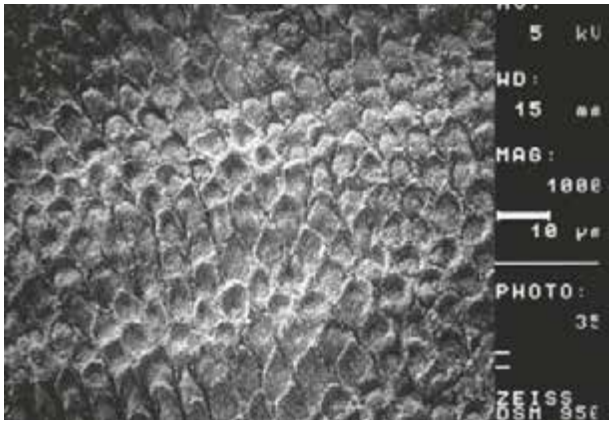

Fig 1-1 Enamel etching pattern after etching with phosphoric acid (scanning electron microscopic photo at 1000× original magnification).

Fig 1-2 Labial view of the hopeless tooth 32 (situation after repeated unsuccessful apicoectomies done elsewhere).

Fig 1-3 Fabrication of an incisal-positioning splint prior to extraction of tooth 32.

Fig 1-4 Situation after extraction of tooth 32. Care was taken to ensure complete filling of the extraction socket with blood.

Fig 1-5 Basal view of the removed tooth revealing an untreated lingual root canal, and a crack in the labial canal wall.

Fig 1-6 Reshaping the root portion with adhesive techniques and composite resin into an ovate pontic shape.

Fig 1-7 Occlusal view of tooth 32 that was adhesively fixed with composite resin reinforced with a lingual fiber net under rubber dam isolation.

Fig 1-8 Labial view of tooth 32 after complete healing.

a polyethylene fiber net (Ribbond). Figure 1-9 presents the restoration after 14 years of clinical service. This case is an example of the excellent durability of bonding to enamel. Mostly, such long-term provisional restorations will fail after several years of clinical service due to a fracture of the elastic fiber-reinforced resin bonding. However, at this stage the hard and soft tissues have healed, so that either a final resin-bonded fixed dental prosthesis or a single tooth implant can be used for the final prosthetic restoration.

These composite resin fixed teeth did not provide good long-term results on a regular basis. To

Fig 1-9 Status 14 years after reinsertion of the extracted reshaped tooth [Source: CDT Matthias Hasselberg, Eckernförde, Germany].

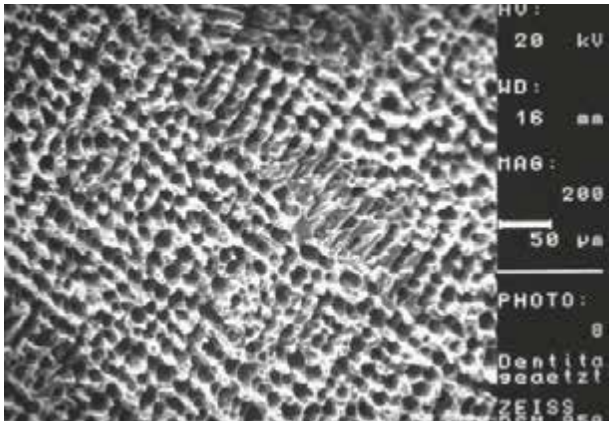

Fig 1-10 Etching pattern of a cobalt-chromium alloy after electrolytic etching (scanning electron microscopic photo at 200× original magnification).

Fig 1-11 Two-retainer metal-ceramic RBFDP replacing tooth 12.

Fig 1-12 Metal-ceramic RBFDP from the lingual view.

Fig 1-13 Status 10 years after insertion from the lingual view...

Fig 1-14 ...and from the labial view. The slightly grayish shine-through of the metal retainer wing is clearly recognizable, especially in comparison to the non-restored left side.

improve longevity, Rochette[80] suggested using metal-based resin-bonded fixed dental prostheses (RBFDPs) with two retainer wings for anterior tooth replacement. Macromechanical retention for the metal retainer wings was provided by means of tapered pinholes into which the luting cement would flow, acting as a resin rivet to secure the RBFDP to acid-etched enamel. Howe and Denehy[35] and, in particular, Livaditis and Thompson[65], from the University of Maryland, Baltimore, USA, advanced the use of metal-based RBFDPs, resulting in the well-known name Maryland Bridge. A significant advancement indicated the use of the

Fig 1-15 Unilaterally debonded two-retainer metal-ceramic RBFDP, replacing tooth 21.

Fig 1-16 Clearly visible caries at the debonded abutment tooth 11 after removal of the RBFDP.

Fig 1-17 Metal-ceramic RBFDP replacing teeth 31 and 41 with four splinted metal retainer wings. Retainer wings on teeth 32 and 42 are debonded.

Fig 1-18 After removal of the RBFDP without retentive tooth preparation, massive caries is recognizable under the debonded retainer wings. Splinting of multiple retainers should be avoided. Principle: Less is more!

electrolytic etching technique for non-precious metal alloys (Fig 1-10), which provided micromechanical retention of the retainer wings for composite resin luting agents, making macromechanical retention holes unnecessary. The introduction of mechano-chemical bonding systems, especially silica coating with subsequent silane application, and the development of modified luting resins containing adhesive phosphate monomers in the mid-1980s, resulted in significant improvements to resin-metal bonding. These advances significantly improved the long-term prognosis of metal-ceramic RBFDPs (Figs 1-11 to 1-14).

One of the most frequent and dreaded complications with two-retainer RBFDPs with a metal framework was the unilateral debonding of one retainer wing, which was often not noticed by the patient, or even ignored.

Such unilateral debondings in multiple-retainer RBFDPs almost inevitably resulted in caries (Figs 1-15 to 1-18). Among the causes for these unilateral debondings of metal-based RBFDPs were errors regarding indication, clinical procedures, and bonding methods. However, unilateral debondings also occurred when everything had been done correctly. In part, this can be explained

Fig 1-19 Two-retainer metal-ceramic RBFDP replacing tooth 13.

Fig 1-20 During laterotrusion and protrusion, differential tooth movements (excursions) occur.

Fig 1-21 Unilaterally debonded retainer on abutment tooth 12 prior to removal of the RBFDP.

Fig 1-22 Clearly visible caries in the area of the lingual tubercle of tooth 12.

by the fact that metal retainer wings with their relatively high flexibility in thin cross-section can bend during loading. This bending results in high peeling forces in the marginal area of the retainer wings, causing a progressing debonding that starts at the retainer margins. When the pontic or the abutment teeth are functionally loaded, minimal and differential tooth movements will always occur. For example, when replacing a missing maxillary lateral incisor or canine with a classic two-retainer RBFDP, the incisors will be deflected anteriorly during protrusion, while during lateral excursion the canine will be deflected laterally. Without retentive abutment tooth preparation, unilateral debonding of one retainer wing could be predicted with some certainty (Figs 1-19 to 1-27).

Since the mid-1990s it has been recommended to routinely attach RBFDPs unilaterally. The single-retainer wing reduces peeling and shear forces resulting from the differential loading forces, preventing the dreaded complications caused by unilateral debondings experienced with two-retainer RBFDPs[16,36]. In the meantime, the concept of metal-based single-retainer RBFDPs with

Fig 1-23 Two-retainer metal-ceramic RBFDP replacing tooth 12 with unilaterally debonded retainer wing on tooth 13 from the lingual view...

Fig 1-24 ...and from the incisal view: Without applying any force the probe penetrates into the gap between the debonded retainer wing and its abutment tooth.

Fig 1-25 The debonded retainer wing is cut off using a carbide burr...

Fig 1-26 ...and removed.

superior longevity compared with multiple-retainer RBFDPs was confirmed by various clinical studies[14,15,27,59,83,102]. Therefore, in the case of a unilateral debonding of a two-retainer RBFDP, one should not try to debond (disconnect) the still attached retainer; instead the debonded retainer wing should be cut off. Then, the previous bonding area in enamel can be polished or coated (sealed) with composite resin (Figs 1-23 to 1-27). In this way, risky previous two-retainer RBFDPs can be transformed into the prognostic, safer, single-retainer RBFDP version. Even when the abutment tooth

Fig 1-27 Lingual remnants of composite resin were polished. The prognosis of the now single-retainer cantilever RBFDP is better than the former two-retainer version.

Fig 1-28 Two-retainer metal-ceramic RBFDP replacing tooth 12 with unilaterally debonded retainer wing on tooth 11 from the lingual view...

Fig 1-29 ...and from the labial view. Abutment tooth 11 has moved (migrated) toward the labial, and the metal RBFDP framework is clearly visible in the proximal area distal of tooth 11.

Fig 1-30 After removal of the debonded retainer wing the resulting caries is clearly recognizable.

Fig 1-31 Status after caries removal and adhesive sealing of the lingual bonding surface. Due to the migration of tooth 11, the proximal contact has been lost.

under the debonded retainer wing has already migrated minimally, a two-retainer RBFDP can normally be saved through transformation into a single-retainer RBFDP. Such abutment tooth migration might occur when a debonding of a retainer is ignored for a longer time or when an unsuitable attempt is made to rebond a debonded retainer wing without previous removal of the unilaterally debonded RBFDP (Figs 1-28 to 1-35). After cutting off the debonded retainer wing, the migrated abutment tooth could be easily moved into its initial position using orthodontic splints.

At the beginning of the 1990s, the author first described the successful use of all-ceramic RBFDPs without a metal framework[41]. By that time, these all-ceramic RBFDPs were fabricated from the first dental ceramic that provided a flexural strength considerably above 400 MPa (glass-infiltrated alumina

Fig 1-32 Labial view of the now single-retainer RBFDP, with missing proximal contact.

Fig 1-33 Caused by the migration of tooth 11, it stands out of the dental arch (misaligned) and is not occluding.

Fig 1-34 Using thermoformed orthodontic splints, tooth 11 was aligned orthodontically...

Fig 1-35 ...and so the proximal contact was also re-established. Again, also in this case, the prognosis of the now single-retainer cantilever RBFDP is better than that of the former two-retainer version.

ceramic; In-Ceram alumina). The two-retainer design of the first all-ceramic followed the design of metal-ceramic RBFDPs, but omitted the retention grooves necessary for metal retainers (Figs 1-36 to 1-41). Due to the rigidity of all-ceramic materials, retention or stiffening grooves were considered unnecessary. The subsequent excellent clinical results regarding the bonding capacity of all-ceramic retainer wings confirm this assumption, as failures were always caused by ceramic fractures (Figs 1-42 to 1-44), but never by debonding of the retainer wings[55].

However, quite commonly two-retainer RBFDPs fabricated from alumina ceramic showed unilateral framework fractures at the connector between the retainer wing and the pontic[55]. Surprisingly, the majority of unilaterally fractured two-retainer RBFDPs remained successfully *in situ* over a longer time than single-retainer RBFDPs.

Fig 1-36 A 16-year-old male patient with congenitally missing maxillary lateral incisors.

Fig 1-37 Two-retainer all-ceramic RBFDPs fabricated from veneered alumina ceramic (In-Ceram).

Fig 1-38 Abutment teeth isolated with rubber dam.

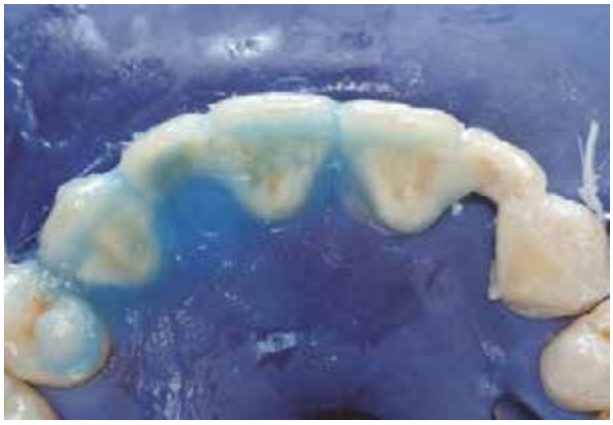

Fig 1-39 Adhesive luting of both all-ceramic RBFDPs, using a phosphate monomer containing composite resin (Panavia TC).

Fig 1-40 The two inserted all-ceramic RBFDPs replacing the maxillary lateral incisors from the occlusal view...

Fig 1-41 ...and from the labial view.

Fig 1-42 Fracture of the incisal edge of abutment tooth 11 due to a traumatic incident...

Fig 1-43 ...with a simultaneous framework fracture of the smaller distal connector to the pontic at tooth 13. Obviously, the resin bond was stronger than the fracture strength of the ceramic material.

Fig 1-44 The unilaterally fractured RBFDP functioned clinically for many years. Several similar cases encouraged the author to generally omit the second retainer wing since 1996.

Therefore, it might be considered a result obtained accidentally that single-retainer all-ceramic RBFDPs were created through unilateral fractures caused by interabutment fatigue stresses and that they provided excellent clinical longevity. These unilateral framework fractures can be explained by the same loading conditions that cause the frequent unilateral debondings of two-retainer metal-ceramic RBFDPs due to occurring peel and shear forces.

While in metal retainer wings minimal twisting and bending is unavoidable, ceramic retainer wings are more torsion-resistant. So peeling forces that might have caused debonding of the ceramic retainer wings obviously did not occur. Therefore, with the medium strength and stiffness of glass-infiltrated alumina ceramic (from a current point of view), overloading never caused debonding of two-retainer RBFDPs, but only unilateral framework fractures in the area of the smaller proximal connector.

Since for years unilaterally fractured all-ceramic RBFDPs fulfilled their clinical function as cantilever restorations[49], sense and a need for the second retainer wing have been rightly questioned – as we know today[47,48]. Hence, since 1996, single-retainer

Fig 1-45 A 15-year-old female patient with unilaterally congenitally missing maxillary right lateral incisor.

cantilever RBFDPs have been almost exclusively provided by the author when replacing anterior teeth (Figs 1-45 to 1-58). Advantages of the single-retainer design are a hard tissue-preserving tooth preparation, a more rational fabrication technique, and the immediate realization of retention loss[12]. In addition, the single-retainer design simplifies oral hygiene, as dental floss can be introduced at the open proximal contact area. Also, in cases of edentulous spaces that are too wide for anatomically well-proportioned pontics, it is possible to create a diastema, if esthetically desired. Only occasionally, and in special situations, are two-retainer RBFDPs considered still appropriate. The splinting of the adjacent retainers of two cantilever RBFDPs quite often makes sense. The indications for these centrically splinted cantilever RBFDPs and the special indications for two-retainer RBFDPs with a conventional fixed-fixed retainer design are described in Chapter 11.

Densely sintered zirconia ceramics with about twice as high a flexural strength and nearly as high an elastic modulus as alumina ceramics have been available in dentistry since the early 2000s

Fig 1-46 An extraoral view of the patient.

Fig 1-47 Missing tooth 12 from the labial view...

Fig 1-48 ...and from the occlusal view.

Fig 1-49 Cast view of the abutment tooth preparation of tooth 11, containing a minimal lingual veneer preparation, a central lingual pinhole, and a flat proximal box.

Fig 1-50 Single-retainer all-ceramic RBFDP fabricated from veneered alumina ceramic (In-Ceram).

Fig 1-51 The inserted all-ceramic RBFDP from the labial view...

Fig 1-52 ...and from the occlusal view.

Fig 1-53 Detailed view of the retainer wing from the lingual view. The occlusal contact is located on the sound enamel above the retainer wing.

Fig 1-54 The single-retainer all-ceramic RBFDP in occlusion.

Fig 1-55 Extraoral view shortly after insertion.

(Figs 1-59 and 1-60). Overloading of zirconia ceramic RBFDPs, e.g. due to traumatic incidences, usually did not result in ceramic fractures, but only in debonding of the retainer wing[86,88]. However, this can be considered a simple clinical complication that can be easily remedied by rebonding the debonded restoration. While single-retainer all-ceramic RBFDPs can be considered an established standard therapy for replacing incisors, the application of all-ceramic RBFDPs for the replacement of canines and posterior teeth is still under clinical evaluation, especially as single-retainer RBFDPs for the replacement of canines and premolars, and as modified inlay-retained FDPs for molar replacement[22].

The concept of the single-retainer all-ceramic RBFDP with its superior longevity has not only been confirmed for zirconia ceramic[61,82,86,88], but also for lithium disilicate ceramic at least in the medium term[81,97]. However, it should be considered that lithium disilicate ceramic exhibits a flexural strength similar to that of glass-infiltrated alumina ceramic, which showed framework fractures when overloading occurred[55]. Therefore, it must be expected that in cases of high stress, RBFDPs made from lithium disilicate ceramic will more likely fracture than debond.

Fig 1-56 The happy patient.

Fig 1-57 The patient 18 years after insertion. The ceramic veneering of the pontic appears considerably brighter than the natural teeth.

Fig 1-58 Extraoral view after bleaching of the natural teeth [Source: Katrin Simons, Cologne, Germany].

Fig 1-59 Single-retainer all-ceramic RBFDP fabricated from veneered zirconia ceramic, replacing tooth 22 from the occlusal view.

Fig 1-60 Zirconia ceramic RBFDP from the labial view.

Within the German social health insurance system since 2005, two-retainer metal-ceramic RBFDPs with a fixed-fixed design were declared the standard of care when replacing incisors in patients between the ages of 14 and 20. Since 2006, patients over the age of 20 could also receive a cost subsidy for two-retainer metal-ceramic RBFDPs when the indication for RBFDPs is given[31]. Despite the superior longevity of single-retainer cantilever RBFDPs (compared with that of two-retainer RBFDPs), their clinical application was not approved by the German social health insurance system for many years, meaning patients did not receive any cost subsidy.

Only after the German Society for Prosthetic Dentistry and Biomaterials (DGPro) had provided several scientific reports on the single-retainer RBFDP therapy were dental guidelines for the German social health insurance modified on 1 July 2016. In this amendment, single-retainer cantilever metal-ceramic RBFDPs, as well as the traditional two-retainer metal-ceramic RBFDPs, can now be provided to patients without age restrictions for the replacement of incisors[17]. However, the replacement of two adjacent missing incisors with metal-ceramic RBFDPs is approved as the standard of care only for patients between 14 and 20. A scientific rationale for the age restriction is not available. However, older patients might be eligible to receive a cost subsidy from social health insurance when two adjacent incisors are replaced with RBFDPs.

Unfortunately, two-retainer metal-ceramic RBFDPs with the fixed-fixed design remain an equivalent treatment option to replace single incisors within the German social health insurance system. From a scientific point of view, and in aiming to provide the best evidence-based dental care, this must be regretted. So, probably two-retainer metal-ceramic RBFDPs will often be applied unnecessarily, despite the increased risks for these patients.

However, it might be considered beneficial from the perspective of the patients and their dentists that, regardless of the patient's age, single-retainer cantilever and two-retainer fixed-fixed all-ceramic RBFDPs are now approved as an equivalent treatment modality to metal-ceramic RBFDPs, so patients receive a cost subsidy from social health insurance when choosing all-ceramic RBFDPs[17].

Chapter 6

When RBFDPs should bond long term

For long-term durable bonding of metal-ceramic or all-ceramic RBFDPs (fabricated either from non-precious metals or zirconia ceramic), all bonding substrates, i.e. enamel, cobalt-chromium (CoCr) alloy or zirconia ceramic, must be conditioned adequately and bonded using a suitable adhesive system. Any contamination of the conditioned bonding surfaces must be strictly prevented. Under these conditions, single-retainer RBFDPs can be considered an extremely reliable treatment modality.

How to bond durably to enamel

A clinically adequate bond strength to enamel requires a sufficient enamel quality and a bonding surface of about 30 mm^2 (0.0465 $inch^2$). Luting RBFDPs to teeth with major bonding areas in exposed dentin is not indicated because the bond strength to dentin is not only significantly lower, but is also not durable long term[18,21,29,100]. Prior to bonding, the prepared enamel surface must be cleaned thoroughly with cleaning paste, e.g. pumice, or prophylaxis spray, e.g. Prophyflex 3. Then, 33 to 40% phosphoric acid gel is applied. A higher or lower concentration will achieve poorer results[24,66].

The etching time should be about 30 s[6,33]. Longer etching times bear no advantages, but merely lead to a further loss of substance (Figs 6-1 to 6-5).

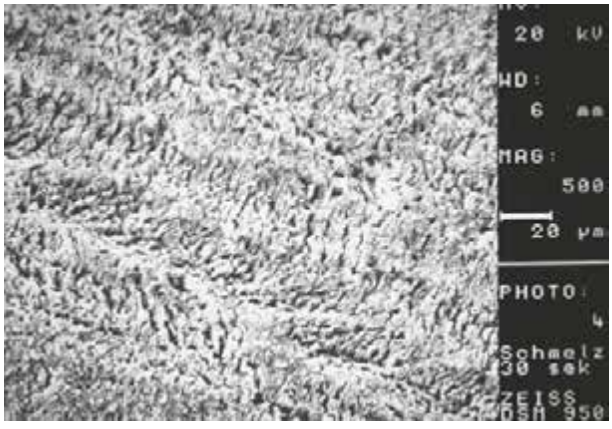

Fig 6-1 Etching pattern after phosphoric acid etching for 30 s (SEM image at 500× original magnification). Differently etched areas can be seen.

Enamel etching increases the surface area and increases its reactivity and wettability (Figs 6-6 to 6-8). Particularly important is the subsequent washing time with water spray. At least 15 s is recommended in order to completely remove the precipitates created by the etching procedure[2]. On unprepared enamel surfaces, a reduced etching pattern often occurs due to the presence of fluoride-rich and aprismatic superficial enamel. For this reason, this superficial layer is removed by gently grinding the complete prospective bonding surface of the retainer wing during the adhesive preparation (see retainer wing preparation in Chapters 9 and 10).

After thorough removal of the phosphoric acid with water spray, the enamel should be thoroughly dried. The frosty-white appearance of the etched enamel provides a good clinical indication that the etching procedure has been correctly completed (Fig 6-8). Contamination of the conditioned highly reactive enamel by moisture, saliva, and/or blood must be absolutely prevented.

This can best be achieved using optimal isolation by applying the rubber dam before cleaning the prepared enamel surface. Should contamination occur, a brief re-etching for 5 s, followed by thorough washing and drying, will reestablish adequate bonding conditions. In the case of adequate clinical procedures, high bond strengths to composite resins and adhesives of about 30 N/mm^2 are obtained that are within the range of the intrinsic strength of enamel and are durable long term[43]. The clinical cases presented in this book with up to 25 years of long-term durable bonding between the enamel and the ceramic retainer wings demonstrate the long-term durability of the bond strength to both substrates. It proves clinical bonding durability despite non-retentive abutment tooth preparations.

The sole use of self-etching primers or adhesives without phosphoric acid etching is not suitable to achieve a sufficiently high bond strength to enamel[28]. Only for temporary luting of provisional RBFDPs, e.g. in the context of fabricating implant-retained prosthetic restorations, might self-etching adhesive systems be used.

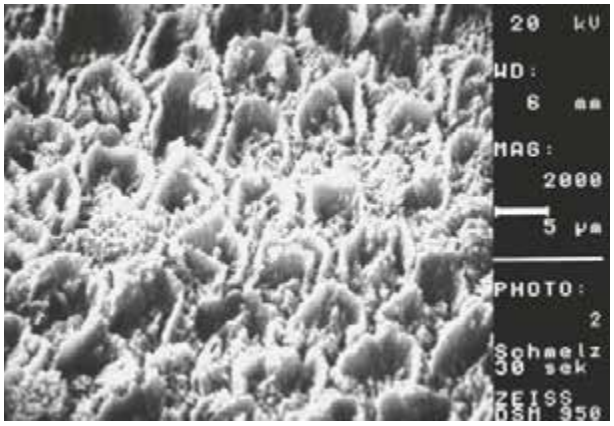

Fig 6-2 At a higher original magnification, a pronounced central etching pattern (SEM image at 2000× original magnification) can be detected in an area after 30 s of etching and...

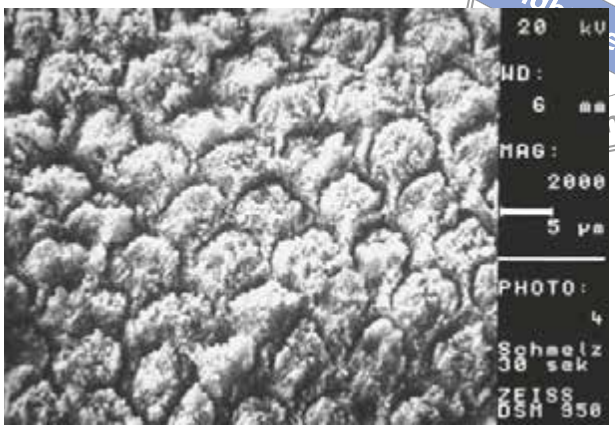

Fig 6-3 ...a similarly embossed external etching pattern (SEM image at 2000× original magnification) in another area on the same enamel surface. Both etching patterns provide high bond strengths.

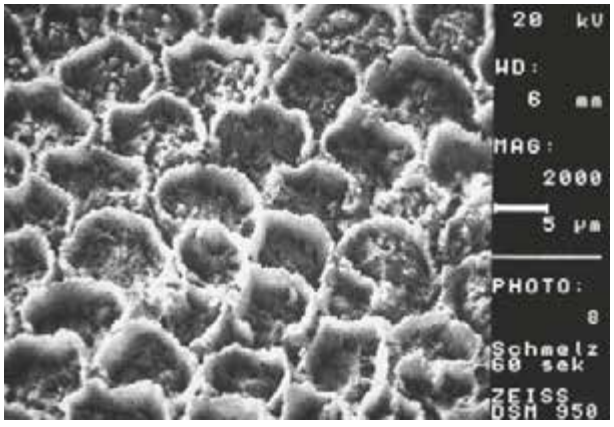

Fig 6-4 With a longer etching time of 60 s, both the internal etching pattern (SEM image at 2000× original magnification) and...

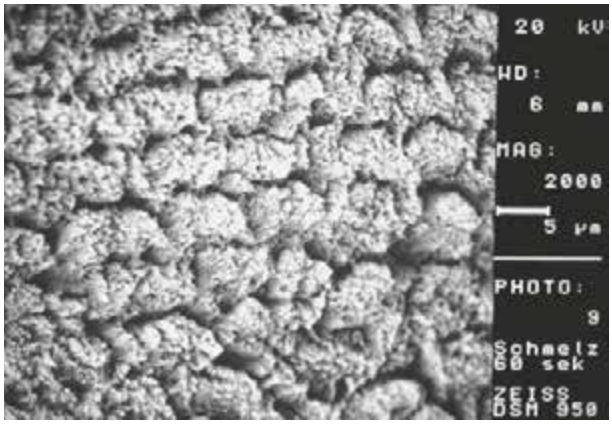

Fig 6-5 ...the external etching pattern (SEM image at 2000× original magnification) are more pronounced. However, that does not increase the bond strength.

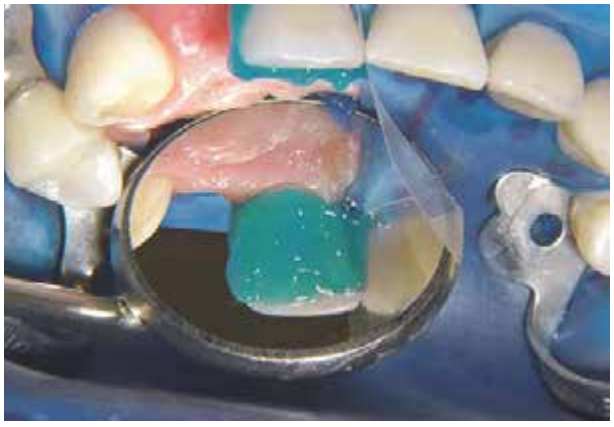

Fig 6-6 Etching of the enamel with 37% phosphoric acid gel. The adjacent tooth is protected from the acid by a plastic matrix.

Fig 6-7 Thorough removal of the acid gel by water spraying is essential so that no gel residuals remain in the etching pattern.

Fig 6-8 The frosty-white areas of the dried enamel are an indicator of an adequately etched surface.

How to bond durably to non-precious metals

Due to their good biocompatibility and good mechanical properties, cobalt-chromium (CoCr) alloys are the first choice when single-retainer metal-ceramic RBFDPs are to be used. Nickel-chromium (NiCr) alloys are considered second choice due to the high rate of patients allergic to nickel. Compared to precious metal alloys, base alloys have significantly higher bond strengths and, because of their high modulus of elasticity, are stiffer, which enhances retention. In the case of an allergy to CoCr or NiCr alloy components, titanium or titanium alloys can be used, whereby the framework stiffness is reduced, so that a slightly thicker framework is then required.

For durable bonding to CoCr, NiCr or titanium alloys, only mechanochemical methods can be recommended today. In these, micromechanical retention and chemical bonding by means of adhesive monomers act synergistically and lead to bond strengths that exceed those achieved to enamel. However, in view of the variety of metal conditioning methods and adhesive systems, this chapter does not present an overview of the available methods, but describes only a principally outstanding method. This method has proven to be excellent both in laboratory investigations[45,46,77] and in the clinic of the author, as well as in the world's longest clinical study on single-retainer metal-ceramic RBFDPs, with an observation period of over 15 years[14].

Using this well-proven method, in a first step the metal bonding surface is air abraded with 50 µm alumina particles (Al_2O_3 = corundum) at 2.5 bar (0.25 MPa) pressure. This corundum blasting, which is falsely often referred to as sandblasting although it is not blasted with sand, has several functions like the enamel etching with phosphoric acid. The alumina particle air abrasion results in a cleaning, roughening, surface enlargement and chemical activation of the metal surface. These are prerequisites for good wettability of the bonding surface and the direct chemical bonding of active monomers to the metal (Figs 6-9 and 6-10). Therefore, the air abraded surfaces should be bonded without delay, i.e. within a few minutes, otherwise contaminants always present in the air will increasingly stick to the conditioned surfaces and inactivate them. Of course, the alumina particle air abraded surfaces must also not be contaminated directly, e.g. by touching with the fingers or by placing the conditioned RBFDP unprotected in areas close to the dental treatment unit, where aerosol always develops during acid etching of enamel.

The alumina particle air abrasion of the inner bonding surfaces of the retainer wings can be carried out either in the dental laboratory or, preferably, after the fitting of the RBFDP, directly chairside by the clinician with an intraoral applicable air abrasion device (e.g. MicroEtcher CD) used in a dust containment system (e.g. MicroCab+) (Figs 6-11 to 6-13). During alumina particle air abrasion, the veneering consisting of silicate ceramic must be protected from the abrasive blasting medium. This can be done easily by covering the veneering ceramic with a thin layer of autopolymerizing resin (e.g. Pattern Resin) that is formed in a half-shell on the veneering (Fig 6-14)[54]. The uniform matting of the metal surface by the air abrasion with alumina particles shows the effectiveness of the conditioning step and also serves at the same time as quality control (Fig 6-15). If there is no matting, blasting pressure and/or powder quantity are too low.

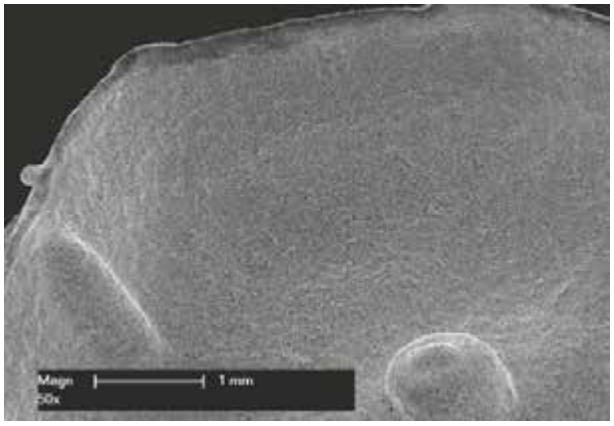

Fig 6-9 Microretentive surface of a CoCr retainer wing after air abrasion with 50 µm alumina particles at 2.5 bar pressure (SEM image at 50× original magnification).

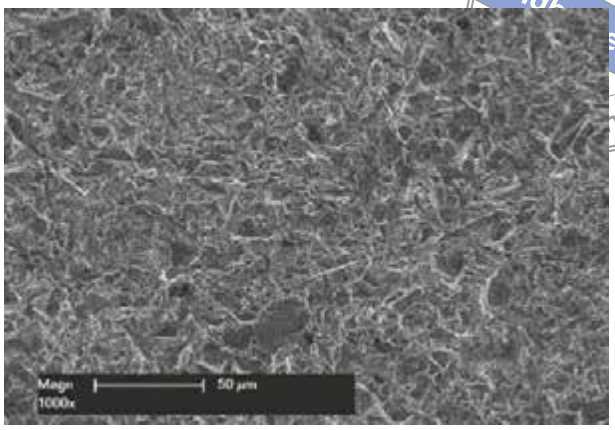

Fig 6-10 Detailed view of the alumina particle air abraded CoCr surface (SEM image at 1000× original magnification).

Fig 6-11 The extra- and intraoral applicable air abrasion device (MicroEtcher CD) can be operated chairside via the Multiflex coupling of the dental unit.

Fig 6-12 The dust containment box (MicroCab+) prevents the pollution of the treatment room during the chairside application of intraoral air abrasion devices.

After the alumina particle air abrasion step, the resin half-shell is removed from the ceramic veneering and the restoration should be cleaned ultrasonically in a disposable cup with fresh 99% isopropanol for 3 min to remove blasting residues (Figs 6-16 and 6-17). It is very important that no impurities (e.g. blood, saliva or silicone oil residues) are present on the unconditioned portions of the RBFDP, which would be dissolved in the alcohol during the ultrasonic cleaning and then precipitate on the conditioned and highly reactive bonding surface. Therefore, the entire RBFDP should be

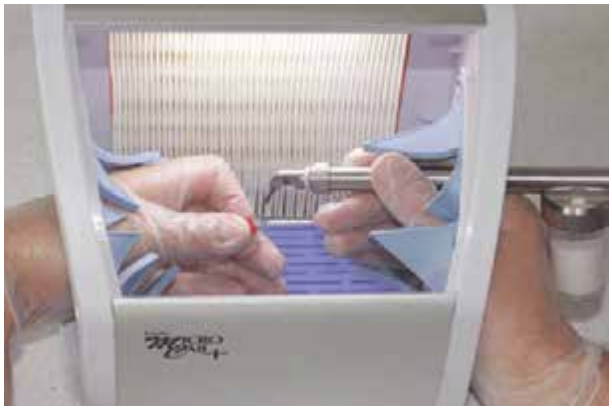

Fig 6-13 Air abrasion of a metal-ceramic RBFDP in the illuminated dust containment box.

Fig 6-14 A half-shell made of PMMA resin (Pattern Resin) is applied by means of the brush technique. This half-shell protects the veneering during air abrasion of the metal retainer wing.

Fig 6-15 The retainer wing is air abraded with 50 µm alumina particles at 2.5 bar pressure in order to achieve a roughening, cleaning, and activation of the bonding surface. The uniform matting of the metal surface can control the effectiveness of the air abrasion process.

Fig 6-16 After the bonding surface has been alumina particle air abraded, the protective half-shell can be easily removed...

Fig 6-17 ...and the RBFDP can then be cleaned of more firmly adhering blasting media residues in the ultrasonic bath with 99% isopropanol.

thoroughly cleaned after the intraoral try-in and before the surface conditioning, e.g. under running warm water with a disposable toothbrush, or by means of steam cleaning.

In a second step, an adhesive bonding system containing the active monomer 10-methacryloyloxydecyldihydrogenphosphate (MDP) should be used. If the bifunctional MDP monomer is applied to an alumina particle air abraded metal surface, its phosphoric acid ester group chemically binds to the surface oxides of the metal surface and its unsaturated double bond initiates a polymerization reaction with the resin molecules of the adhesive system (Fig 6-18).

The autopolymerizing composite luting resin Panavia 21, which has proven itself over more than two decades, has integrated the MDP monomer as an additive so that no additional primer has to be put on the metal surface air abraded with alumina particles. Therefore Panavia 21 (color EX = white opaque) is applied directly to the conditioned retainer wing (Figs 6-19 to 6-21). In many alternate bonding systems, the MDP monomer is not integrated into the

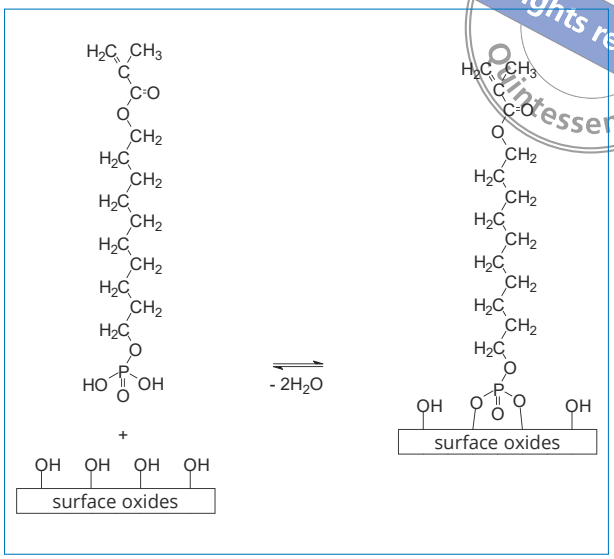

Fig 6-18 MDP is a reactive monomer that binds to the surface oxides of non-precious alloys, pure titanium, and zirconia ceramics in a condensation reaction.

Fig 6-19 The autopolymerizing white-opaque luting resin (Panavia 21 EX) is placed in equal strips of base and catalyst paste on the mixing block.

Fig 6-20 Within 20 s, the luting resin is mixed homogeneously and...

adhesive, but must be applied as a primer beforehand. Examples for such two-step systems are the dual-polymerizing adhesives Panavia V5 (requires Alloy Primer or Ceramic Primer Plus beforehand), and Multilink Automix (requires Monobond Plus beforehand). However, it must be stated that at the time of writing this book, positive clinical data on the long-term performance of single-retainer metal-ceramic RBFDPs are only available for the autopolymerizing adhesive luting resin Panavia 21.

Fig 6-21 ...is applied to the CoCr retainer wing in sufficient thickness.

Chapter 8

Pretreatment is of utmost importance

While the pretreatment prior to the prosthetic therapy with RBFDPs covers the normal treatment spectrum, as with conventional restorations, particular attention should be paid to some specific points. Whether the patient will be motivated to perform adequate oral hygiene is determined in the hygiene phase. Since the supragingival restoration margins are plaque retention sites, RBFDPs can be successful in the long term only with adequate oral hygiene. Since patients with missing anterior teeth suffer a lot, the author's impression is that (especially young) patients are more likely to be motivated to perform good oral hygiene, and more so in the pretreatment phase than when the RBFDP is already inserted. In cases of poor oral hygiene, the hygiene phase during pretreatment is a good time to emphasize the importance of adequate oral hygiene.

Orthodontic pretreatment

In adolescent patients with agenesis of teeth or early traumatic tooth loss, often an unfavorable gap distribution is present. It is usually indicated to

Fig 8-1 A 20-year-old female patient with a peg-shaped tooth 12 and a congenitally missing tooth 22 after the completion of her orthodontic therapy before the debanding. The opened space in region 12 and 22 is acceptable and the overbite of about 3 mm allows for the application of a RBFDP.

Fig 8-2 The occlusal view shows approximately the same width ratios in the areas 12 and 22. The patient did not want any further orthodontic treatment for fine adjustment.

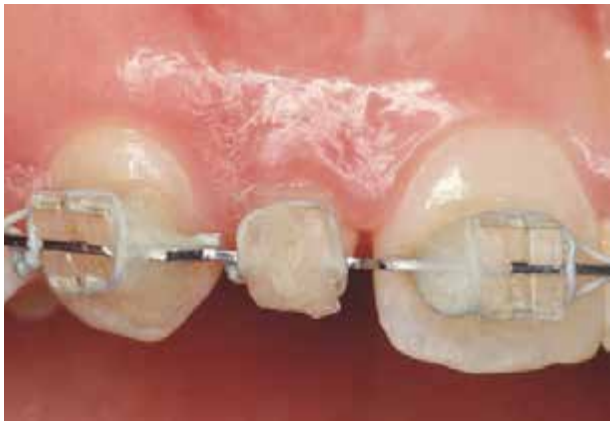

Fig 8-3 Detailed view of region 12...

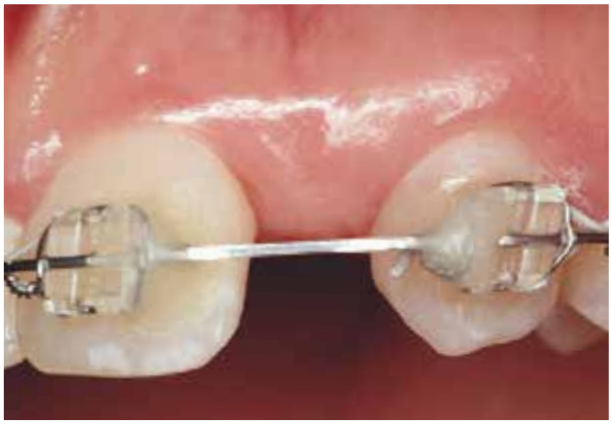

Fig 8-4 ...and 22 before debanding.

Fig 8-5 Tooth 12 prepared for an all-ceramic veneer crown (preparation completely in the enamel).

Fig 8-6 Soft tissue contact zone in region 22 shaped with a concave depression.

Fig 8-7 Detailed view of the inserted veneer crown 12...

Fig 8-8 ...and the single-retainer RBFDP replacing tooth 22.

improve this situation orthodontically prior to the prosthetic therapy with RBFDPs.

Ideally, the orthodontic adjustment of the pontic space is performed in close consultation with the dentist providing the prosthetic therapy. The orthodontic treatment should only be completed and the multiband appliance removed if the restorative dentist has checked whether the corrected spaces can be adequately restored with RBFDPs. The gap width should correspond to the normal width of the missing tooth and there must be sufficient intermaxillary space for the retainer wing (Figs 8-1 to 8-9).

Fig 8-9 Labial view of both restorations.

Fig 8-10 Extraoral view of an 18-year-old female patient with a deep bite and missing tooth 22.

Fig 8-11 View with retracted lips and teeth in maximum intercuspation.

Fig 8-12 The lateral view reveals the missing space for a retainer wing.

Fig 8-13 Extraoral view with multibracket orthodontic appliance.

In the case of an overbite not exceeding 3 mm, the adhesive preparation and the retainer wing in the maxilla can be placed below the occlusal contacts, so that the ceramic framework does not interfere with the occlusion. In the case of a deeper vertical overbite of 4 to 5 mm, it is critical to check whether there is a sufficiently large enamel surface of 30 mm^2 cervical to the occlusal contacts and whether a sufficient connector height and thickness of 3 × 2 mm can be achieved (see Chapter 7).

If this is not the case, as in deeper bite situations with retroclined maxillary incisors, an adequate orthodontic erection of the incisors is a necessary prerequisite for the use of RBFDPs, in spite of the deep bite (Figs 8-10 to 8-21). A sagittal clearance of 0.6 to 0.7 mm should be established orthodontically between the mandibular and maxillary incisors, so that – after the adhesive preparation – a zirconia ceramic retainer wing with a minimum thickness of 0.7 mm can be bonded. The occlusal contacts of the mandibular incisors will then be on the polished zirconia ceramic that will also provide the anterior guidance. In the illustrated case with a unilateral tooth agenesis, however, the contralateral incisor also loses its anterior tooth contact through the protrusion of the incisors. This should then be restored with a lingual ceramic wing, i.e. a lingual veneer (Figs 8-19 to 8-21).

Fig 8-14 The view with retracted lips and teeth in maximum intercuspation shows that the incisors were slightly protruded and intruded. The space formed mesial to the small tooth 12 is to be closed by means of a ceramic veneer.

Fig 8-15 Labial view of the edentulous space in region 22.

Fig 8-16 The intermaxillary space conditions now permit the application of a RBFDP. However, the anterior guidance has to be restored by lingual veneers (retainer wings) on both central incisors.

Fig 8-17 Extraoral view after fine correction of the gap distribution and removal of the multibracket orthodontic appliance.

Fig 8-18 The view with retracted lips and teeth in maximum intercuspation after completed orthodontic treatment.

Fig 8-19 Lingual view of the inserted RBFDP made of zirconia ceramic for replacement of tooth 22. The retainer wing on tooth 11, integrated into the anterior guidance, was splinted with the retainer wing of tooth 21 in order to preserve the orthodontic result.

Fig 8-20 The view with retracted lips and teeth in maximum intercuspation shows the glass-ceramic veneer on tooth 12 and the RBFDP for replacement of tooth 22.

Fig 8-21 Extraoral view of the treatment result.

In another case of a two-retainer metal-ceramic RBFDP that was inserted elsewhere in order to replace tooth 11, there was insufficient space on the lingual surfaces of the abutment teeth for adequately dimensioned retainer wings (Figs 8-22 and 8-23). For this reason, the thin retainer wing on tooth 21 had already debonded a short time after the RBFDP had been inserted and had been cut off. Due to premature contacts, the retainer wing on tooth 12 had to be greatly reduced, so that its stability was compromised and loss of retention could be expected at any time (see Figs 14-9 and 14-10). After the patient had been informed about the space required for the long-term function of the RBFDP, she agreed to orthodontic pretreatment with clear plastic aligners to protrude tooth 21 by 0.3 mm and to retrude the mandibular teeth slightly. An additional 0.3 mm space could also be created at tooth 31 (Figs 8-24 to 8-27). After 6 weeks of wearing two sets of In-line aligners in the maxilla and mandible, the desired space of at least 0.6 mm was obtained (Figs 8-28 to 8-30). Suitability of the obtained space could be easily checked by inserting a 0.6 mm-thick strip of tin foil between the prospective abutment tooth 21 and

Chapter 10
All-ceramic RBFDPs – detailed

During the past two decades, the author and his staff have used mostly all-ceramic RBFDPs for anterior tooth replacement for their patients. When patients are informed about the advantages and disadvantages of the different framework materials (see Chapter 5), they usually choose the all-ceramic version.

Single-retainer all-ceramic RBFDPs have the major advantage that parallelization of tooth surfaces and the application of technique-sensitive retention grooves can be omitted. Due to the rigidity of the ceramic retainer wings, there is no risk that the retainer wings might bend. Therefore, detrimental peeling forces do not occur. Without the application of retention grooves, an intraoral paralellometer, or similar means, are not required. Instead of retention grooves, an additional flat proximal box is prepared (about 0.5 mm-deep and 2 × 2 mm-wide) within the enamel, since it significantly increases the fracture strength of all-ceramic RBFDPs[42]. In this way, together with the lingual pinhole, a defined seat of the single-retainer RBFDP is ensured (Figs 10-1 to 10-3).

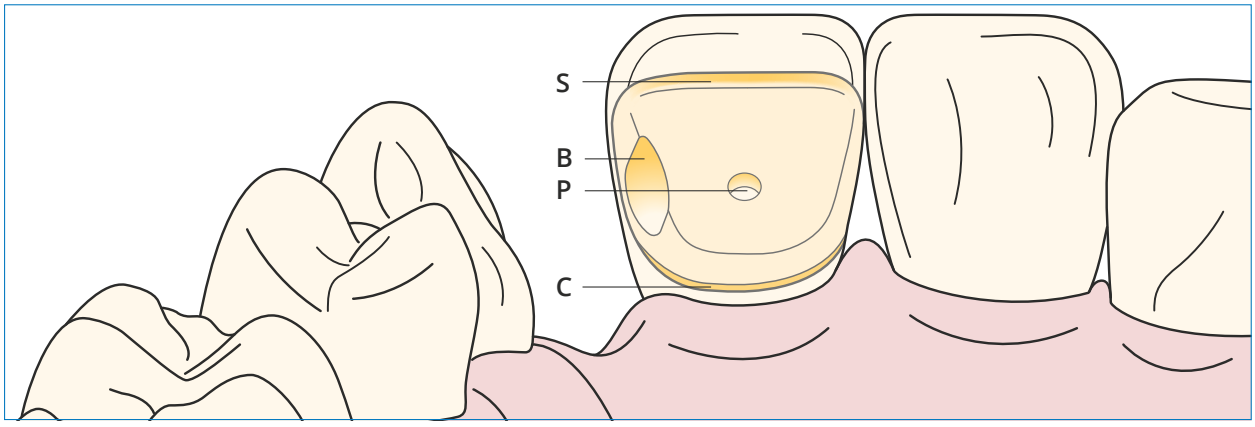

Fig 10-1 Schematic drawing of the recommended enamel-restricted preparation for anterior all-ceramic retainer wings. C – light cervical chamfer, P – pinhole, B – flat proximal box, S – light incisal shoulder.

Fig 10-2 Representation of the recommended adhesive preparation limited to enamel on anterior teeth for all-ceramic retainer wings on a cast with typodont teeth.

Fig 10-3 The lingual retention nub and the proximal box are clearly visible on the corresponding all-ceramic retainer wing.

Mock-up for visualization

In general, it is recommended to have a diagnostic wax-up of the pontic and the retainer wing made in the dental laboratory on diagnostic casts mounted with a facebow in the articulator. If the wax-up is subsequently transferred intraorally with the aid of a silicone index as a mock-up, the achievable function and esthetics of the RBFDP can be initially checked and reasonable or necessary pretreatment measures can be ideally assessed (compare to Chapters 3 and 7). A diagnostic abutment preparation on the planning cast is particularly helpful if the minimally invasive adhesive preparation is not in the usual repertoire of the practitioner. The diagnostic abutment preparation is best done by marking the centric and eccentric occlusal contacts, so that their position can be taken into account. Usually, existing occlusal contacts are not removed and are not included in the preparation of the retainer wing.

In the illustrated case of a 14-year-old female patient with congenitally missing maxillary lateral incisors, an unexpected opening of the proximal contact between the two central incisors was

Fig 10-4 A 14-year-old female patient with congenitally missing lateral incisors after completion of orthodontic treatment [Source: Bärbel Kahl-Nieke, University of Hamburg, Germany].

Fig 10-5 Extraoral view: The patient does not expose the gingiva when smiling.

Fig 10-6 Labial view with retracted lips. The composite resin splint to secure the proximal contact of the central incisors had debonded and had been removed incompletely elsewhere. There was a minimal midline diastema present.

Fig 10-7 View of the inserted mock-up of provisional resin. This was transferred from the wax-up made on the diagnostic cast with splinted incisors. Therefore, the inserted mock-up with retainer wings also eliminated the midline diastema.

Fig 10-8 Extraoral view with inserted mock-up. A soft tissue augmentation in the area of the missing teeth appears unnecessary. The esthetic effect of the mock-up is much more appealing than the existing replacement teeth attached to the orthodontic retention device (Figs 10-9 and 10-10).

observed (Figs 10-4 to 10-6) within a short time after completion of the extensive orthodontic pretreatment (see Figs 8-31 to 8-36). A wax-up on the diagnostic cast where the central incisors were splinted (compare to Figs 7-46 to 7-51) was transferred intraorally as a mock-up using provisional resin in a silicone mold. The mock-up therefore simulated not only the RBFDPs and the mesial broadening of the left canine but also the closure of the small diastema between the two central incisors (Figs 10-7 and 10-8). The patient and her mother were satisfied with the simulated result. Soft tissue augmentation in edentulous regions with horizontal defects was dispensed with since the patient did not expose these regions during function (Fig 10-8). The proximal contacts of the replacement teeth of the orthodontic retention device were reinforced with composite resin to a level that restored the proximal contact between the two central incisors (Figs 10-9 and 10-10). Patient and mother were informed that splinting the retainer wings was recommended in order to secure the proximal contact permanently. Three weeks later, the proximal contact remained intact after removal of the orthodontic

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Nowadays, single-retainer metal-ceramic and all-ceramic resin-bonded fixed dental prostheses (RBFDPs) often present a truly minimally invasive alternative to single-tooth implants or other conventional prosthetic methods. Their excellent clinical outcome has been proven by several recently published long-term studies.

With the growing body of evidence showing that implants placed in the esthetic zone of younger patients present a high risk of esthetic problems in later years, RBFDPs made from zirconia ceramics are experiencing a great renaissance.

This book presents, concisely and precisely, what has to be considered and what must be avoided in order to be successful with single-retainer RBFDPs replacing incisors. Although the method is technically sensitive, it is simple and extremely reliable when adequate procedures are employed. In the meantime, even the replacement of canines and premolars appears to be promising if the principles outlined in this book are applied. Numerous high-quality figures detail the procedures for metal-ceramic and all-ceramic RBFDPs. Many illustrated cases, some with 20 and more years of follow-up, document the development of the success story of RBFDPs.

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