Resin-bonded prostheses: The current state of development

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In the 25 years since the first resin-bonded prosthesis was described, this adhesive technique for splinting mobile teeth has developed into a conservative method for replacing missing teeth. There was a high debond rate associated with the early resin-bonded prostheses, which led many clinicians to question their clinical appropriateness for long-term use. These early failures were attributed to the limited bond strength between the metalwork and etched enamel. Despite improvements in the adhesive bond strengths, there was still an unacceptable number of clinical debonds. The biomechanical design of resin-bonded prostheses did not develop with the same rapidity or with the same predictability as did the advancements with the associated adhesive technology. Through ongoing development, studies have shown various biomechanical designs that may improve clinical retention. The purpose of this article is to examine the biomechanical principles for current resin-bonded prosthesis design, including aspects of tooth preparation and framework design that will improve clinical retention. (Quintessence Int 1999;30:525–534)

Key words: adhesive technique, biomechanics, fixed partial denture, resin-bonded prosthesis

Resin-bonded (RB) prostheses have been associated with lower retention rates than conventional bridgework; for this reason, RB prostheses have been an unpredictable and unpopular restorative option for many clinicians. However, recent studies have shown that, with improved prosthesis design, RB prostheses are lasting longer than the earlier, pioneering RB prostheses. The purpose of this article is to examine aspects of development of current RB prostheses and highlight the features of RB prosthesis design that have shown to improve retention so that recommendations can be made for tooth preparation and framework design to ensure successful clinical use.

EARLY DEVELOPMENT OF RESIN-BONDED PROSTHESES

In 1973, Alain Rochette was the first to describe the use of a resin-bonded prosthesis for the splinting of periodontally mobile teeth. He used a metal frame-work that was cemented with acrylic resin to acid-etched enamel. This conservative solution to a periodontal problem initiated the development of a new procedure for the replacement of missing teeth, the resin-bonded fixed partial denture (Fig 1).

Although the early RB prostheses were considered a conservative, reversible, and cost-effective procedure for replacing missing teeth, significant numbers of debonds were observed among the many clinical successes. The debonding of the early RB prostheses was initially attributed to the weak link of the adhesive interface: the metal-to-cement bond. Several techniques were developed for improving the metal-cement bond; these included the use of macroretentive and microretentive features on the fitting surface of the retainer for improved adhesion. Later, the development of chemically active resin cements was perhaps the most significant factor in improving the tooth-to-metal bond strength, not only by increasing the bond strength but also by simplifying the adhesive technique.

However, despite the improvements in adhesion, clinical results still showed unsatisfactory retention rates for RB prostheses. Several studies examined the biomechanics of tooth preparation and framework design in relation to RB prosthesis success and considered retention and, in particular, resistance form essential to increasing the clinical retention of RB prostheses. Improvement in retention and resistance form is important for reducing stresses from functional and parafunctional tooth contacts on the cement lute.
FACTORS AFFECTING RETENTION OF RESIN-BONDED PROSTHESSES

At present, no general agreement appears evident on the principles of tooth preparation and bridge design for the provision of RB prostheses; this is particularly apparent when compared to the virtual unanimity of the principles of tooth preparation found in prosthodontic textbooks for conventional crown and bridgework. Today, now that bonding technology between metal and tooth appears to have reached an accepted standard, namely the use of an adhesive resin cement to a nonprecious alloy, it is predominantly the biomechanical aspects of tooth preparation and metal framework design that contribute to unpredictable clinical retention.

Two important considerations for improving clinical retention of RB prostheses are framework design and tooth preparation; both of these must be optimal for clinical success. The greater the biomechanical demands induced by restoration of an edentulous space, the greater the resistance and retention form needed by the tooth preparation and metal framework to cope with the functional and parafunctional forces.

Framework design

Retainer thickness and configuration. Few studies have emphasized the importance of, or investigated, the optimum thickness of RB prosthesis retainers for clinical success. Textbooks on conventional crown and bridgework almost universally have guidelines on optimal metal thickness and the design features of cast restorations to ensure durability and clinical success; however, such guidelines for RB prostheses do not appear evident.

The thickness of the RB prosthesis retainer is not usually prescribed by the clinician, which often means that technicians will provide a retainer with an axial contour that is considered physiologic; such retainers are usually much thinner and therefore more flexible than conventional bridge retainers.

Resin-bonded prosthesis retainers are essentially partial veneer restorations with little occlusal coverage; in the case of posterior RB prostheses, they have a geometric “c”-shaped configuration. This configuration could be significantly strengthened, particularly for long spans, if the ends of the retainers were joined over the occlusal surface or around the axial contour of the tooth.

It is perhaps these aspects of RB prosthesis retainer thickness and configuration that have significantly contributed to the failures associated with posterior fixed-fixed RB prostheses. Despite the increased rigidity of a nonprecious alloy, occlusal loading may flex the thin and geometrically incomplete retainer so that the cement lute will be stressed and allow debonding of the prosthesis.

Clinicians have suggested that the optimal thickness for RB prosthesis frameworks should be between 0.3 and 0.6 mm, depending on the site, stress on the prosthesis, and the metal used. However, Caputo and Standlee showed, in photoelastic studies, that occlusal forces create very high and complex stresses on the RB prosthesis framework; these forces translate into high flexure of the retainer arms, which, in turn, fatigues the cement lute. The authors showed that increasing the thickness of the retainers for posterior RB prostheses from 0.4 to 0.6 mm causes a significant decrease in the level of stress concentration.

Because practical experience has shown that a 0.6-mm retainer for a molar tooth can be flexed between the fingers, it is recommended that, where possible, RB prosthesis retainers for molars be 0.8 mm thick or greater if the retainers are not joined over the occlusal surface (Figs 2a and 2b). Retainer thickness should be increased in patients with high occlusal demands, such as patients who exhibit bruxism, and for long-span RB prostheses.

Retainers should be of sufficient thickness without interfering with the occlusion and should have margins and contours that are consistent with periodontal health. In a study of the impact of RB prostheses on periodontal tissues, increased probing depths and attachment loss on abutments with RB prostheses were observed. However, in this study the control teeth were sound, unrestored teeth. No comparison was made to conventional fixed partial dentures, although the authors did explain that the clinical effect was minimal and comparable to that observed with other types of restorations.

Bonding area. Maximizing the surface area for bonding the framework to enamel is one of the basic
premises of good retention and resistance form for RB prostheses. Coverage involves extension of the metalwork as far occlusogingivally and circumferentially around the tooth as is possible. Such extension will usually necessitate axial tooth preparation to lower the survey line. This can be performed very conservatively, when a suitable path of insertion is chosen, with tooth preparation largely confined to the interproximal surfaces.

Wraparound. One of the earliest framework design features for RB prostheses was the extension of the metalwork retainer around 180 degrees of the axial tooth surface. This so-called wraparound was intended to provide buccolingual stability and was particularly recommended for posterior prostheses. Where demands on the retainers may be increased because of long spans or increased occlusal loads, 360-degree wraparound of the abutment tooth may be appropriate to ensure clinical longevity.

In a clinical study, Creugers and coworkers showed the importance of wraparound on posterior RB prostheses; they reported that minimal tooth preparation and a framework without wraparound were insufficient for a durable prosthesis. In another clinical study, Crispin changed the proposed preparation design of posterior RB prostheses to include wraparound when an unacceptable number of debonds occurred on preparations with only axial reduction and grooves.

Occlusal extension of metalwork. Anterior palatal metalwork. Clinical studies either do not mention this design consideration in their protocol or recommend that the incisal extension finish 1.0 to 3.0 mm short of the incisal edge, without explanation. Some authors have recommended that the anterior metalwork finish short of the incisal edge to prevent metal from shining through the tooth or possible occlusal interferences.

However, for conventional bridgework, it is accepted that inlays are not suitable as a retainer for fixed-fixed prostheses. In such situations, occlusal contacts on tooth tissue of the abutment rather than on the inlay retainer of the fixed-fixed prosthesis may force the abutment tooth away from the retainer, eventually causing fatigue of the cement lute. This biomechanical principle appears to have been overlooked during the development of fixed-fixed RB prostheses, where partial coverage of the occlusal surfaces of abutments will not control all possible functional and parafunctional tooth contacts. It is not surprising to see how fixed-fixed RB prostheses debond where tooth contacts are possible on the abutment tooth and not the framework of the retainer (Fig 4).

More recent studies suggest that the palatal metalwork extension of fixed-fixed RB prostheses should cover the incisal edge to receive possible tooth
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**Fig 4** Fixed-fixed prosthesis in which the palatal metalwork is left short of the incisal edge. The patient has obvious incisal wear facets that are not covered by the metalwork. This allows the patient to “bite the tooth” out of the retainer during functional and parafunctional contacts.

**Fig 5a** Metal visible behind artificially created, translucent enamel when opaque cement is not used.

**Fig 5b** Metal concealed by the use of opaque cement.

contacts and to prevent occlusal forces on the tooth from stressing the adhesive bond. However, with extension of the metal framework to the incisal edge, there is a potential problem of incisal graying of the abutment tooth if the teeth are thin or the incisal edge is translucent. In such cases, the RB prosthesis should be cemented with an opaque luting cement (Figs 5a and 5b) or the metal shine through should be incorporated in the porcelain of the pontic to harmonize the anterior appearance.

Alternatively, if one of the teeth adjacent to the pontic site has little or no incisal translucency, then the choice of this tooth as an abutment for a 2-unit cantilever may overcome the esthetic concern. Also, a 2-unit cantilever would make it possible to finish the metalwork short of the translucent area because there is no concern that the abutment tooth will be forced away from the retainer—there are no interabutment forces in a 2-unit cantilever.

**Posterior occlusal metalwork.** The extension of metalwork to the occlusal surfaces of posterior abutment teeth has 3 important biomechanical features for RB prosthesis design: resistance to displacement apically or laterally, increased rigidity of the framework, and greater surface area for bonding.

In vitro, extension of the metalwork to the occlusal
surface has also been shown to improve retention of posterior RB prosthesis retainers. In vivo, the use of multiple rest seats, occlusal channels, occlusal bars or struts, and intracoronal extension of the metal-work have all been shown to be clinically successful for retaining RB prostheses.

Occlusal coverage is particularly important on a tilted molar abutment, where the “short” mesial surface reduces both the resistance and retention form of the abutment and the surface area for bonding. Extension of the framework to the occlusal surface will partially overcome these problems and, at the same time, allow restoration of the occlusal plane (Fig 6).

**Connector design.** Significant stresses are applied to the retainers of fixed-fixed RB prostheses because of differential tooth movements between the abutments during functional and parafunctional tooth contacts. These complex interabutment forces stress the cement lute, which may lead to its failure and debonding of the prosthesis.

Stresses to the cement lute should be reduced by increasing the resistance form of the abutment or by changing the design of the fixed-fixed prosthesis to a fixed-movable or 2-unit cantilever design. Two-unit cantilever RB prostheses and fixed-movable hybrid designs have been shown to be clinically successful, and, in 3 clinical studies, 2-unit cantilevers were more successful than comparable fixed-fixed designs.

**Length of span.** Several studies have shown that long-span resin-bonded prostheses have a shorter clinical life. Dunne and Millar showed that splints and RB prostheses with 3 or more abutment teeth have a significantly higher debond rate than do those prostheses with 1 or 2 abutment teeth.

This does not mean that long-span RB prostheses should not be provided but rather that the tooth preparation and framework design should be designed to reduce potential debonding stresses on the retainer (Fig 7).

**Tooth preparation**

The importance of increasing resistance form through abutment preparation to ensure greater clinical success has been suggested by several authors. It is perhaps this aspect of RB prosthesis design, along with predictable bonding technology, that has most significantly increased the success rates of recent RB prostheses.

**Axial tooth preparation and finish lines.** Axial tooth preparation is important not only to increase the area for bonding by lowering the survey line but also to increase the resistance and retention form of the prosthesis. However, increasing the retention form of an RB prosthesis abutment with axial tooth preparation is difficult to achieve clinically because opposing parallel axial surfaces, ie, buccal-lingual and mesial-distal, are not normally prepared.

Therefore, if the palatal or lingual surface of an abutment has a naturally low survey line, the preparation of this surface for increasing the retention form may be unnecessary (see Fig 3). In this instance, a knife-edged finish line may be used on the palatal or lingual surface. This margin may be extended to the interproximal surfaces after the height of contour is lowered. Such a knife-edged margin, however, would require gingival metalwork with an acute emergence profile from the tooth to allow a physiologic contour that can be easily cleaned. This is achieved easily and accurately on an investment cast (Fig 8).

To maximize retention of the RB prosthesis retainers, the framework should extend as far apically and circumferentially on the abutment as possible; poor design of framework extension may compromise periodontal health. However, periodontal health on the abutment teeth is also determined by the cleanliness of the retainer, the patient’s oral hygiene, and the susceptibility of the individual to periodontal disease.
Grooves. The preparation of grooves on the abutments for RB prostheses has been advocated both from in vitro and in vivo evidence. Grooves also allow greater resistance form to lateral displacement and may increase retention. Grooves have been suggested both for resin-bonded splints\textsuperscript{30} and for improving the retention of RB prostheses.\textsuperscript{31} Results of photoelastic studies\textsuperscript{32} on fixed-fixed RB prostheses have suggested that the placement of grooves at the proximolingual line angles of posterior teeth adjacent to the pontics may improve clinical success (Fig 9).

The use of grooves not only increases resistance and retention form for what is essentially a partial-coverage restoration but also increases the structural rigidity of the metal framework after cementation.

In vitro, the use of 2 grooves per abutment, in comparison to no grooves, has been shown to significantly increase resistance to debonding forces for both anterior\textsuperscript{31} and posterior teeth.\textsuperscript{33} Grooves are especially important on anterior teeth because 180-degree wrap-around usually cannot be achieved because of esthetic concerns.\textsuperscript{34} El Salam Shakal and coworkers\textsuperscript{33} showed, in vitro, that varying the positions of axial grooves on posterior abutment yields significantly different retention. The placement of axial grooves diagonally apart at the mesial and distobuccal surfaces of posterior teeth necessitated greater forces for dislodgment than did grooves placed only on the mesial and distal surfaces.

Several clinical studies have supported these in vitro findings on the use of grooves. Teeth prepared with axial grooves show greater retention of RB prostheses than do teeth with minimal preparations.\textsuperscript{3,11,21,27,13,35} Rammelsberg and coworkers\textsuperscript{21} showed the use of 1 axial groove and at least 1, 1-mm-deep occlusal channel with "near parallel opposing walls" per tooth to result in only a 4\% loss of RB prostheses during a 6-year evaluation period. This result was in contrast to a 65\% loss of retention in teeth with minimal tooth preparation (no grooves or channels). The authors claimed that the retentive tooth preparation reduced the risk of failure to only about 5\% of that for minimal tooth preparation.

In a longitudinal study, Simon et al\textsuperscript{36} showed 95\% retention of posterior fixed-fixed partial dentures prepared with multiple grooves and slot-type rest seats. This was in comparison to 60\% retention for posterior prostheses with no grooves and a denture-type rest seat. The authors did not find the same success when comparing anterior fixed-fixed prostheses with and without grooves. However, in these groups, both types of anterior preparation received a 2-plane proximal reduction on the abutments, which may have created a single path of insertion with sufficient resistance form for similar clinical success.

In an 11-year study, Barrack and Bretz\textsuperscript{37} showed that anterior RB prostheses with 2 interproximal grooves exhibit better retention than do anterior preparations with only warparound and no grooves. No debonding of anterior prostheses with grooves occurred during the study.

Posterior "rest seats." Rest seats on posterior fixed partial dentures not only allow the transmission of occlusal forces along the long axis of the tooth but also provide resistance form and may, therefore, limit shear forces applied to the cement lute.

To obtain greatest resistance form, clinical studies have demonstrated the importance of rest seats, which should ideally be prepared in the form of a slot\textsuperscript{38} or "occlusal channel,"\textsuperscript{24} and not like a denture rest seat.

In a clinical study, Barrack and Bretz\textsuperscript{37} changed the design of the proposed tooth preparations after finding 2 rest seats (mesial and distal) for each posterior abutment to be more successful than a single rest seat.

Anterior rest seats. Although axial transmission of occlusal forces is easily achieved with posterior teeth, the situation is not as straightforward for anterior abutments. The placement of cingulum rest seats...
has been advocated for directing forces along the long axes of the teeth and to reduce the shear forces on the cement lute. However, the nature of the interincisal angle will create complex stresses on the cement lute in a fixed-fixed design, regardless of the presence of cingulum rests; the use of axial grooves with an apical stop may negate the need for a cingulum rest.

Intracoronal preparation. Extension of the metal framework intracoronally into existing restorations or small carious lesions has also been advocated to achieve improved resistance form.²³,³⁶

One recent study described the replacement of posterior teeth using resin-bonded metal inlay and onlay retainers without the use of lingual bracing arms.²³ The intracoronal and extracoronal retainers were prepared in either intact or minimally carious tooth tissue to support the pontic. Only 1 of 51 prostheses had debonded after 5 years. However, the use of inlay retainers without lingual bracing arms should be considered carefully because of the possible wedging effect to tooth tissue; in fact, the other failure in this study was the result of cuspal fracture.

A type of mesio-occlusodistal metalwork extension has been recommended by Kilpatrick and Wassell³² for posterior cantilever fixed partial dentures. The mesial and distal rest seats of the retainer are joined over the occlusal surface to form an occlusal bar to improve the rigidity of the retainer. This is clinically useful because it not only enhances the retainer’s resistance to deformation but also improves the resistance form of the abutment tooth preparation and increases the surface area for bonding (Fig 10).

Pins. The use of parallel pins, incorporated in the framework, has also been advocated³⁷ and shown to be clinically successful for providing additional retention to RB prostheses,³⁸ although there appear to be no other clinical studies supporting this. Pin preparation is also demanding both clinically and technically to ensure complete seating of the cast, pinned framework. This type of tooth preparation has not gained clinical acceptance and appears to be superseded by the use of axial grooves.

Occlusal contacts. Clinical studies rarely mention the influence of occlusion, whether static or dynamic, on the retention of RB prostheses. Only a few studies have commented on the effect of tooth contacts and parafunctional activity on RB prosthesis success.

From a study of 203 fixed-fixed RB prostheses, Creugers et al.²⁵ observed that the occurrence of occlusal contacts on abutments rather than the retainers is an important factor in predicting failure. From these observations, they suggested that retainers be designed to receive the occlusal contacts in the intercuspal position. Crispin²⁶ made a similar suggestion in a study of 71 fixed-fixed RB prostheses. He advised that canine abutments supporting posterior pontics will be more successful if occlusal contacts are located on the retainers in the intercuspal position and not on the teeth (Fig 11).

The nature of dynamic tooth contacts occurring between tooth or retainer in failed prostheses has been reported. Hansson and Bergstrom³⁹ observed that 4 of 5 debonded prostheses in their study showed intercuspal occlusal contacts on the retainers, but in protractive and laterotractive movements tooth contacts were possible on tooth tissue (see Fig 4). These authors also considered bruxism to be a significant stress factor in the premature debonding of 3 prostheses. Samama⁴⁰ observed parafunctional activity in 10 of 15 patients with failed periodontal splints. The author advised that tooth preparation with optimal retention is desirable to reduce stresses caused by mobile teeth for patients who exhibit parafunction. However, Barrack and Bretz⁴¹ did not consider either parafunction or tooth mobility to be contraindications to clinical care, finding a RB prosthesis retention rate of 93% for almost 6 years.
TABLE 1  Clinical longevity of resin-bonded prostheses (RBPs)

<table>
<thead>
<tr>
<th>Study</th>
<th>Size of study</th>
<th>Significant design features</th>
<th>Mean service life</th>
<th>Retention rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Besimo(1993)</td>
<td>82 RBPs</td>
<td>Guide planes, multiple grooves, and rest seats</td>
<td>1 y 9 mo</td>
<td>99%</td>
</tr>
<tr>
<td>Barrack and Bretz(1993)</td>
<td>127 RBPs</td>
<td>Multiple grooves, rest seats, and intracoronal extension</td>
<td>5 y 8 mo</td>
<td>92% for old design; 100% for new design (101 RBPs)</td>
</tr>
<tr>
<td>Rammelsberg et al(1993)</td>
<td>141 RBPs</td>
<td>Guide planes, rest seats, and occlusal channels 1 mm deep</td>
<td>6 y</td>
<td>96% for retentive preparation; 37% for minimally invasive preparation</td>
</tr>
<tr>
<td>Stokholm and Isidor(1996)</td>
<td>51 RBPs</td>
<td>Inlay and onlay retainers</td>
<td>5 y</td>
<td>98%</td>
</tr>
<tr>
<td>Hussey et al(1996)</td>
<td>142 2-unit cantilevers</td>
<td>Minimal preparation, wraparound, and cingulum rests</td>
<td>3 y</td>
<td>88%</td>
</tr>
<tr>
<td>Brabant(1997)</td>
<td>501 pontics, 838 abutments</td>
<td>Opposing grooves, axial walls, and proximal rests</td>
<td>Placed between 1985 and 1995</td>
<td>95% by retainer</td>
</tr>
<tr>
<td>Ferrai and Mason(1997)</td>
<td>82 RBPs</td>
<td>Mesial and distal grooves and posterior occlusal coverage</td>
<td>3 y 10 mo (estimated)</td>
<td>90%</td>
</tr>
</tbody>
</table>

CLINICAL SUCCESS

Clinical studies that have investigated the success rates of RB prostheses usually define success as a prosthesis that has not debonded. However, some studies also consider a debonded prosthesis that can be successfully rebonded a success; for this reason, retention rates, rather than success rates, will be discussed.

Retention rates for RB prostheses have varied widely, from 46% at 11 months10 to 93% over 11 years.11 A longevity study often quoted is that of Creugers and Van’t Hof,12 who performed a statistical meta-analysis of 25 clinical studies and showed the retention rate of RB prostheses to be 74% over 4 years. However, this analysis included some of the earliest clinical studies on RB prostheses, which would have used bonding technologies and prosthesis designs that have now been significantly improved.

The improvement in clinical results of RB prosthesis retention is supported by in vivo studies that show retention rates of RB prostheses to increase during the progress of the clinical study.625 In these cases, the improvements have been attributed to the development of better designs and bonding technology for RB prostheses, replacing older materials and techniques.

Recent clinical studies show very promising retention rates for RB prostheses over the short to medium term (Table 1). However, longer follow-up times are necessary to confirm the clinical success of these improved designs.

RECOMMENDATIONS FOR RESIN-BONDED PROSTHESIS DESIGN

These recommendations for improved retention of RB prostheses are based on the results of both in vivo and in vitro studies showing that, with careful planning and design, present-day RB prostheses are more successful than earlier generations of this prosthesis. The successful design of RB prostheses is dependent on a number of design and clinical factors: tooth preparation, framework design, the number and location of abutments and pontics, and whether the retainers are fixed, freestanding, or hybrid.

Anterior prostheses

Tooth preparation. With the use of dentin adhesives, tooth preparation for RB prostheses with appropriate resistance form may extend into dentin without significant concern for decreased retention.

For optimal retention and resistance form for anterior prostheses, 2 grooves per abutment14 should be placed for fixed-fixed, fixed-movable, hybrid, or cantilever designs. The preparation of cingulum rests as an occlusal stop may be superseded by the apical stop provided by the axial grooves.

Framework design. Recent studies show anterior 2-unit cantilever RB prostheses to be as successful as, if not more successful than, fixed-fixed anterior RB prostheses.24-27 In view of this, 2-unit cantilevers should be the preferred restorative option when ante-
terior teeth are replaced with a RB prosthesis. Such 2-unit cantilevers are easier for the operator to prepare, record an impression for, cement, and, if a debond occurs, repair.

If a fixed-fixed anterior RB prosthesis is to be provided for a patient with wear facets on the abutment teeth, it is recommended that the framework be extended to cover these wear facets to prevent tooth contacts from "biting the tooth" out of the retainer. A cantilever design obviates the need for complete occlusal coverage, as the abutment tooth cannot be occluded out of the retainer because it is freestanding.

**Posterior prostheses**

**Tooth preparation.** Occlusal coverage and the use of grooves should be considered essential for the clinical success of posterior prostheses. Posterior fixed-fixed prostheses should ideally have a minimum of 2 grooves per abutment. The grooves should be placed to withstand functional forces from all directions. The recommended sites for placement are at the proximolingual line angles. Intracoronal extension of the framework should be considered when small restorations are present or when carious lesions can be prepared with resistance form. For long spans, or even for routine use, additional occlusal coverage can be achieved by joining the mesial and distal rest seats over the occlusal surface to form an occlusal bar or by reducing the lingual cusp to allow a three-quarter crown-type coverage.

**Framework design.** The required thickness of the retainer depends on the geometric configuration of the retainer and the biomechanical demands of the edentulous space. If the ends of the retainer are joined through an occlusal bar joining, partial occlusal coverage, or a 360-degree wraparound, the retainer may be approximately 0.8 mm thick. However, for RB prosthesis preparations with occlusal rest seats only, for abutments with high functional demands (long span), or in patients who exhibit bruxism, it is recommended that the metalwork be a minimum of 1.0 mm thick.

In patients with parafunctional activity, tooth preparations with maximal resistance form and prosthesis designs with optimal framework rigidity are necessary to ensure clinical success.

**RECOMMENDATIONS FOR BONDING**

The bond strength between the framework and tooth tissue is dependent on many variables, such as the type of alloy used, the surface preparation of the bonding surfaces (tooth and metal), and the type of luting cement used. Surface preparation for the fitting surface of the retainer for resin bonding has gone through a diverse and rapid technologic development. Today, this has almost reached a "standard," and the use of 50-μm aluminum oxide particles for airborne abrasion is a simple, quick, and predictable metal surface treatment. This type of metal surface preparation has been made possible through the development of chemically adhesive resin cements that are capable of providing high bond strengths between nonprecious alloys and conditioned tooth tissue. Despite the high bond strengths that are possible between these surfaces, it cannot be overemphasized that the best RB prosthesis design will fail if meticulous care is not taken during all stages of the bonding procedure.

**CONCLUSION**

Since their development, RB prostheses have shown increasing longevity and success as dental material technology and understanding of the importance of tooth preparation and framework design have evolved. This has, however, meant more extensive tooth preparations and framework coverage than were found with earlier RB prosthesis designs.

The notion that tooth preparation is easier for successful RB prostheses than for conventional prostheses is a fallacy. The preparation of a conservative yet retentive tooth abutment for an RB prosthesis is a fine balance between minimal tooth preparation, confined predominantly to enamel, and precise preparation of retention and resistance form features. It is all too easy to overprepare an RB prosthesis abutment so that excessive dentin is exposed and that the tooth preparation is almost as destructive as a conventional preparation. It is the opinion of the author that good RB prosthesis preparations can be as difficult as, if not more difficult than, conventional abutment preparations.

The use of 2-unit cantilever and fixed-movable RB prostheses is proving to be highly successful and clinically appropriate. In particular, if debonding does occur, the patient will know to return for possible recementation. Although this debond may be considered a retentive failure, the prosthesis may still be considered a functional success if it can be rebonded.

Further studies are required to determine the long-term cost effectiveness of the improved designs of RB prostheses and how further improvements for their longevity can be made.
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REFERENCES