Resin-bonded fixed partial dentures past and present – an overview

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Précis

This article aims to provide a general overview, along with guidelines and recommendations for use, of resin-bonded fixed partial dentures in practice.

Abstract

Resin-bonded fixed partial dentures have been in use for over 30 years, since the concept was first introduced in the 1970s. Initial efforts in this field suffered frequent early debond, but advances in metal alloys, treatment of the fitting surface and bonding techniques have made the resin-bonded fixed partial denture a predicable treatment modality. Design principles have also evolved. Originally these restorations were retained purely through adhesion, but now minimal preparation of the abutment teeth may be undertaken to optimise mechanical resistance and retention forms. This facilitates delivery of a more predicable medium- to long-term restoration. Alternative materials such as ceramic, zirconia and fibre-reinforced composite resin have emerged for retainers. While these alternatives show promise, they are not without their disadvantages and do not yet have long-term data regarding their use for this application.

Introduction

For the last 30 years, resin-bonded fixed partial dentures (RBFPDs) have provided a conservative, medium-term restoration. Initially, these restorations failed through frequent debond but advancements in technology (treatment of the fitting surface and bonding techniques) have improved their predictability. Principles of design and abutment preparation have also evolved. Originally these restorations were retained purely through adhesion, but now minimal preparation of the abutment teeth may be undertaken to optimise mechanical resistance and retention forms. This facilitates delivery of a more predicable medium- to long-term restoration. An alternative approach to tooth preparation employs the Dahl technique, where restorative space is gained by cementing the restoration in hyperocclusion. Alternative materials such as ceramic, zirconia and fibre-reinforced composite resin have been explored for the retainers. While these alternatives show promise, they are not without their disadvantages and there is as yet no long-term data regarding their use for this application.

A brief history

The introduction of bonding by Buonocore[1] in 1955 heralded new possibilities in dentistry. Adhesive technology means that more conservative preparation of the abutment teeth is possible than with cemented conventional restorations. Rochette in 1973[2] introduced the concept of bonding a metal retainer to enamel using adhesive resin. His application was to splint periodontally involved mandibular anterior teeth using a cast gold bar bonded to the lingual surfaces of the teeth. The cast metal splint described had perforations to provide mechanical interlocking between the cement and the metal. His introductory article made reference to modifying the technique for application as an RBFPD. Today, this type of design with perforated retainers, as depicted in **Figure 1**, can be used to facilitate retrievability when an RBFPD is used as a provisional restoration

FIGURE 1: RBFPD using Rochette design with perforated retainers.

Howe and Denehy[3] modified this application to introduce the first form of RBFPD. Livaditis[4] proposed abutment preparation, including reduction of proximal and lingual surfaces to create a path of insertion, along with occlusal rest seat preparation to resist tissueward displacement of the retainer. These modifications enhanced the retention and resistance forms of the metal retainer to the tooth.

Attention then turned to treatment of the retainer's fitting surface to increase the resin to metal bond strength. Livaditis and Thompson[5] introduced the concept of electrolytically etching a non-precious metal to microscopically roughen the metal surface. Electrolytic etching works on the principle of selective dissolution of the most corrosion-sensitive phases of the metal. Mean tensile bond strengths of 27.3MPa for resin composite bonded to an electrolytically etched alloy were reported, which exceeded the bond found between resin and etched enamel (8.5-9.9MPa).[5] While this was a step forward in design it was somewhat impractical in most general practice settings, given that this etching process is quite a sensitive technique, requires special laboratory equipment, and the restoration needs to be cemented immediately to avoid contamination. Further, the quality of etching depends on numerous factors including the type of casting alloy, type of acid etchant, acid concentration, etching time and electrical current density. A microscope is required to verify the quality of etching, which cannot be accurately assessed by visual inspection.

Airborne particle abrasion with aluminium oxide was proposed as a more practical alternative to increase surface roughness.

FIGURE 2: Airborne particle abrasion of the fitting surface with 50µ aluminium oxide particles.

The equipment required is inexpensive and the surface alteration can be appraised visually (as shown in **Figure 2**) making it a more user-friendly and accessible method for general practice. Another method available is silicoating, which involves the fusion of a thin layer of silica (approx 0.5µ) to the metal fitting surface. This silica coating then reacts chemically with a silane coupling agent applied prior to application of the resin cement. Bond strengths reported for microabraded and silicoated surfaces are similar.

Common indications and contraindications for RBFPDs are listed in **Table 1**.

Table 1: Indications and contraindications for RBFPD.

INDICATIONS	CONTRAINDICATIONS
Replacement of a single missing tooth	Unfavourable occlusal scheme
Periodontal splinting	Heavily restored abutment teeth
Fixed retention following orthodontic treatment	Mobile abutment teeth
Sound teeth adjacent to the open space	Diastema required between abutment and pontic
Excellent moisture control possible	Nickel allergy

Abutment tooth selection when using a cantilever design

The canine is the abutment tooth of choice when replacing a lateral incisor. It has a longer root over which to dissipate the increased forces when supporting an additional tooth as well as the overall length of the tooth, which maximises groove length. Further, retention is increased by a greater surface area for bonding, and the convexity of the palatal surface of the canine may increase rigidity independent of retainer thickness. Conversely, the lateral incisor lacks all these attributes because of its flatter, smaller size and thus is a weak abutment choice.

Preparation design

Schillingburg *et al*.[6] defines retention and resistance as follows: "Retention prevents the removal of the restoration along the path of insertion or the long axis of the tooth preparation. Resistance prevents dislodgement of the restoration by forces directed in an apical or oblique direction and prevents any movement of the restoration under occlusal forces". Resistance form can be evaluated prior to cementation of the restoration. It optimises dissipation of forces and minimises dependence on the resin bond.[7] Tooth preparation aims to create a definite outline form and path of insertion for the restoration, therefore optimising resistance and retention forms while minimising metal display or show through. Tooth reduction is conservative (remaining in enamel) for RBFPD preparation. This is one of numerous advantages of this restoration, as shown in **Table 2**.

Table 2: Advantages and disadvantages of RBFPD.	
ADVANTAGES	**DISADVANTAGES**
Minimal tooth preparation (0.5mm reduction, remaining in enamel)	Preparation (albeit minimal) of abutment tooth/teeth is required
Supragingival margins	Good alignment of abutment teeth required (**Figure 4**)
Reduced intraoral procedures (comparatively)	
Rebond possible	

Anterior abutment tooth preparation

The incisal finish line is conventionally 2mm short of the incisal edge to avoid any aesthetic impairment of incisal edge translucency (see **Figure 3**).

FIGURE 3: Two anterior three-unit RBFPDs placed following orthodontic treatment.

This may vary and should be assessed clinically by moving a metal instrument from the cervical to the incisal of the tooth and assessing visibility from the facial aspect. This ensures good aesthetics from the facial aspect (**Figure 5**).

FIGURE 5: Two anterior three-unit RBFPDs in situ (from facial aspect).

Calcium hydroxide catalyst paste can be used to try in the retainer as it reproduces the white opaque shade of resins used to cement RBFPDs. A reduction of 0.5mm palatally will suffice to allow adequate bulk of metal for strength of the retainer while keeping the preparation in enamel.[8] The gingival finish line ends 1mm supragingivally for optimal hygiene and thus tissue health, and further to maintain the preparation in enamel for optimal bonding. Keeping the preparation supragingival also facilitates the use of a rubber dam when cementing the restoration. Interproximally, the finish line ends at the centre of the contact area. This maximises wraparound while minimising visibility of metal from the facial aspect. The proximal surfaces of two abutments should be as parallel as possible to increase the retention form as well as reducing any negative space (black triangles). Proximal grooves compensate for the lack of proximal wraparound, which is limited by aesthetic requirements. The suggested proximal groove placement and preparation is illustrated in **Figure 6**.

Saad *et al.*[9] in an *in vitro* study, found that a 30.8% increase in shearing force was required to dislodge the retainer after the addition of proximal grooves. A rest seat in the cingulum area resists tissueward movement of the casting, which aids correct seating of the restoration during cementation. This should be prepared with a flat-ended, tapered diamond bur. This part of the preparation should also remain in enamel. Sometimes incisal rests are incorporated to aid correct seating of the casting. They should not be surface treated to facilitate ease of removal after cementation.

FIGURE 6: Suggested preparation for anterior RBFPD

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Posterior abutment tooth preparation

As with anterior preparations, the gingival finish lines terminate 1mm supragingivally for the same reasons as cited above. Enough enamel is removed lingually to eliminate the lingual bulge, but ensuring that the preparation remains in enamel. To optimise resistance form at least 180º wraparound of the preparation should be achieved. The interproximal finish lines terminate lingually to the facial line angles. Similar to the preparation for anterior abutments, rest seat preparations can be incorporated to prevent tissueward movement of the retainers. These are ideally placed mesially, distally and either mid-lingual or at the distopalatal groove to optimise axial loading of the abutment teeth. Alternatively the retainers can cover the occlusal surfaces of the abutment teeth, which maximises retention and resistance forms of the restoration as depicted in **Figure 7**. The proximal sections act as connectors as well as providing buccolingual bracing of the abutments. Interproximal grooves also increase retention of these restorations when used posteriorly. Alternatively, slot or box preparations that incorporate existing restorations can be utilised.

FIGURE 7: Cemented three-unit RBFPD.

The Dahl approach

Preparation of the abutment tooth serves two functions: restorative space is created; and, retention and resistance forms are greatly enhanced.[9] Some authorities would favour greater coverage of the abutment tooth to increase adhesion over preparation of the abutment tooth as well as using the Dahl approach to create restorative space.[10] The Dahl technique is an alternative approach where restorative space is gained by cementing the restoration in hyperocclusion. Dahl originally reported on this technique using a removable cobalt chromium splint 2mm thick to create restorative space on the palatal surfaces of maxillary anterior teeth that had experienced erosive wear.[11] The splint was retained by buccal clasps on the canines and first premolars. For the purposes of measuring changes in the vertical dimension of the face, tantalum needles were implanted near the midline of the basal portions of the maxilla and mandible. Lateral cephalograms were taken at two, five and eight months, and interocclusal space was observed to increase up to eight months, when it became equivalent to the thickness of the splint. The initial article only reported on one patient; however, seven years later Dahl and Krogstad reported similar observations in a group of 20 patients.[12] Cementing the restoration using this approach relies entirely on adhesive retention. The abutment tooth and its antagonist intrude to allow the remaining dentition to return to occlusal contact.

Design choice?

A single abutment, single pontic prosthesis (**Figure 8**) has a reduced biologial and financial cost, is easier to prepare, and simplifies impression making and cementation over a three-unit design. Further, a single retainer is usually preferred as debonding will not go unnoticed. Using a single cantilever eliminates the differential bond strength due to differing size and mobility of abutments.[13] If selecting a three-unit design, both abutments should have similar mobility, otherwise the weakest may detach from the enamel, compromising the entire result. If an RBFPD is to be placed following orthodontic treatment a three-unit design may be desirable because of its dual function as a fixed orthodontic retainer, as shown in **Figure 3**.

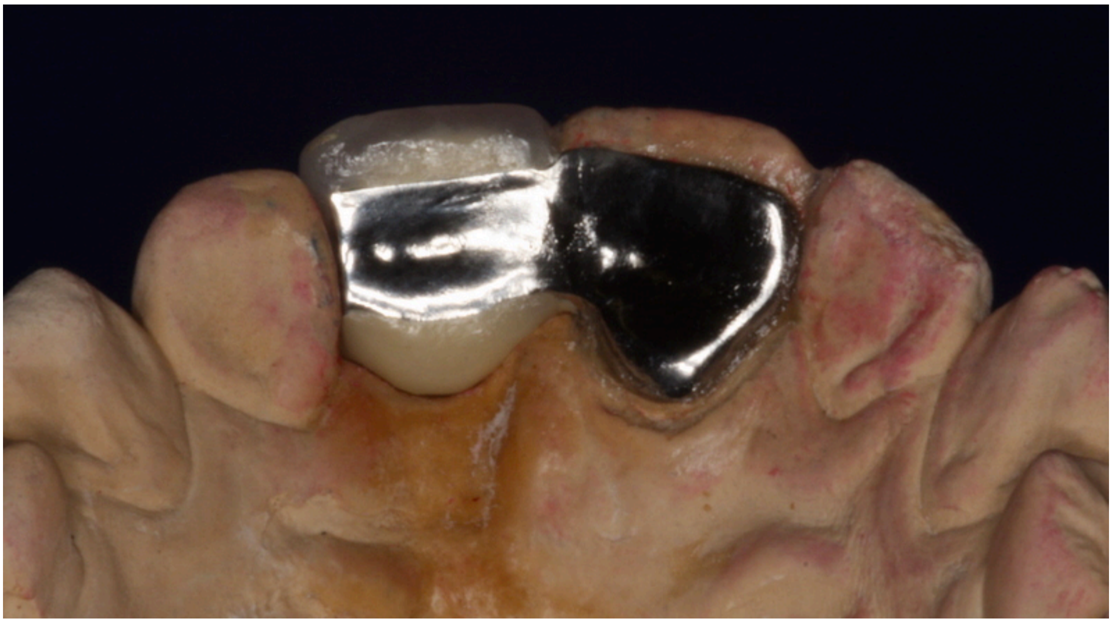

FIGURE 8: Single abutment, single pontic cantilevered RBFPD.

Hussey and Linden[14] observed 142 cantilevered RBFPDs placed in 112 patients, which had been in clinical service for a minimum of 12 months prior to recruitment to the study. The mean length of clinical service was 36.8 months, and 88% of the RBFPDs remained bonded for the duration of the study.

A retrospective study of 269 two-unit RBFPDs placed in 214 patients observed a 95.5% clinical retention rate.[15] Results from this study should be cautiously interpreted, however, as there was wide variation in the length of service time among the restorations studied (13.2-141.6 months). The mean service life was 51.7 months +/- 19.5 months' standard deviation; hence, while a large study, it can only report on the short- to medium-term success of these restorations.

Material selection

Rochette's original paper[2] used gold alloy. Knowledge has evolved since then and nickel chromium is now the alloy of choice for RBFPDs. This is due to the greater bond strengths observed with base metals, as well as the strength of these metals in thin section. Retainers of cobalt chromium alloy should ideally be a minimum of 0.5mm thick.[8] Ibrahim *et al.*[8] found *in vitro* that increasing metal retainer thickness necessitated increasing force to dislodge the retainer. The authors concluded that using alloys with a high modulus of elasticity is beneficial along with a retainer thickness of ≥0.5mm. Base metals, despite their hardness, elastic modulus and superior sag resistance at elevated temperatures are more challenging to cast and presolder. The potential for nickel sensitivity must be borne in mind when selecting an alloy. **Figure 9** shows a base metal framework prior to porcelain application.

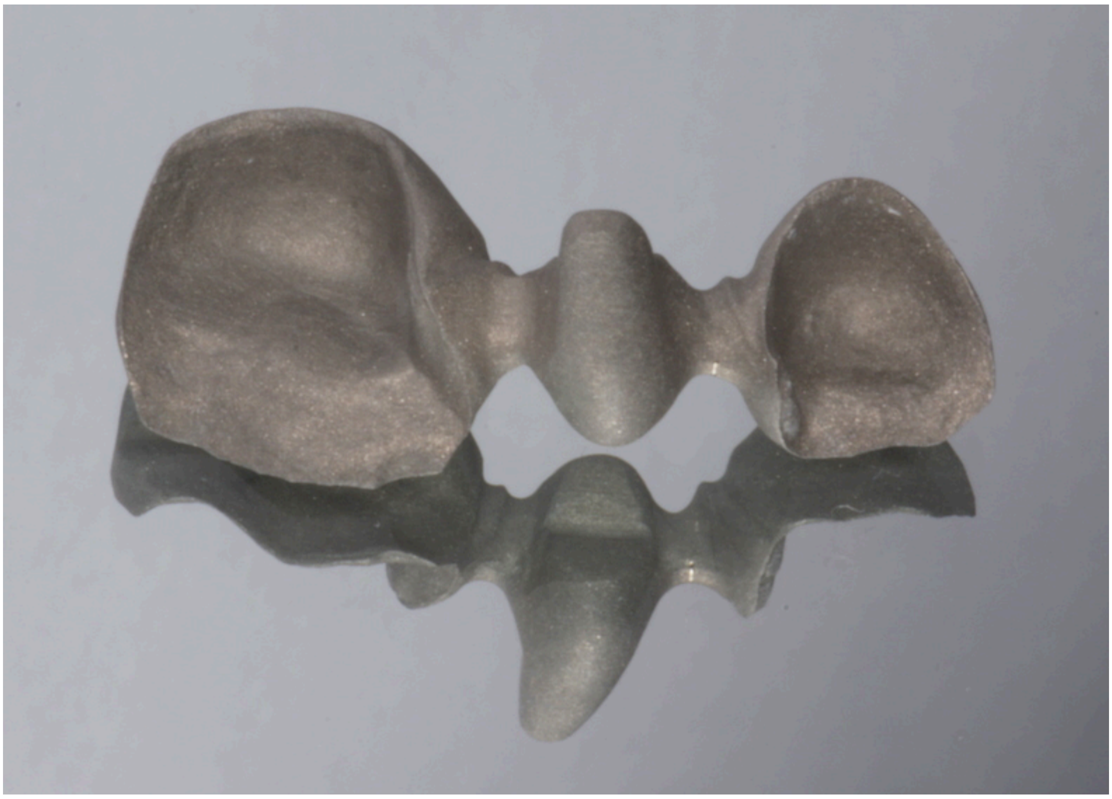

FIGURE 9: Base metal framework prior to porcelain application.

All-ceramic RBFPDs were introduced in the early 1990s as a more aesthetic alternative to traditional RBFPDs. Kern[16] conducted a prospective study to evaluate the clinical survival of all-ceramic (glass infiltrated alumina ceramic In-Ceram) RBFPDs with a cantilever design compared with conventional two-retainer design. Thirty-seven anterior RBFPDs were made with a mean observation time of 76+/-46 months for the two-retainer group and 52+/-17 months for the single-retainer group. There was a high fracture rate within the first years of clinical service, which the author attributes to movement differential between the abutment teeth during function. The study concluded that the cantilever design presented a promising alternative.

Fibre-reinforced composite (FRC) has been proposed as an alternative material for the retainer, citing advantages of better adhesion of the composite resin luting agent to the retainer, superior aesthetics and ease of repair. Glass fibres are commonly chosen for this purpose because of their strength and aesthetic qualities. Delamination and framework fracture are the most common modes of failure seen with this material. The wear properties of composite resin are inferior to those of ceramic and they will also discolour over time. Greater occlusal clearance is required (1-2mm), which poses a biological disadvantage for this choice. A multi-centre study looking at 52 patients who received 60 indirectly made FRC RBFPDs reported success rates of 45% and survival rates of 64% after five years of observation.[17] The same group[18] found a success rate of 71% and a survival rate of 78% after five years of observation of a group of 77 patients who had received 96 FRC RBFPDs in the posterior area of the mouth. A systematic review[19] of the use of fibre reinforced polymer to replace missing teeth found very little good evidence to support its use. Most literature available was in the form of case reports; no randomised controlled trials are available, or any long-term cohort studies. The authors concluded that the use of fibre-reinforced polymer for fixed partial dentures must still be regarded as experimental.

FIGURE 10: Zirconium RBFPD framework try in (picture courtesy of Dr M O'Sullivan).

Zirconia offers superior strength and fracture toughness, can be milled and is a more aesthetic alternative to traditional retainer materials (**Figures 10** and **11**). Certainly there is no doubt regarding the mechanical performance of zirconia (strength, fracture resistance and toughness); however, the main mode of failure of these restorations is still fracture of the veneering porcelain. Zirconia's chemical inertness and glass-free composition means that acid etching and silanation is ineffective on its surface. A novel surface treatment (selective infiltration etching) emerged in 2006, which has been claimed to create a highly reactive surface.[20] Using this protocol, the surface is coated with a glass infiltration agent and heated above its glass transition temperature. At this temperature, the molten glass allows for sliding and splitting of the surface grains. This creates nanoporosities where the adhesive resin can infiltrate and interlock. Bottino *et al*.[21] report that a bond strength of 50-55MPa can be achieved with this surface treatment. Findings from a recent *in vitro* study demonstrate that a better bond to zirconia can be achieved using a universal primer (Monobond) rather than conventional silane with adhesive luting cement (Multilink).[13] These findings, although promising, need to be verified in further studies and ideally reproduced *in vivo*. There are still unknowns in relation to using this material – longevity of restorations made from this material compared with more traditional alternatives, optimal design of the retainer, etc.

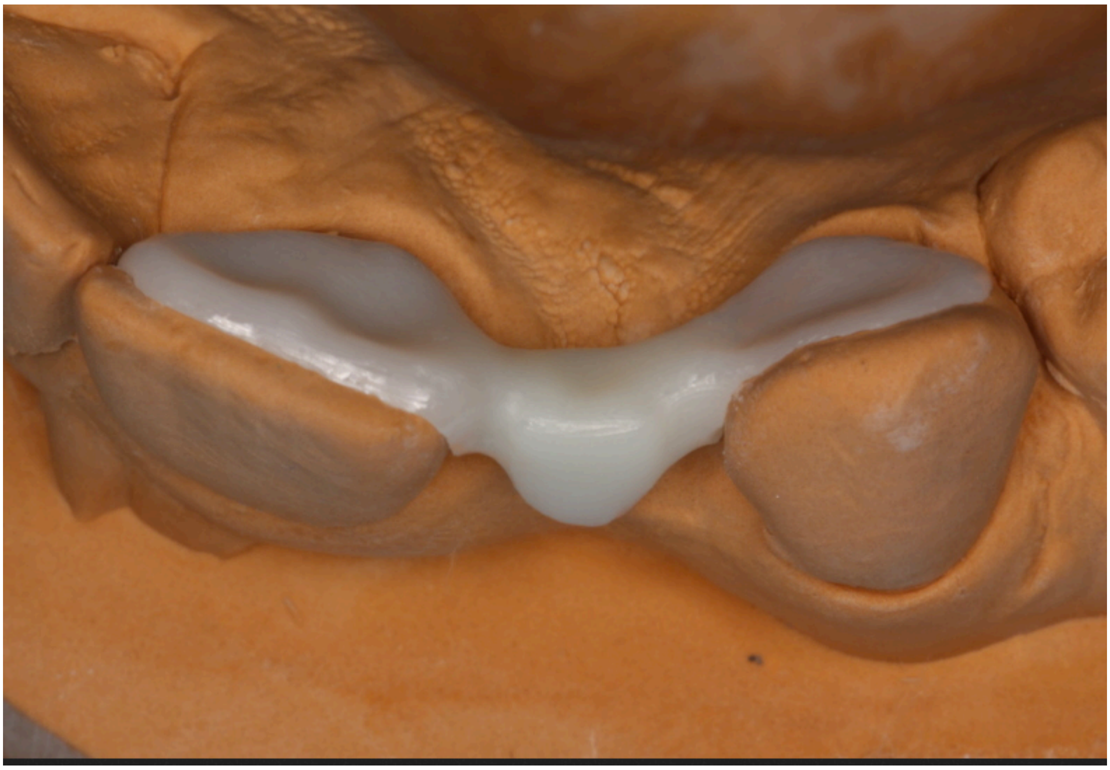

FIGURE 11: Zirconium FBFPD framework from occlusal perspective (picture courtesy of Dr M O'Sullivan).

Bonding/cementation

The original RBFPD frameworks were perforated to enhance mechanical retention of the cement to the framework. This had the disadvantage of the perforations weakening the framework strength, as well as leaving resin exposed to potential abrasion/leakage through exposure to the oral cavity.

The attachment complex consists of three separate parts:

- enamel to resin bond;
- cohesive bond of the composite resin; and,
- resin to framework bond.

Panavia EX was first introduced in 1984 and is capable of bonding cobalt chromium to enamel. It is based on bis-GMA resin and contains MDP (10-methacryloxydecyl dihydrogen phosphate). Hussey *et al.*[22] in a clinical trial found the debond rate of RBFPD cemented with Panavia EX (16%) to be less than Comspan (45%). Panavia has a compressive strength of 200-300MPa while its tensile strength is 20-40MPa.[23] Livaditis and Thompson[5] demonstrated that the tensile bond strength of the resin-alloy interface is approximately two times that of the resin-enamel interface. 4-META (e.g., C&B Metabond, Parkell, USA) has been found to adhere strongly to smooth dental alloys, particularly non-precious metals. El-Guindy *et al.*[24] found a superior bond strength with base metals over noble alloys. Oxidation of the metal increases the durability of the adhesion. While nickel and chromium are easily oxidised, nickel-chromium contains 8% copper and manganese, which inhibits oxide formation. Nitric acid successfully creates an oxide film on the surface of nickel-chromium. Tanaka *et al.*[25] found the durability of 4-META applied to nickel-chromium extremely durable in an *in vitro* study. Thinner film thicknesses facilitate complete seating of the casting and minimises internal flaws in the cement. Diaz-Arnold *et al.* found 80µm created the highest metal to resin bond strength.

Air abrasion of the alloy surface with 50µ alumina prior to bonding roughens the surface and also provides a molecular coating of alumina. This alumina helps oxide bonding of phosphate-based adhesive systems (e.g., Panavia). Hussey *et al.*[22] found in a longitudinal, prospective clinical study involving 400 adhesive bridges that the mean length of clinical service was the same for both etched and sandblasted bridges.

Placing an RBFPD in a porcelain furnace at 480ºC for three minutes will remove any remaining resin without affecting the surface glazing of the porcelain.[26]

Moisture control is essential to optimal bonding. Application of a rubber dam is the most predictable method of preventing contamination during cementation. This is not always practically feasible where the rubber dam may cover the margin or in fact cause pooling of saliva/gingival crevicular fluid in this area. Cotton wool isolation is an acceptable alternative where a rubber dam cannot be applied.

Case selection

Occlusal considerations

The RBFPD should be checked in maximum intercuspation (MIP) and dynamic excursions. The retainer should be in light contact in MIP even if the tooth was not in occlusion prior to RBFPD placement. The pontic should also be in light contact in maximum intercuspation but any contact in excursions eliminated. Some studies have reported a higher rate of debond of RBFPDs in patients with parafunctional activity.[27] Where parafunctional activity is suspected, it would be prudent to prescribe a protective acrylic occlusal device (e.g., Michigan splint).

Cast metal retainers bonded to the lingual surfaces of anterior teeth are subject to varying forces during function. When the opposing teeth contact the retainer, they experience compressive and shear forces. When parts of the abutment tooth not covered by the retainer are contacted by the opposing teeth, tensile and shear forces are applied to the retainer. In the anterior region, tensile and shear forces are most destructive in causing the retainer to debond from the tooth; this is magnified in situations where there is a deep vertical overlap.[13]

Longevity/survival/success

Partial or complete debonding should be monitored carefully at review appointments to intervene before caries develops or the prosthesis is swallowed, aspirated or lost. Creugers *et al.*[28] found a survival rate of 75% for anterior and 44% for posterior bridges at 7.5-year follow-up. However, results of this study must be cautiously interpreted as survival was taken to mean that the bridge was still *in situ*, so caries or fracture of porcelain were not documented as failures.

Hussey *et al.*[22] reported on the performance of 400 RBFPDs placed between 1984 and 1989. The mean duration of service observed was 2.7 years. A high debond rate was reported, with 25% having debonded on at least one occasion. Preparation design was not standardised and surface alteration (electrolytic etching) was still an emerging treatment at this time, which is likely to account for this observation.

A 13-year prospective follow-up study of 74 RBFPDs found a survival rate of 69% after 13 years.[29] A total of 15 failures (20.3%) were observed; the main causes of failure reported were loss of retention, carious lesions and fractures of the veneering porcelain. Djemal *et al.*[30] studied 832 RBFPDs and splints provided at a postgraduate teaching hospital and reported mean survival of seven years and 10 months with retainer design, area of coverage and operator experience associated with survival.

Pjetursson *et al.*[31] conducted a systematic review of the survival and complication rates of resin-bonded bridges after an observation period of at least five years in 2008. The authors conclude that RBFPDs still debond relatively frequently, which can consume a lot of extra chairside time. The estimated survival rate after five years was 87.7%. They recommend further research with greater than 10-year observation periods to evaluate long-term outcomes in more detail.

Conclusions

While survival rates for RBFPDs remain lower than for conventional fixed partial dentures, they still have an important role to play in certain circumstances. The importance of careful case selection cannot be overemphasised. Preparation of abutment teeth as outlined in this article is to be strongly recommended, as it has been shown to increase retention and resistance forms and therefore yield higher success rates. Even with abutment tooth preparation, these restorations rely heavily on adhesive retention, so occlusal forces should be carefully controlled and night protection should be provided for patients with parafunctional activity. Reports of tooth-coloured RBFPD frameworks suggest that they may be a viable alternative, but long-term data of comparable duration to traditional cast metal RBFPDs is required for a true comparison. They may be of value in situations where metal retainers would be an aesthetic compromise.

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