Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: www.elsevier.com/locate/mjafi

Original Article

Comparative evaluation of retentive properties of acid etched resin bonded fixed partial dentures

Lt Gen Vimal Arora, vsm^{*a,*}, Col M.C. Sharma, (Retd)^b, Ravi Dwivedi^c^a DGDS & Col Commandant, AD Corps, 'L' Block, IHQ of MoD (Army), New Delhi 110 001, India^b Prof & Head, (Prosthodontics), Maitri Dental College & Research Centre, Anjora, Durg, Chattisgarh, India^c Prof & Head, (Prosthodontics), BBD College of Dental Sciences, BBD University Campus, Faizabad Road, Lucknow, India

ARTICLE INFO

Article history:

Received 6 February 2013

Accepted 30 March 2013

Available online 20 August 2013

Keywords:

Acid etched resin

Resin bonded fixed partial denture

RBFPD

Alloy pre-treatment

ABSTRACT

Background: Little consensus exist in suitable tooth preparation design and alloy pre-treatment methods for improving the retention of resin bonded fixed partial dentures (RBFPDs).

Methods: An in-vitro experiment was done with four designs. Group A: standard form, B: wings and proximal slices, C: wings, proximal slice and grooves, D: wings, proximal slice, grooves and occlusal coverage. Alloys were subjected to pre-treatment procedures like Group I: control, II: sand blasting, III: electro etching, IV: tin plating. Debonding forces of the castings were recorded in a universal testing machine and results were analyzed by student's 't' test.

Results: Group B, C and D showed higher debonding forces compared to A. However, there were no significant differences in mean force values among Groups B, C and D. Group II, III and IV with different alloy pre-treatment methods demonstrated higher values against control. Inter group variations among Group II, III and IV were not significant.

Conclusion: Tooth preparation with adequate surface extensions and pre-treatment procedures of casting alloys are two parameters that play important role in determining the retentive features of RBFPDs. Different types of tooth preparation designs and alloy pre-treatment methods exert almost similar influence in increasing the retention of acid etched RBFPDs.

© 2013, Armed Forces Medical Services (AFMS). All rights reserved.

Introduction

Rehabilitation of edentulous spans in dental arches is accomplished by replacing missing teeth by means of removable/ fixed partial dentures or implant supported prosthesis. In patients where implants are not feasible or where retention of the

prosthesis can be achieved with minimal preparation of the abutment teeth, resin bonded fixed partial dentures (RBFPD) offer a favourable option for restoring missing teeth. Earliest attempt to make a RBFPD to periodontally compromised anterior teeth was made by Rochette in 1973.¹ Later in 1977, Howe and Denehy² applied this method to fabricate interim

* Corresponding author. Tel.: +91 011 23094764.

E-mail address: vimalaroravsm@gmail.com (V. Arora).

0377-1237/\$ – see front matter © 2013, Armed Forces Medical Services (AFMS). All rights reserved.

<http://dx.doi.org/10.1016/j.mjafi.2013.03.011>

partial dentures. Conservative reduction of abutment teeth was an appealing concept and thus started the era of RBFPDs.

Resin bonded partial dentures, thereafter have undergone tremendous changes in terms of materials and designs. 'Cast perforated resin bonded dentures' are based on 'mechanical retention' where retention of metal casting to tooth preparation is improved by perforations. 'Virginia bridges' are another type which make use of 'macroscopic mechanical retention' mechanisms that create large undercut areas for retention.³ 'Etched cast resin bonded dentures' (Maryland bridges) employs 'micromechanical retention' and for this, electrolytic etching of alloy surface is done. 'Adhesion bridges' make use of adhesives with provision for chemical bonding to metal. In addition to all these designs, several *pre-treatment methods* like sand blasting, electrolytic etching or metal plating may be applied to the fitting surface of the casting to enhance bonding of RBFPDs.⁴ Since metallic alloys are integral parts of RBFPDs, bonding of casting to tooth preparation is achieved through the use of adhesives like BIS-GMA resins or composite luting cements which have glass fillers and adhesion promoters. Few of the products have even fluoride releasing mechanisms to reduce enamel decalcification around tooth preparation.⁵ Currently, 'etched cast resin bonded fixed partial dentures' enjoys wider acceptance and popularity due to their relative ease of fabrication and predictable results.⁶

The success of etched cast RBFPDs is largely dependent on *tooth preparation*. Different designs have been proposed by various authors, with varying claims for enhancing retention and resistance form. The standard preparations have wings and occlusal rests on the abutment teeth, while other patterns reported have proximal slices, grooves and extended coverages on occlusal surfaces.⁶ Nonetheless, there is little agreement among clinicians, either on the 'appropriate design for tooth preparation' or for the 'alloy surface pre-treatment'.⁷ In this context, it is imperative to evaluate the effectiveness of different types of tooth preparation/designs and metal pre-treatment procedures so as to determine the suitable combinations for enhancing the retention and clinical longevity of etched cast RBFPDs. The retentive properties between metal casting and tooth preparation are usually assessed in standard testing equipments by determining its debonding forces.

The aim of this study was therefore to compare the retentive properties of etched cast RBFPDs using various modifications in the tooth preparation designs on abutment teeth and different pre-treatment procedures on the fitting surfaces of castings in an in-vitro simulated clinical set up. The objective was to find out the most appropriate abutment design and surface pre-treatment method for casting alloys.

Material and methods

Lower first pre-molar and molar Ivorine teeth were used for the study (Columbia Dentoform Corp, NY). Teeth were mounted upright on acrylic blocks of 5 × 8 × 2.5 cm dimensions, replicating a partially edentulous clinical situation (missing lower second pre-molar). Four such master models were prepared with identical morphology. Each model was surveyed using Ney's surveyor (Dentsply, Milford) and undercut areas were marked. Four types of tooth preparation

Fig. 1 – Standard tooth preparation with wings and occlusal rest (Group A).

designs (Figs. 1–4) and four types of casting alloy pre-treatment methods: sand blasting, electro etching and tin plating were used. Samples were thus grouped into 4; (Groups A to D) based on their design preparations and as per the surface pre-treatment methods carried out on the fitting surface of castings alloys, they were categorized into Group I to IV. The study frame work thus formed a total of 80 samples as shown in Table 1.

Impressions were made of each master block using Polyvinyl siloxane® (Reprosil, De Trey, Dentsply, Milford) using specially constructed trays, from which wax patterns were

Fig. 2 – Tooth preparation with proximal slice (Group B).

Fig. 3 – Tooth preparation with wings, proximal slice and grooves (Group C).

Fig. 4 – Tooth preparation with wings, proximal slice, grooves and occlusal coverages (Group D).

generated and then adapted on to the dies, exactly matching to the extensions of each design, with necessary precautions to minimize dimensional changes. The patterns were invested and cast using a cobalt chromium alloy (Wironium alloy®; Bego, Germany) and compatible investment material (Bellasan®, Bego, Germany). The adhering investment material was removed by sand blasting (Korox 250, Bego, Germany). All the castings: sand blasting, electro etching and tin plating, were made identical in terms of technique and temperature. Each casting was cemented to the master specimen model with the help of a glass filled BIS-GMA resin; Panavia® cement (Kuraray, Osaka, Japan) as per manufacturer instructions. Retentiveness of the casting was assessed in a universal testing machine (Model 11955500R, Instron, Canton, Mass). Debonding forces/readings were noted in pounds/inch² (psi). Mean values of the groups were compared using Student's 't' test at $p < 0.05$.

Results

Mean values of debonding forces for all the study groups are shown in Table 2. Group B, C and D with different tooth preparation designs showed high forces, compared to standard preparation (Group A). Significant differences in mean readings were noticed between Groups A–B, A–C and A–D. However, differences between Groups B–C, B–D and C–D were not significant (Table 3).

Table 2 – Descriptive statistics of study groups.

Group	No of castings	Mean debonding readings in psi			
		Group I	Group II	Group III	Group IV
A	20	185.8	336.8	358.2	362.2
B	20	269.8	438.8	452.0	469.2
C	20	287.2	464.0	479.6	495.6
D	20	293.6	471.4	486.0	474.4

Groups (II, III and IV) with different pre-treatment methods for castings, demonstrated higher debonding values compared to the untreated samples (Group I). Highly significant differences in mean forces were observed between Group I–II, I–III & I–IV. However, between Groups II–III, II–IV and III–IV, there were no significant differences in the average readings (Table 4).

Discussion

Small edentulous areas bounded by healthy abutment teeth are preferred to be restored with RBFPDs, which implies that the supporting teeth should have adequate crown dimensions and be free from caries/periodontal diseases.⁷ Minimal tooth reduction is therefore fundamental to the practice of RBFPDs. Most of them are designs with little display of metal surface but with lingual/palatal extensions and cingulum/occlusal rests. The present study evaluated the retentive features of standard design preparations (Group A) along with other types of designs which had extensions to proximal, distal and palatal/lingual areas. Blue inlay wax was used to prepare wax patterns by a single operator, having preparations with wings and proximal slice (Group B), those with wings, proximal slice and grooves (Group C) and those with wings, proximal slice, grooves and occlusal coverages (Group D). Thickness of wax patterns was checked before investing and metal thickness was verified post casting to maintain uniformity of all samples.

Design of tooth preparation for RBFPDs is vital to its clinical success.⁸ Earlier designs for this type of dentures, proposed minimal reduction of enamel surface in the lingual/palatal and inters proximal areas. Recent preparations, however advocate more extensive designs with proximal grooves at the line angles adjacent to edentulous area, though it is

Table 1 – Study design.

Groups	Preparation	I	II	III	IV	Total
		Control	Sand blasting	Electro etching	Tin plating	
A	Standard preparation with wings and occlusal rest	5	5	5	5	20
B	Wings with proximal slice	5	5	5	5	20
C	Wings with proximal slice and grooves	5	5	5	5	20
D	Wings with proximal slice, grooves and occlusal coverage	5	5	5	5	20
Total		20	20	20	20	20

Table 3 – Inter group (tooth preparation design) comparisons of 't' values of mean debonding forces.

Groups	t value	Significance
A vs B	2.14	S
A vs C	2.60	S
A vs D	2.73	S
B vs C	0.49	NS
B vs D	0.51	NS
C vs D	0.005	NS

confined to enamel only. Designs are usually terminated at supra gingival levels; a distance of 1 mm away from the incisal/occlusal and gingival margins so as to reduce periodontal response. For anterior prosthesis, a wider area of enamel, which is not visible is used, but for posteriors, occlusal rests and inter proximal wraps are placed. Preparation design differs for maxillary and mandibular tooth also. Lingual surface of mandibular tooth are prepared in a single plane whereas maxillary tooth requires a two plane reduction. Designs of the current study were for the lower teeth and were made as per these guidelines.

The study design tried to incorporate all the design patterns currently in vogue for etched cast RBFPDs. Results proved that Group B, C and D had significantly higher mean debonding forces compared to standard design, Group A. It implied that the groups which used more surface area for tooth preparation performed better in the debonding experiment. This was in agreement to the findings of Emara et al,⁹ Kourtis¹⁰ and Palinfield et al,¹¹ who have highlighted the importance of proximal grooves in augmenting retention. Goodacre et al⁷ reported a sharp fall in failure rates of RBFPDs from 47 to 11% with such extensions on preparations. Potts et al¹² specifically studied the retention and resistance characteristics of preparation designs and found that increase in surface area of the abutment offered greater resistance. This was in conformity to few other reports also.¹³⁻¹⁶ However, the design preparations of group B, C and D did not show marked differences in debonding force values among themselves. This was evident from the statistical analysis.

Clinical failures of RBFPDs are mainly due to the problems associated with breakage of casting from tooth surface emanating from the long-term repeated loading of masticatory forces. Modifications on RBFPDs with and without surface pre-treatment of metallic alloys have been tried to enhance the retentive features of RBFPDs.¹⁷ Methods like sand blasting, electrolytic etching or coating cast metal

surface with a better retentive material is aimed at creating microscopic roughness on the alloy topography.¹⁸ Advantages of sand blasting are that it does not require expensive equipment to perform and the change in appearance of the surface is quite apparent. Electrolytic etching of base metal alloys like nickel-chromium and chromium-cobalt have been found to increase the bonding of resin to etched metal surface.¹⁹ In electrolytic etching, the microstructure of alloy is preferentially dissolved to form porous structure into which hydrophobic composite resins can penetrate for bonding. Unlike sand blasting, where surface roughness created can be visually inspected, electrolytic etching has to be evaluated with the help of a scanning electron microscope. Tin plating of noble metal alloys are also known to increase the bond strength of RBFPDs. The plating can be done as a chair side or laboratory procedure that generates a light gray surface that can facilitate better bonding.²⁰

Results of the study proved that the debonding force values of the castings which were subjected to sand blasting (Group II), electro etching (Group III) and tin plating (Group IV) were significantly higher as compared to the untreated, control group. In Group I, mean readings of treated castings ranged from 336.8 to 362.2 psi as compared to 185.8 psi of the control group. This was in tandem with previous results¹⁷ and to a report that described an increase in the survival rate of RBFPDs up to 64% with pre-treatment procedures.²¹ Among the different alloy pre-treatment methods, Group IV (Tin plating) showed the maximum debonding force values. However, the groups did not show significant differences among themselves.

Composite resins are good for bonding metal frame work to etched enamel. Though conventional BIS-GMA resins are still used, interest on resin metal adhesives like Panavia® (Morita USA), which contain glass filled BIS-GMA are on the rise and was used for the present study.²² Results of the experiment proved that a combination of the following can contribute to effective retention of RBFPDs: (i) tooth preparation that encompasses adequate surface area, (ii) surface pre-treated casting alloy and (iii) glass filled resin composite cement. Successful results for such combinations have been reported in a well conducted meta analysis by Creugers et al.^{23,24}

From the findings of the study, it was concluded that two factors are important for acid etched RBFPDs to ensure optimum clinical results. (i) It should have surface extensions to cover wider area, but the different design patterns do not matter in retention. (ii) Pre-treatment procedures of casting alloys like sand blasting, electro etching and Tin plating can improve retention of the process, irrespective of the method used. Nevertheless, an in-vitro and in-vivo study with large number of samples needs to be under taken to validate current findings.

Table 4 – Inter group (cast pre-treatment) comparisons of 't' values of mean debonding forces.

Groups	t value	Significance
I vs II	5.46	HS
I vs III	6.18	HS
I vs IV	6.34	HS
II vs III	0.49	NS
II vs IV	0.68	NS
III vs IV	0.20	NS

Intellectual contribution

Study concept: Lt Gen Vimal Arora, vsm**.

Drafting and manuscript revision: Lt Gen Vimal Arora, vsm**, Col M.C. Sharma (Retd), Ravi Dwivedi.

Statistical analysis: Col M.C. Sharma (Retd).

Study supervision: Lt Gen Vimal Arora, vsm**, Ravi Dwivedi.

Conflicts of interest

This study has been financed by the research grants from the office of the DGAFMS.

REFERENCES

1. Rochette AL. Attachment of a splint to enamel surface of lower anterior teeth. *J Prosthet Dent.* 1973;30:418–423.
2. Howe DF, Denehy GE. Anterior fixed partial dentures utilizing the acid-etch technique and a cast metal framework. *J Prosthet Dent.* 1977;37:28–31.
3. Lin C, Hsu K, Wu C. Multi-factorial retainer design analysis of posterior resin-bonded fixed partial dentures: a finite element study. *J Dent.* 2005;33:711–720.
4. Koutayas SO, Kern M. Influence of design and mode of loading on the fracture strength of all-ceramic resin-bonded fixed partial dentures: an in vitro study in a dual-axis chewing simulator. *J Prosthet Dent.* 2000;83:540–547.
5. Eshleman JR, Janus CE, Jones CR. Tooth preparation designs for resin-bonded fixed partial dentures related to enamel thickness. *J Prosthet Dent.* 1988;60:18–22.
6. Simonn JF, Gartrell RG, Grogono A. Improved retention of acid-etched fixed partial dentures. A longitudinal study. *J Prosthet Dent.* 1992;68:611–615.
7. Goodacre CJ, Bernal G, Rungcharassaeng K, Kan JY. Clinical complications in fixed prosthodontics. *J Prosthet Dent.* 2003;90:31–41.
8. Saunders W. The effect of fatigue impact forces upon the retention of various designs of resin retained bridge work. *Dent Mater.* 1987;3:85–94.
9. Emara RZ, Byrne D, Hussey DL, Claffey N. Effects of groove placement on the retention/resistance of resin-bonded retainers for maxillary and mandibular second molars. *J Prosthet Dent.* 2001;85:472–478.
10. Kourtis SG. Bond strengths of resin-to-metal bonding systems. *J Prosthet Dent.* 1997;78:136–145.
11. Palinfield S, Wood V, Podesta R. Stress-relieved resin-bonded fixed partial denture. *J Prosthet Dent.* 1989;61:291–293.
12. Potts RG, Shillingburg HT, Duncanson MG. Retention and resistance of preparation for cast restorations. *J Prosthet Dent.* 1980;43:303–308.
13. Priest GF, Donatelli HA. A four-year clinical evaluation of resin-bonded fixed partial dentures. *J Prosthet Dent.* 1988;59:542–546.
14. Barrack G. Recent advances in etched cast restorations. *J Prosthet Dent.* 1984;52:619–626.
15. Gody GF. Shear bond strength of two resin adhesives for acid etched metal prosthesis. *J Prosthet Dent.* 1991;65:767–789.
16. Saad AA, Claffey, Byrne D, Hussey D. Effects of groove placement on retention/resistance of maxillary anterior resin-bonded retainers. *J Prosthet Dent.* 1995;74:133–139.
17. Livaditis GJ, Thompson VP. Etched castings: an improved retentive mechanism for resin-bonded retainers. *J Prosthet Dent.* 1982;47:52–58.
18. Shillingburg Herbert T, Hobo S, Whitsett Lowell D., Jacobi R, Brackkett SE. *Fundamentals of Fixed Partial Prosthodontics*. 3rd ed. Quintessence Publishing Co, Inc.
19. Livaditis GJ, Thompson VP. Etched casting resin bonded retainers I. Resin bond to electrolytically etched non precious alloys. *J Prosthet Dent.* 1983;50:771–778.
20. Breeding LC, Dixon DL. The effect of metal surface treatment on the shear bond strengths of base and noble metals bonded to enamel. *J Prosthet Dent.* 1996;76:390–397.
21. El-Mowafy O, Marcia HMR. Resin-bonded fixed partial dentures- A literature review with presentation of a novel approach. *Int J Prosthodont.* 2000;13:460–467.
22. Pegoraro LF, Barrack G. A comparison of bond strengths of adhesive cast restorations using different designs, bonding agents and luting resins. *J Prosthet Dent.* 1987;57:133–139.
23. Creugers NH, Kayser AF, Van't Hof MA. A meta-analysis of durability data on conventional fixed bridges. *Community Dent Oral Epidemiol.* 1994;22:448–452.
24. Tsiltrou E, Tsangari KN. Fracture strength and mode of anterior single retained all ceramic resin-bonded bridges using a CAD/CAM system. *Int J Comput Dent.* 2012;15:125–136.