ORIGINAL RESEARCH

Evaluation of Bond Strength of Cantilever Resin-retained Bridge Designs: An *In Vitro* Study

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Abstract

Aim: The aim of the study was to compare the bond strength of three cantilever resin-bonded bridge (RBB) designs cemented with resin cements.

Materials and methods: Twenty-four extracted human mandibular canines with eight teeth per group were used in this study to evaluate the bond strength of cantilever resin-retained bridge designs of the mesh, perforated, and combination of mesh and perforated luted to the prepared lingual surface of canine teeth using resin cement. Debonding was done using Instron universal testing machine by applying load on the mid-buccal region of the pontic and the obtained values were evaluated. The data was analyzed statistically.

Results: The mean shear bond strengths of mesh, perforated, and combination of mesh and perforated are 0.88 ± 0.31 MPa, 0.81 ± 0.31 MPa, and 0.93 ± 0.32 MPa. However, there is no significant differences in the statistical analysis that were performed using a one-factor analysis of variant (ANOVA) test ($p = 0.744$).

Conclusion: Within the limitation of this study for cantilever resin-retained bridge designs, the combination of mesh and perforated design showed greater mean shear bond values when compared with the mesh design and perforated designs. This shows equal *in vitro* performance to the gold standard designs (group A is mesh design and group B is perforated design).

Clinical significance: The new design which is the combination of mesh and perforated shows equal *in vitro* performance to the gold standard designs. Thus, their use in clinical situation can bring better result in concern to cantilever resin-retained prosthesis.

Keywords: Bond strength, Fixed partial denture, Mandibular anterior, Resin-bonded bridges, Resin cement.

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Introduction

Quality restorative dentistry has always had one of its goals the conservation of tooth structure. The modern restorative dentistry witnessed the advances in RBBs.[1] Resin-bonded bridges have become a standard treatment option in the field of restorative dentistry. Adhesive technique has transformed the various aspects of dentistry.[2]

Resin-bonded bridge are minimally invasive options for replacing missing teeth. They are reversible as there is little or no tooth preparation, the bridges can be retrieved with no much harm to the abutment tooth.[3] This aspect is beneficial when this type of prosthesis is used as an interim restoration in the young; for example, before implant treatment. Laboratory bills are reduced, as well as chair side time hence they are cheap and quick. Patient preference toward resin bridges is also high due to reduced chair-time, reduced cost, lack of tooth preparation, and minimal requirement of anesthesia.[4] Therefore, it is more beneficial for patients who are hesitant for multiple dental appointments or not able to commit to extensive treatment procedures.[5]

Although these techniques are described as uncomplicated and effective, a detailed treatment planning and precise execution have been necessary for an acceptable success rate.[6] The restorations' duration is still limited, and they have earned an unjustified reputation for failure. Factors related to debonding are restricted enamel surface for bonding, contamination of prepared enamel surface or metal of the resin-bonded prosthesis, improper treatment of the metal surface, insufficient tooth reparation of the abutments, long span edentulous ridges, and excessive occlusal force.[2] When opaque cement is not used there can be trouble with incisal shine-through of metal. Retainers that extend onto the occlusal or incisal surfaces may be seen as well. Small spans tend to be more successful than larger ones. Temporization/trial prosthesis is not usually possible and this prevents evaluation of aesthetics, guidance, and speech. When diastemas are present, or pontic space is too large or small, it is often difficult to distribute the space between pontic and abutment teeth.[4]

The development of Panavia, which contained phosphate monomers, led to a predictable outcome.[4] Panavia a showed higher survival rate than other luting cement which were compared. Durey et al. report that earlier composite resins exhibit degradation and reduced bond strength with time and, in contrast, Panavia demonstrates prolonged high bond strength.[5]

Cantilever RBBs use a single abutment tooth for retention. Resin-bonded bridges are more successful as cantilevers than fixed-fixed restorations. Due to the differential movement of abutment teeth, RBBs with many abutments are more prone to debond, especially when occlusal contact involves the natural

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tooth surface.[5,7] Thus, removal of the debonded restoration and converting the bridge effectively into cantilever design can be an acceptable means of managing partially debonded restoration.

There has not been much study on cantilever RBB designs and thus this study was done to evaluate the bond strength of the mesh design, perforated design, and combination of mesh and perforated framework bonded with resin cement on a mandibular canine supported cantilever design.

Materials and Methods

This study was approved by the Institutional Review Board (IRB reference number- IGIDSIEC2020NRP23PGJRPRI). The study was conducted in a private dental institution at Puducherry. The sample size was estimated based on the previous studies as 24 mandibular extracted canines with 8 for each group.[8]

Collection of Sample

A total of 24 extracted human mandibular canine teeth that had poor periodontal prognosis and mobile teeth with no restoration or dental caries and teeth that have sufficient enamel with the intact crown structure were collected, cleaned of plaque/calculus, and stored in saline.

Preparation of Acrylic Jig

To keep the sample tooth in a fixed position, a wax block of 25 mm × 3 mm was made and an impression was made with addition silicone (DPI Photosil soft putty). Autopolymerizing resin (DPI-RR Cold Cure), liquid monomer and powder polymer was mixed and was poured into the index impression and the tooth were immersed in the center up to the cement–enamel junction. This was done for all 24 samples to obtain a tooth mounted on an acrylic jig.

Preparation of Tooth Surface

Tooth preparation was carried out using diamond rotary instrument on high-torque handpiece (NSK-Pana Air FX handpiece) as per manufacturers' instruction, confining the preparation on the enamel to a depth of 0.7 mm. Chamfer finish line on the lingual surface with definite limit and vertical stops on the cingulum was prepared on the tooth using the diamond point.[4]

The prepared samples were randomly divided into three groups to receive the restoration.

- Group A: Mesh design (D1)
- Group B: Perforated design (D2)
- Group C: Combination of mesh and perforated design (D3)

Die Preparation and Wax Pattern Fabrication

Impression of the prepared samples were made using condensation silicon (Zhermack Zetaplus C silicone) and type IV die stone (Gold Stone) was poured to obtain die on which wax pattern were fabricated using type II inlay wax (GC Inlay wax medium) for three designs of resin-bonded cantilever bridges. For mesh design, a nylon mesh was placed on the prepared surface of the tooth and required size was obtained. A thin layer of type II wax was placed on the nylon mesh and wax pattern was fabricated.

Casting Procedure

After wax pattern was set investing with phosphate bonded investment material (Bellavest SH Bego) and casting was done. The metal framework was checked after which finishing of the metal cast was done (Fig. 1) Three of the castings were defective due to incomplete casting and cracks during casting procedure which were discarded and remade.

Cementation of Prosthesis

The metal prosthesis was cemented to the tooth using Panavia F2.0 which is a self-etching, dual cure; fluoride-releasing cement following the manufacturers guide lines for cementation of base metal alloy (Fig. 2). The cemented prosthesis was tested for shear bond strength after 24 hours following other study data.[9]

Testing of Samples

The shear bond strength was tested using an INSTRON universal testing machine (INSTRON 8874) with crosshead speed of 1 mm per minute (Fig. 3). The force was applied on the mid-buccal region of pontic tooth and the unit load was calculated in Newton and converted to Mega Pascals (MPa). The point of debonding was evaluated using the inbuilt INSTRON software at which load it had occurred. The data were presented as mean and standard deviation for values which were explored for normality using

Fig. 1: Finished and polished castings of cantilever design with mesh, perforated and combination of mesh and perforated (from left to right)

Fig. 2: Cemented prosthesis of all samples of three groups comprising cantilever design with mesh, perforated and combination of mesh and perforated design

Kolmogorov–Smirnov and Shapiro–Wilk tests. The ANOVA test was used to study the shear bond strength on mean values. The significance level was set at $p \leq 0.05$ and 95% confidence interval.

Results

The results obtained from the Instron testing machine were presented in Table 1. The observations were subjected to statistical analysis using statistical package for the social sciences (SPSS) software. Mean, standard deviation, and ANOVA analysis were conducted to evaluate any statistical significance.

The data were presented as mean and standard deviation (SD) for values. The data were explored for normality by checking the data distribution using Kolmogorov–Smirnov and Shapiro–Wilk tests. The ANOVA test was used to study the shear bond strength on mean values. The significance level was set at $p \leq 0.05$ and 95% confidence interval. The mean shear bond strength values of cantilever resin-bonded fixed partial dentures (RBFPDs) are shown in Table 1. The mean shear bond strengths for groups I, II, and III are 0.88 ± 0.31 MPa, 0.81 ± 0.31 MPa, and 0.93 ± 0.32 MPa. Group III (combination of mesh and perforated design) shows higher mean shear bond strength compared to group II (perforated design) and group I (mesh design). The minimum and maximum values of group III (Combination of mesh and perforated design) were also greater when compared to group II (Perforated design) and group I (Mesh design). However, there is no significant differences in the statistical analysis that were performed using a one-way ANOVA test ($p = 0.744$) (Table 2). Hence *post hoc* test was not required.

Fig. 3: Load applied on the mid-labial of pontic of the test specimen to test bond strength

Discussion

The study was done to evaluate the bond strength of three designs of cantilever RBBs luted on the prepared lingual surface of extracted mandibular canine using Instron testing machine. Kolmogorov–Smirnov and Shapiro–Wilk tests were done to analyze the data obtained by debonding. The ANOVA test was used to study the shear bond strength on mean values. The significance level was set at $p \leq 0.05$ and 95% confidence interval. The mean shear bond strength for groups D1, D2, and D3 is 0.88 ± 0.31 MPa, 0.81 ± 0.31 MPa, and 0.93 ± 0.32 MPa, respectively. Mean shear bond strength values were found to be greater in combination of mesh with perforation design (D3). However, there is no significant differences in the statistical analysis that was performed using a one-way ANOVA test ($p = 0.744$).

The resin-bonded prosthesis is classified as direct and indirect based on wax pattern fabrication in which the indirect is further classified as macro-mechanical, micromechanical, and chemical based on the type of retention.[10] In this study, the combination of mesh and perforated design was used (group D3). The mesh design and perforated design comes under macro-mechanical retention therefore the new design fabricated in this study also comes under the macro-mechanical type of retention.

Burgess and McCartney concluded that the resin-bonded prosthesis may be regarded as permanent restoration and a valuable asset in the clinician's armamentarium. Electrolytically etched castings of different designs were cemented to prepared enamel and the load required to displace these castings was compared with the load required to displace anterior and posterior three-quarter crowns. The prosthesis was cemented with zinc phosphate cement. In this study, it was confirmed that the most efficient preparations involved distinct proximal grooves or a labial extension (wrap). Preparations without facial wraparound, grooves or a single pinhole were significantly less retentive.[9]

On comparison of Rochette and Maryland bridge design by TL Berekally and Smales RJ, with excluding pontic failures, Maryland

Table 1: Mean shear bond strength values of cantilever RBFPD

Group	*N*	*Mean*	*Standard deviation*	*Standard error*	*95% Confidence interval for mean*		*Minimum*	*Maximum*
					Lower bound	*Upper bound*		
Mesh design	8	0.881	0.314	0.111	0.618	1.144	0.500	1.427
Perforated design	8	0.815	0.319	0.112	0.548	1.082	0.300	1.358
Combination of mesh and perforated design	8	0.938	0.321	0.113	0.669	1.207	0.646	1.550
Total	24	0.878	0.308	0.063	0.748	1.008	0.300	1.550

Table 2: One-way ANOVA test of data from the tested samples

	Sum of squares	*df*	*Mean square*	*F*	*Significant value (p)*
Between groups	0.061	2	0.030	0.300	0.744
Within groups	2.131	21	0.101		
Total	2.192	23			

bridges had a significantly better survival rate than did the Rochette bridges.[11] However, in this study, the data shows superior bonding in group D3 (combination of mesh and perforated design). Also, this study did not involve Maryland design.

Olin, Hill, and Donahue conducted a retrospective study on clinically evaluating the RBBs in which the results showed that prostheses with more than two retainers had twice the probability for problems of failure and debonding.[12] Chan and Barnes compared the clinical performance of cantilever RBBs with a fixed-fixed design for the replacement of a maxillary permanent incisor and concluded that debonding occurred in only fixed-fixed type, which was successfully rebounded. There was no debond in the cantilever group.[1] This was also supported by Kern who said that cantilever all-ceramic RBFPDs made from high-strength oxide ceramics present a promising treatment alternative to two-retainer RBFPDs in the anterior region.[13] Thus, cantilever design was chosen for this study.

Ibrahim et al. evaluated the effect of three different thicknesses of base metal restoration bonded retainer (0.3-, 0.5-, and 0.7-mm thickness) bonded to central incisors, lateral incisors and canine. Greater the thickness, greater was the force needed for the dislodgment in this study.[2] The thickness of the retainer in this study was chosen as 0.7 mm and the tooth to be bonded was chosen as canine based on this study result.

A study was conducted by Charles–Ellie Sillam et al. to compare the effect of tooth surface preparation on the bond strength of zirconia cantilever single-retainer RBFPDs. The load was applied on the mid buccal region of the pontic tooth until the debonding of the restoration occurred. The mean shear bond strength values for the groups are as follows: group D1: retainer with a surface of 20 mm^2 + proximal box with a surface of 12 mm^2, group D2: retainer with a surface of 10 mm^2 + proximal box with a surface of 12 mm^2, group D3: no retainer and only a proximal box with a surface of 12 mm^2 were 2.39 ± 0.53 MPa, 3.13 ± 0.69 MPa, and 5.40 ± 0.96 MPa, respectively.[14] In our study, the debonding force was applied on the mid buccal region of the pontic tooth using the data of this study.

The effect of five retainer designs on the retention of resin-bonded prosthesis was studied by Williams et al. and concluded that all designs were retentive enough for the force of occlusion on anterior tooth region which was generated by human beings.[8] The fabrication of the perforated and mesh design of the prosthesis which is used in this study was based on this previous study in which retentive holes were drilled with a No. 1/2 round bur for perforated design and polyester mesh screen was used for the mesh design. The mesh was adapted to the lingual surface of the prepared die and hard inlay wax was used to form the periphery of the pattern. They also concluded that failures occurred on the retainer-composite interface.

Panavia F2.0 was used as a luting agent since, strong and durable adhesive bonding between a metal framework and tooth is important to withstand various changes in the oral environment. Adhesion of resin to a substrate depends on both micromechanical interlocking and physicochemical bonding.[15] Balasubramaniam, in his study, stated that bridges cemented with Panavia showed the highest survival rate (67%) among the luting cements analyzed for 5 years.[7]

Yun designed his study to evaluate the effect of sandblasting and metal primers on the shear bond strength of three commercial resin cements to Yttria–Tetragonal Zirconia Polycrystal (Y-TZP) ceramics. His results showed that in Panavia F 2.0, the bond strength of the specimens treated with sandblasting and metal primer (alloy primer) was significantly higher than those of the other subgroups (V-primer – Superbond C&B, Metaltite – M bond).[16] Hence, Panavia F2.0 was the material of choice for luting of the RBB in this study.

Limitations

The limitation of the study included being *in vitro* in nature, and the clinical performance of this new design which is yet to be evaluated for success by the further *in vivo* studies.

Conclusion

Within the limitation of this study, the combination of mesh and perforated design showed greater mean shear bond values when compared with the mesh design and perforated designs. However, there is no significant differences in the statistical analysis that were performed. The results obtained from this study shows that the bond strength of the combined mesh and perforated design showed equal *in vitro* performance to the gold standard designs (group A: mesh designs and group B: perforated designs).

Further studies on clinical performance of this new design are yet to be evaluated for success.

Author Contributions

Jenie Rosna Albert: Concept, design, literature search, experimental studies, data acquisition, data analysis, statistical analysis, manuscript preparation, and manuscript editing; David Livingstone: Concept, design, the definition of intellectual content, data analysis, statistical analysis, manuscript editing, and manuscript review; Shivasakthy Manivasakan: Design, manuscript editing and manuscript review; Rajkumar Eugene: Data analysis, manuscript review; Varsha Ravichandran: Literature search.

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