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Effect of Surface Treatment on Shear Bond Strength of Two Intraoral Porcelain Repair Systems: An In Vitro Study

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ABSTRACT

Background: Metal-ceramic restorations exhibit high potential to fracture and pose an aesthetic & functional dilemma. This has created a demand for the development of practical repair options which do not necessitate the removal and remake of the entire restorations.

Aim: To evaluate and compare the shear bond strength of two intraoral porcelain repair systems after two different surface treatments.

Materials and methods: Forty four metal ceramic disc specimens were fabricated using a base metal alloy and feldspathic porcelain in which a defect was created to simulate fracture. They were then divided into 2 groups according to the porcelain repair system used to repair the fractured specimens viz Group I - A.C.E repair system (Prevest Denpro) and Group II - Angelus repair system (Angelus). Each group was further divided into two subgroups depending on the surface treatment method used prior to repair viz sandblasting and diamond bur roughening. Shear bond strength of the repaired specimens was evaluated with a universal testing machine after storing in distilled water at 37^{0}C for 7 days. The bond strength was analyzed by one-way ANOVA & independent t-test followed by post hoc comparison using Tukey's test & two- way ANOVA. The type of fracture failure was also recorded for each sample.

Results: The difference between the groups was statistically significant for sandblasting surface treatment. A.C.E repair system with sandblasting surface treatment showed the greatest value than any other groups. Mode of failure did not show any statistically significant difference in all the four subgroups.

Conclusion: The results of this study showed that A.C.E repair system along with sandblasting surface treatment showed the highest shear bond strength values as compared to all other groups. Overall, more of adhesive and mixed failures were observed indicating good inherent strength of the repair materials.

Keywords: Shear bond strength, Angelus repair system, A.C.E repair system, Porcelain repair, Composite resin.

INTRODUCTION

Porcelain fused to metal restorations have always been widely used in dentistry as natural looking tooth restorations.[1] They still remain the 'gold standard' in Prosthodontics since their introduction in the1960s. They combine the biomechanical advantages of metals with the aesthetics of porcelain materials resulting in restorations with considerable clinical longevity.[2] Almost all the restorations are responsive to failure during function. Failure may be due to biological,

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mechanical or combination of both. These kind of failures can be classified as simple i.e., involving only the porcelain body, mixed i.e., associated with the exposure of metal and porcelain and complex i.e., with substantial metal exposure.[3] Hence, despite bonded porcelain being exceptionally strong, porcelain fracture in the metal-ceramic restorations may occur due to repeated stresses and strains during chewing.[4] The universality of fracture of metal-ceramic restoration is approximately 2-5%.[5] Fractured porcelain will affect aesthetics and function of the prosthesis, due to which patients seek instant treatment.[6] The replacement of failed prostheses, is often not possible, as it requires additional time, cost and effort. In these circumstances, repair is a suitable method to rebuild the contour and colour of fractured restorations.[3] Intraoral repair options such as various intraoral repair materials prevent replacement of the fractured restoration.[7] Various porcelain repair systems available are based on dimethacrylate or hydroxyethylmethacrylate.[3]The benefit of porcelain repair system depends upon the strength of the bond between porcelain and resin material. The bond is achieved either by the mechanical or chemical methods.[8] The treatments that promote mechanical retention include airborne particle abrasion with aluminium oxide, roughening with a diamond rotary cutting instrument or etching with hydrofluoric acid, or phosphoric acid. Chemical adhesion can be achieved with silanization or application of adhesive primers.[9] Shear bond strength is an important parameter to assess the clinical success of the repair. There is limited literature available on the effect of type of repair system and surface treatment on shear bond strength. Thus, the present study was initiated to evaluate this property of two intraoral porcelain repair systems i.e. A.C.E repair system and Angelus repair system after two different surface treatments viz. sandblasting and diamond bur roughening. Also, the type of repair fracture was evaluated in all the specimens.

MATERIALS AND METHODS

Forty four metal ceramic discs were fabricated (20 mm in diameter and 2.5 mm in thickness) with nickel-chromium base metal alloy forming 0.7 mm and porcelain forming 1.8 mm of the total thickness of the disc. To standardize the dimensions of metal ceramic disc, a metal jig was fabricated with a circular ring of 2.5 mm depth and 20 mm internal diameter (Figure 1&2). For the same, forty four wax patterns were fabricated using inlay wax and a stainless steel metal die with internal diameter of 20 mm and 0.7 mm height. The wax patterns were invested in a casting ring using phosphate bonded investment material which was mixed using a vacuum mixer. The casting ring with invested patterns was placed in an oven, which had been previously heated to 800^{0}C to carry out the wax burn out according to manufacturer's instructions. Next, the casting ring was removed from the oven and molten alloy was casted using an induction casting machine. The metal specimens were then retrieved from the investment. Care was taken not to damage the edges of the disc. Finishing of the specimens was done with the help of carborundum discs to achieve a uniform dimension of 20 mm diameter× 0.7 mm thickness.

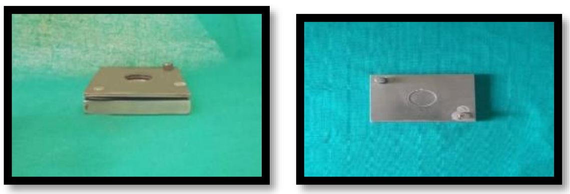


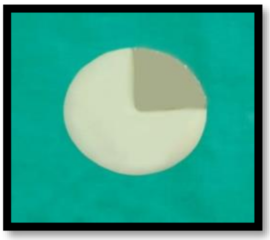
Fig 1&2: Metal jig for metal ceramic specimens (20mm diameter and 2.5mm thickness)

After that the porcelain application was done on metal specimens. Porcelain was applied over metal disc in the thickness of 1.8 mm (0.2 mm opaque, 0.8 mm dentine and 0.8 mm enamel) with the aid of the metallic jig. Finally, the samples were finished and glazed to achieve metal ceramic discs of 20 mm diameter and 2.5 mm thickness. The metal ceramic specimens were then bonded to Polymethyl methacrylate (PMMA) resin to aid in holding the specimens in Universal Testing Machine. In order to simulate ceramic fracture, a defect was created in all the specimens by removing one-fourth diameter of ceramic till the metal was exposed. All the fractured metal ceramic discs were then divided into two groups according to porcelain repair systems i.e. A.C.E repair system and Angelus repair system. Each group was further subdivided into two subgroups depending on the surface treatment (n=11): a) sandblasting and b) diamond bur roughening (Table 1).

Table 1: Surface Treatments

Repair system	Surface treatment	Groups
ACE repair system (PrevestDenpro)(Methylmethacrylate based)	Sandblasting	Group Is
	Diamond bur roughening	Group Id
Angelus repair system (Angelus) (Urethane Dimethacrylate based)	Sandblasting	Group IIs
	Diamond bur roughening	Group IId

Before application of porcelain repair system, specimens of Groups Is and IIs were sandblasted (Figure 3) using 50µm sized alumina particles for 15 seconds in the defect area and then cleansed with steam cleaner. Groups Id and IId specimens were surface treated with diamond bur roughening (Figure 4) in the defect area using tapered coarse grit diamond point and then cleansed with steam cleaner. After surface treatment of all samples, repair was carried out using the two systems following the manufacturer's instructions.



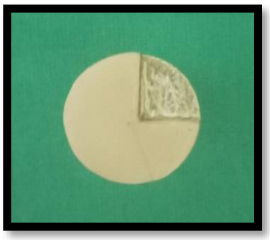


Fig 3: Sandblasting surface treatment, Figure 4: Diamond bur roughening.

Group I specimens were subjected to A.C.E. porcelain repair system (Figure 5). First of all, metal primer was applied on treated surface to improve the metal-composite bond. After that, 5% hydrofluoric acid etchant was applied for 90s and then rinsed with water and allowed to dry. Silane coupling agent was then applied and allowed to dry for 1 min. After that, bonding agent was applied and polymerized with a light curing unit for 20s. Then, a thin layer of composite was applied to mask the metal and light polymerized for 40s. Additional composite resin was applied till the level of ceramic surface and light polymerized for 40s followed by finishing of the repaired surface (Figure 6).

Fig 5: A.C.E Repair System kit

Fig 6: A.C.E repair system application

Group II specimens were subjected to Angelus porcelain repair system (Figure 7). First of all, metal primer was applied on the treated surface. This was followed by 10% hydrofluoric acid etchant gel, which was applied for 1 min, then washed abundantly with water, and dried thoroughly. Silane coupling agent was then applied for 1 min and dried. Next, the bonding agent was applied and after air drying, the surface was polymerized with a light curing unit for 10s. Then, a thin layer of composite was applied and light polymerized for 40s. Additional composite resin was applied till the level of ceramic surface and polymerized for 40s followed by finishing of the repaired surface (Figure 8).

Fig 7: Angelus Repair System kit.

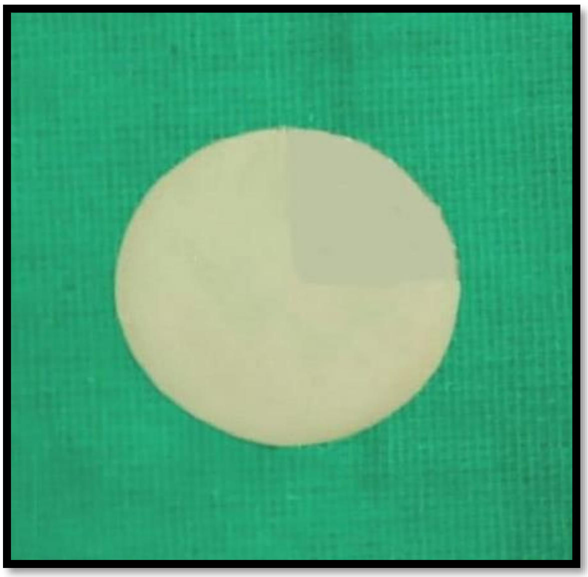


Fig 8: Angelus repair system application.

The repaired samples were then stored in distilled water at 37⁰C for a week before being subjected to a shear load using Universal Testing Machine with a 10 KN load cell at a crosshead speed of 0.5mm/min. Each sample was held in a metal jig for shear bond testing. A chisel load applicator was used to direct a parallel shearing force as close as possible to the metal/repair material interface (Figure 9). The fracture load values for each subgroup were recorded and the type of fracture was observed for each specimen.

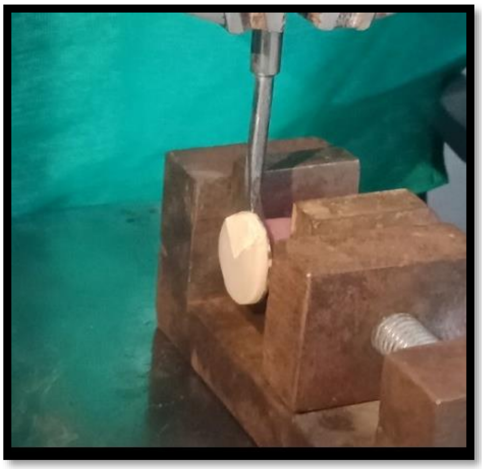


Fig 9: Load application for shear bond testing

Fracture load was converted to shear bond strength (MPa) using the following formula:

Shear bond strength (MPa) = Fracture load (kg) /Area of the repair composite (mm^2)

The type of fracture failure was recorded for each sample i.e. whether adhesive or cohesive or mixed.

Statistical analysis

Data was analysed using Statistical Package for Social Sciences (SPSS) version 21, IBM Inc. Shapiro Wilk test was used to check which all variables were following normal distribution. As data was found to be normally distributed, bivariate analyses was performed using independent t test and one-way ANOVA followed by post hoc comparison using Tukey's test and two-way ANOVA.

RESULTS

Mean shear bond strength of the two intraoral porcelain repair systems was compared and overall difference was found to be statistically significant as $p<0.05$ i.e. shear bond strength was found to be better for Group I (Table 2). Among samples of Group I, mean shear bond strength was found to be 17.56±1.15 when treated with sandblasting and 16.79±1.44 when treated with diamond bur roughening. Among samples of Group II, mean shear bond strength was found to be 13.56±0.90 when treated with sandblasting and 15.49±1.88 when treated with diamond bur roughening (Table 3). Intergroup comparison of shear bond strength of Group I and Group II samples treated with sandblasting (Table 4) showed that it was significantly higher in Group I samples as compared to Group II samples. Intergroup comparison of shear bond strength of Group I and Group II samples treated with diamond bur roughening (Table 5) showed no significant difference. The type of failure was evaluated among different study groups using Chi square test, the overall difference failed to reach the level of statistical significance as p>0.05 (Table 6).

Table 2: Mean shear bond strength of two intraoral porcelain repair systems

Groups	Mean	Std. Deviation
Group I- A.C.E. repair system	17.1823	1.33979
Group II Angelus repair system	14.5286	1.75052
p value	<0.0001*	

Table 3: Sub-group wise distribution of Mean shear bond strength of two intraoral porcelain repair systems.

Groups	Subgroups (Surface treatment)	Mean	Std. Deviation
Group I- A.C.E. repair system	Sandblasting (Group Is)	17.5691	1.15923
	Diamond bur roughening (Group Id)	16.7955	1.44796
Group II- Angelus repair system	Sandblasting (Group IIs)	13.5627	.90564
	Diamond bur roughening (Group IId)	15.4945	1.88741

Table 4: Intergroup comparison of shear bond strength of Group I and Group II samples treated with sandblasting.

Groups	Subgroups (Surface treatment)	Mean	Std. Deviation
Group I- A.C.E. repair system	Sandblasting (Group Is)	17.5691	1.15923
Group II- Angelus repair system	Sandblasting (Group IIs)	13.5627	.90564
P value	<0.0001 S		

Table 5: Intergroup comparison of shear bond strength of Group I and Group II samples treated with Diamond bur roughening.

Groups	Subgroups (Surface treatment)	Mean	Std. Deviation
Group I- A.C.E. repair system	Diamond bur roughening (Group Id)	16.7955	1.44796
Group II- Angelus repair system	Diamond bur roughening (Group IId)	15.4945	1.88741
P value	0.146 NS		

Table 6: Distribution of study sample according to type of failure.

			Type of failure			Total
			Mixed	cohesive	adhesive	
Subgroups.	Group I-s	N	5	1	5	11
		%	45.5%	9.1%	45.5%	100.0%
	Group 1-d	N	4	0	7	11
		%	36.4%	0.0%	63.6%	100.0%
	Group II-s	N	7	1	3	11
		%	63.6%	9.1%	27.3%	100.0%
	Group II-d	N	5	3	3	11
		%	45.5%	27.3%	27.3%	100.0%
Total		N	21	5	18	44
		%	47.7%	11.4%	40.9%	100.0%
P value		0.307 NS				

DISCUSSION

Porcelain fused to metal restorations have always been one of the most commonly used restorations in fixed prosthodontics. Unfortunately, they are more prone to fracture under shear stress. Hence, it is essential to quantify the strength of the intraoral porcelain repairs with the shear bond test. These failures are fairly common in porcelain and have been reported in the range of 2.3%–8%[7,8,9,10]. Currently available intraoral porcelain repair systems enhance the mechano-chemical bond between resin and metal or ceramic substrate by mechanically increasing the surface area, decreasing the surface tension and causing physical alteration which promotes adhesion of resin to porous surface of metal ceramic restoration. The recently introduced repair systems make use of silane coupling agents containing methacrylate group which promotes adhesion of resin to fractured metal-ceramic restorations.[11]

This study was conducted to evaluate the effect of two different metal substrate surface treatments on the shear bond strength of two intraoral porcelain repair systems. The results of this study showed that mean shear bond strength of A.C.E. repair system was 17.56±1.15MPa when treated with sandblasting (Group Is) and 16.79±1.44 MPa when treated with diamond bur roughening (Group Id) and among samples of Angelus repair system, mean shear bond strength was found to be 13.56±0.90 MPa when treated with sandblasting (Group IIs) and 15.49±1.88 MPa when treated with diamond bur roughening (Group IId). The comparative difference in the values was statistically significant for all the four groups except for that between Group Is and Group Id. For A.C.E repair system, sandblasting surface treatment showed higher values than diamond bur roughening and for Angelus repair system, diamond bur roughening showed higher values than sandblasting surface treatment.

As per the studies done earlier, shear bond strength of composite to porcelain with various porcelain repair systems have been reported in the range of 6–29.9 MPa.[7,8,13] The bond strength values of both the repair systems along with both the surface treatments lie well within this range. The results for ACE repair system are in agreement with studies done earlier where no significant difference could be seen in shear bond strength of composite resin to metal after surface preparation of metal with diamond bur or sandblasting.[14,15,16]. Some studies have shown that higher bond strength values were obtained with the diamond bur roughening on exposed metal as compared to sandblasting.[17,18,19] Whereas, Ji-Young Yoo et al[7] in their study found that higher bond strength values of composite resin to metal and ceramic were obtained with sandblasting as compared to diamond bur roughening.

The bond between porcelain and metal substructure is due to mechanical entrapment, compressive forces, Van der Waals forces and chemical bonding, whereas in porcelain repair system, it depends on multiple factors such as type of etchant, the composition of alloy primer used in porcelain repair systems and type of surface treatment of metal substructure.

Both the systems showed good bond strength values which could be due to the presence of 4-META (in A.C.E repair system) and MDP (in Angelus repair system) in their adhesive systems and the presence of 5% buffered hydrofluoric acid etchant (A.C.E repair system) and 10% hydrofluoric acid etchant (Angelus repair system)[20]. Sandblasting enhances the bond strength of intraoral repair systems as it promotes micromechanical retention by creating roughness on the surface, thereby increasing total surface area, decreasing surface tension and enhancing wetting by the resin. Whereas, roughening with diamond bur may create surface irregularities and micro cracks within the metal surface. In this study, the two surface treatments showed a statistically significant impact on shear bond strength of the two repair materials.

Type of failure was also recorded during the fracture, which was classified into three types: adhesive, cohesive and mixed. On a comparative evaluation, A.C.E repair system (Prevest Denpro) showed more of adhesive failure and Angelus repair system (Angelus) showed more of mixed failure. No statistically significant distribution could be found in all the four groups though overall more of adhesive and mixed failures were observed indicating good inherent strength of the repair materials.

Based on the above results and discussion, it is recommended that both repair systems can be used with either of the two surface treatments. Though, A.C.E repair system (Prevest Denpro) with sandblasting as surface treatment may be preferred and Angelus repair system with diamond roughening may be preferred.

CONCLUSION

Within the limitations of the study, the following conclusion could be drawn:

- Comparative evaluation of the mean bond strength of the two repair systems showed that the values for A.C.E repair system were higher than Angelus repair system and the difference was statistically significant.
- Comparative evaluation of the mean bond strength of all the four subgroups showed that A.C.E repair system with sandblasting had the highest value and Angelus repair system with sandblasting had the lowest value.
- Application of sandblasting with A.C.E repair system resulted in significantly higher shear bond strength in comparison to sandblasting with Angelus repair system.
- Application of diamond bur roughening with A.C.E repair system resulted in higher bond strength in comparison to diamond bur roughening whereas in Angelus repair system there was not statistically significant difference.
- Application of sandblasting and diamond bur roughening with A.C.E repair system showed no significant difference in shear bond strength.
- Application of sandblasting and diamond bur roughening with Angelus repair system showed no significant difference in shear bond strength.
- Mode of failure did not show any statistically significant difference in all the four subgroups.
- Based on the above findings, it is recommended to use both the repair systems clinically for porcelain repair, A.C.E repair system preferably with sandblasting and Angelus repair system preferably with diamond bur roughening.

Further clinical studies with larger sample size are required to evaluate shear bond strength of various repair systems with various other surface treatments to generalize the results and to verify the systems that offer the best clinical performance.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

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