Comparison of shear bond strength of two porcelain repair systems after different surface treatment

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Abstract

Introduction: Intraoral chair side porcelain repair system is a quick, painless and highly patient acceptable procedure, without removal of restoration or fabrication of new restoration. There are very limited studies conducted to evaluate the shear bond strength of repair systems after different surface treatment. **Objectives of Research:** The objective of research was to evaluate the shear bond strength of two intraoral porcelain repair systems Clearfil repair system (Kuraray) and Ceramic repair system (Ivoclar) to repair metal-ceramic restoration after three different surface treatment. **Materials and Methods:** Totally, 120 discs of base metal alloy were fabricated. The opaque, dentine and enamel of ceramic were applied to achieve the uniform thickness. Defect was created, and repair was done using two repair systems after different surface treatment. Shear bond strength was measured. **Results:** Analysis of variance was utilized. Ceramic repair system after 40% phosphoric acid surface treatment showed the highest mean value and Clearfil repair system after surface treatment with 37% phosphoric acid showed the lowest. The statistical difference was found to be significant between the groups. **Conclusion:** The shear bond strength of Ceramic repair system with 40% phosphoric acid etching showed highest shear bond strength as compared to other system and surface treatment used in the study.

Keywords: Metal, porcelain, primer

Introduction

Ceramic was first introduced in dentistry for making denture teeth by De Chemant in 17th century and followed by Alex Duchateau.[1] Their success was limited due to low tensile strength and brittleness. Subsequently, innovations and advancements were attempted to strengthen dental ceramic. The prevalence of fracture of metal-ceramic restorations is approximately 2–5%[2] and has been reported as the second greatest cause for the replacement of restorations after dental caries.[3] The conventional metal-ceramic restorations may fracture in the form of chipping or de-veneering of ceramic due to bond failure between ceramic and metal.

Fracture may result from trauma, fatigue, occlusal prematurity, parafunctional habits, poor abutment preparation, inappropriate coping design and incompatibility of coefficient of thermal expansion between ceramic and the metal structure. Intraoral chairside porcelain repair system is a quick, painless and highly patient acceptable procedure, without removal of restoration or fabrication of new restoration.

Many repair agents such as cyanoacrylates, acrylic and composite resins were used but were partially successful due to esthetic and mechanical limitations.[1,4] The earlier repair systems generally used two-component silane coupling agents (silane and acid) designed to chemically bond composite to the silica (SiO_2) component of ceramic, but had low shear bond strength.[5]

The recently introduced repair systems contain 10-methacryloyloxydecyl dihydrogen phosphate (MDP), which recommends physical alteration of ceramic and metal substrates in conjunction with chemical agents such as metal primer, ceramic primer and improved silane coupling agents to promote adhesion of resin to fractured metal-ceramic restorations. The wide range of bond strength values from 3 to 37.4 MPa have been documented for repair systems in the literature.[6,7] There are very limited studies conducted to evaluate the shear bond strength of various intraoral porcelain repair systems to ceramic and metal substrates after different surface treatment.

Objectives of research

The objective of research was to evaluate the comparative evaluation of shear bond strength of two commercially available different intraoral porcelain repair systems Clearfil repair system (Kuraray) and Ceramic repair system (Ivoclar)

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to repair metal-ceramic restoration after three different surface treatment that is, air abrasion with 50 μ aluminum oxide followed by 40% phosphoric acid, air abrasion with 50 μ aluminum oxide followed by 37% phosphoric acid, and air abrasion with 50 μ aluminum oxide followed by 8% hydrofluoric acid. The shear bond strength was calculated using Universal Testing Machine (UTM) and the mode of failure was analyzed by visual examination.

Materials and Methods

Methodology

One hundred and twenty discs of base metal alloy (Wiron 99, Bego, Germany) of 20 mm diameter and 0.7 mm in thickness were fabricated after investing and casting of wax patterns (Y-Dent). Two coats of opaque layer (VITA VMK 95, Germany) were applied in the thickness of 0.2 mm and fired according to manufacturer's instructions. A layer of 0.8 mm of dentine was applied to the samples with an aid of a custom made metallic jig followed by application of 0.8 mm of enamel layer (VITA VMK 95, Germany). Finally, the samples were finished and glazed to achieve a uniform thickness of 2.5 mm. In the center of samples, the ceramic was removed until the metal is exposed to create a circular defect of 4 mm in diameter.

Distribution of samples

A total of 120 samples, after the sandblasting with 50 μ alumina (Zhermack), were categorized in six groups on the basis of a combination of surface treatment with porcelain repair system used [Table 1].

All samples were stored in 37°C distilled water for a week before thermocycling. After this, the samples were thermocycled at temperature ranging from 6°C to 60°C with a total thermocycling time of 24 h (approx 500 cycles). A metal jig was used for holding of the samples to determine the shear bond strength. UTM with a 10 KN load cell and a crosshead speed 0.5 mm/min was used. A chisel load applicator was used to direct shearing force parallel and as close as possible to the composite/defect substrate interface [Figure 1]. The fracture load was recorded with the help of graph shown on digital monitor attached to the machine. Fracture loads (kg) were converted to shear bond strengths (MPa) by formula:

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

The mode of failure of samples were recorded visually by observer and classified as adhesive (failure at substrate-resin interface), cohesive (failure within the substrate or within restorative material) or combination failures (area of adhesive and cohesive failure).

Data obtained were entered into MS Excel spreadsheet and the statistical operations were carried out through Statistical Presentation System Software, IBM (SPSS version 8) for Windows. Descriptive statistics was calculated for each variable for the six groups. The values of the shear bond strength of six groups were compared using one-way analysis of variance (ANOVA) test.

Results

One-way analysis of variance

In the present study, ANOVA was utilized to find out the significance of difference between and within groups of repair systems after different surface treatment. The comparison was made between the mean shear bond strength values and their respective standard deviation, of Groups I to Group VI repaired with both repair systems [Table 2].

Among the Groups, Group IV samples repaired with Ceramic repair system (Ivoclar) after 40% phosphoric acid surface treatment showed the highest mean value (16.08 ± 1.99) and the lowest mean value was shown by the samples of Group II repaired with Clearfil repair system (Kuraray) after surface treatment with 37% phosphoric acid with mean value

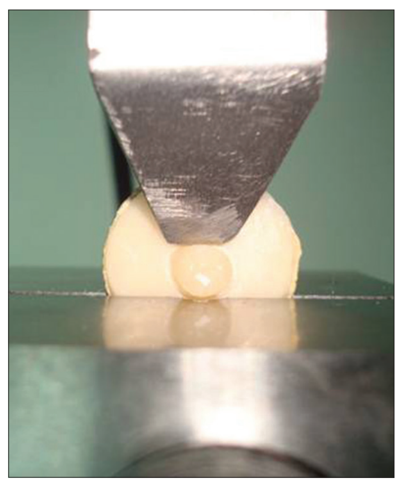


Figure 1: The chisel placement

Table I: Distribution of samples

Metal-ceramic disc (*n*=120)					
Kuraray repair system			**Ivoclar repair system**		
Various surface treatment provided					
Group I 40% Phosphoric acid (*n*=20)	Group II 37% Phosphoric acid (*n*=20)	Group III 8% Hydrofluoric acid (*n*=20)	Group IV 40% Phosphoric acid (*n*=20)	Group V 37% Phosphoric acid (*n*=20)	Group VI 8% Hydrofluoric acid (*n*=20)

of (13.37 ± 2.05) [Graph 1]. The statistical difference was found to be significant between the groups ($P < 0.05$) [Table 3].

The statistical difference was found to be nonsignificant between the Groups I-III ($P > 0.05$) and Groups IV-VI.

Type of failure analyzed visually showed that in Group I-III had more of adhesive failure whereas Group IV-VI had more of cohesive failure [Graphs 2 and 3].

Discussion

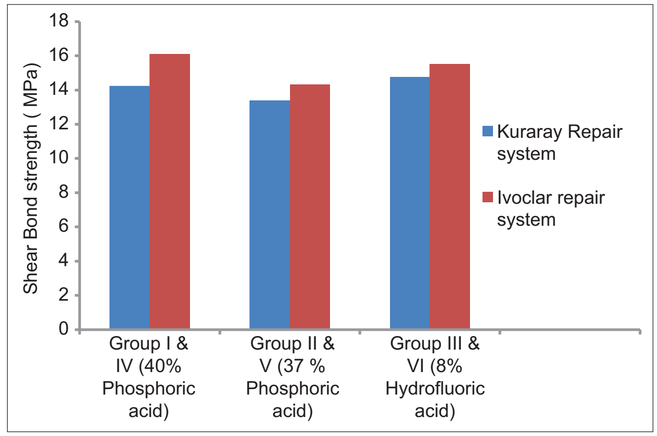
It is evident from data available in the literature that anterior metal-ceramic restorations are more prone for fracture.[19,20] Anterior restorations are primarily subjected to shear stress, and the shear bond test is considered appropriate for quantifying the strength of the intraoral porcelain repairs.[18]

Intraoral repair system enhances the mechano-chemical bond between resin and metal or ceramic substrate by mechanically increasing the surface area, decreasing the surface tension and by causing physical alteration which promoted adhesion of resin to porous surface of the metal-ceramic restoration. The physical alteration is achieved by selectively dissolving the glassy matrix chemically.[13,14,15]

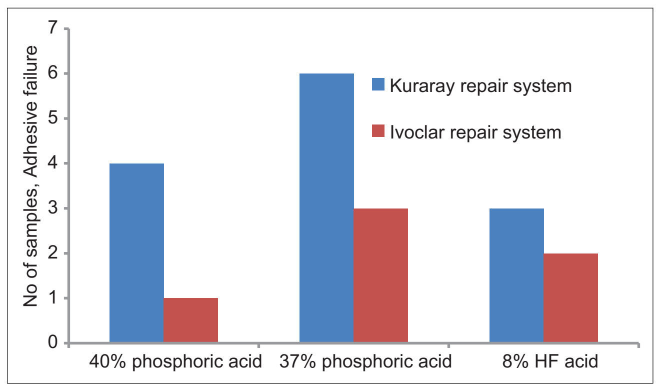
In this study, a standardized protocol for defect formation, etching, silanization and primer application was followed as recommended by the manufacturer for repair of metal-ceramic restoration. Thus, the shear bond strength calculated from this study is the true representation of bond strength values of the respective system with the best combination of acid etching in the testing conditions.

It is evident from the above results that, air abrasion with 50 μm aluminum oxide, followed by etching with 40% phosphoric acid with Ceramic repair system (Ivoclar) is more effective than any other surface treatment and another repair system. These findings are in agreement with the previous studies[5,8,11,16,17,21,23] who reported that higher bond strengths of intraoral repair systems to ceramic and metal were achieved with air abrasion than the roughening with diamond bur. However, these results are in disagreement with Jochen and Caputo[7] and Suliman *et al*. 1993,[12] who stated that higher bond strength of intraoral repair systems were obtained with roughening with diamond bur and etching with hydrofluoric acid than air abrasion alone.

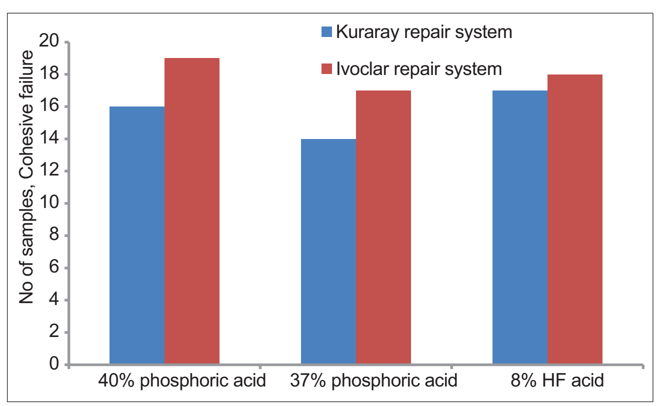
Air abrasion with 50 μm aluminum oxide particles enhances the bond strength of intraoral repair systems as it promotes micromechanical retention by creating very fine obtuse angular roughness on the surface, thereby increasing total surface area, decreasing surface tension and enhancing wetting by the resin.[19] Whereas, roughening with diamond bur may create sharp surface irregularities and microcracks within the ceramic surface causing stress concentration and subsequent fracture. Air abrasion when used for metal substrate produces uniformly frosted surface having shallow interconnected furrows. These furrows draw primer and adhesive agents onto the abraded surface through capillary



Graph 1: The comparison of shear bond strength between Group I and IV, Group II and V and Group III and VI after being subjected to different surface treatments



Graph 2: The number of adhesive failures among the samples of all groups, repaired with both repair systems after various surface treatments



Graph 3: Showing the number of cohesive failures among the samples of all groups, repaired with both repair systems after various surface treatments

Table 2: Comparison of Groups I-VI showing the mean, SD and minimum/maximum values of the shear bond strength for all groups (*n*=120)

Descriptives (MPa)								
Groups	*n*	Mean	SD	SE	95% CI for mean		Minimum	Maximum
					Lower bound	Upper bound		
I	20	14.23	2.91	0.65	12.87	15.59	6.40	16.64
II	20	13.37	2.05	0.45	12.41	14.33	8.08	16.00
III	20	14.76	2.16	0.48	13.75	15.78	12.60	18.60
IV	20	16.08	1.99	0.44	15.14	17.01	13.60	18.64
V	20	14.32	3.86	0.86	12.51	16.12	10.40	27.80
VI	20	15.51	2.13	0.47	14.51	16.51	12.00	18.72
Total	120	14.71	2.70	0.24	14.22	15.20	6.40	27.80

SD: Standard deviation; SE: Standard error; CI: Confidence interval

Table 3: Showing the comparison of shear bond strength between the Groups I-VI and their significance

ANOVA (MPa)					
	Sum of squares	df	Mean square	*F*	Significance
Between groups	93.75	5	18.75	2.75	0.022*
Within groups	775.37	114	6.80		
Total	869.13	119			

*Significant. ANOVA: Analysis of variance

action[14] thereby enhancing the shear bond strength of intraoral repair system to the metal.

Ceramic repair system (Ivoclar) used in this study showed higher shear bond strength values to metal substrate after air abrasion followed by etching with 40% phosphoric acid as a surface treatment which may be due to the presence of alloy primer containing MDP. MDP contains an ester phosphate group, which forms a strong chemical bonding with oxide layer on the surface of the alloy and thus forms reliable bond of the resin to alloy.[22]

On a comparative evaluation, Clearfil repair system (Kuraray) showed the adhesive failure and Ceramic repair system (Ivoclar) showed cohesive failure. This is in agreement with most of the studies in the literature,[8,20,24] which indicates that the bonding of Ceramic repair system (Ivoclar) to metal-ceramic was superior than the actual inherent strength of the composite repair materials.

The average bond strength reported between metal and ceramic is 16–24 MPa.[9] The masticatory forces between the incisors vary between 155 and 222 N and upto 830 N for molars.[10] Since the strength is directly proportional to the masticatory forces and inversely proportional to area (Strength = F/A), it may be assumed that minimum bond strength required for intraoral repair material is 8–9 MPa.

In this study, the bond strength values obtained for the two intraoral repair systems were higher (14–15 MPa) than assumed bond strength value (8–9 MPa). This gives enough justification to recommend both repair systems with above-mentioned surface treatment in conjunction with air abrasion as surface pretreatment for intraoral chairside repair of metal-ceramic restoration. However, for larger defects and in situation where metal exposure occurs, Ceramic repair system (Ivoclar) containing MDP based alloy primer after etching with 40% phosphoric acid as surface treatment may be preferred. Further, *in vivo* studies would definitely give more information and clearer understanding about the clinical performance of these systems.

Conclusions

Within the limitations of the study, following conclusions were drawn:

- Mechanical alteration of fractured ceramic and exposed metal substrate is a prerequisite for chair side intraoral repair
- The shear bond strength of Ceramic repair system (Ivoclar) with 40% phosphoric acid etching showed the highest shear bond strength values as compared to other system and surface treatment used in the study
- The mode of failure between Ceramic repair system (Ivoclar) with 40% phosphoric acid etching showed the minimal number of adhesive failures compared to Clearfil repair system (Kuraray) with 37% phosphoric acid etching which showed the maximum number of adhesive failures.

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

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