Original Article

# Comparing two intraoral porcelain repair systems for shear bond strength in repaired cohesive and adhesive fractures, for porcelain-fused-to-metal restorations: An *in vitro* study

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## Abstract

**Aim:** The objective of research was to evaluate the shear bond strength of two commercially available intraoral porcelain repair systems, Clearfil repair system (Kuraray) and P and R repair system (Shofu) for repairing cohesive and adhesive fracture in metal-ceramic restorations.

**Settings and Design:** *In vivo* – comparative study.

**Materials and Methods:** Ninety samples of Nickel–Chromium metal discs were fabricated. Each disc was veneered with 2 mm thickness of ceramic material using custom made metal jig. Samples were divided into control (Group I $n = 10$) and two test groups (Group II $n = 40$ and Group III $n = 40$). Adhesive and cohesive fractures were created in test group samples, Group II (Ceramic substrate or cohesive defect) and Group III (metal substrate or adhesive defect). The samples of ceramic substrate (Group II) and metal substrate (Group III) were further subdivided into A and B containing 20 samples each according to the repair material used (A; Clearfil porcelain repair system and B; P and R porcelain repair system). All specimens were subjected to a standard shear load in the UTM until fracture occurred. Data were analyzed using one-way analysis of variance and *post hoc* Bonferroni test.

**Statistical Analysis used:** One-way analysis of variance (ANOVA) and *post hoc* Bonferroni test.

**Results:** Clearfil repair system showed significantly higher shear bond strength value (29.16 Mpa) as compared to P and R repair system (27.23 Mpa) for cohesive fractures. Whereas if compared for repairing adhesive fractures P and R repair system had significantly higher shear bond strength values (26.59 Mpa) than Clearfil repair system (25.74 Mpa).

**Conclusions:** From the present study, it was be concluded that for cohesive fracture Clearfil repair system is a better material and for adhesive fractures P and R repair material gives better results.

**Keywords:** Adhesive fracture, cohesive fracture, dental ceramics, porcelain repair systems, shear bond strength

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## INTRODUCTION

Porcelain fused to metal restorations have been one of the most common restorations used in fixed Prosthodontics because of the high strength properties of the metal, durability with added cosmetic appearance of porcelain.[1] Although porcelain or ceramic has been used extensively in dentistry, it has its own limitations and disadvantages. Feldspathic porcelain, which is used most often, has compressive strength 2.5 times less than enamel.[2] Subsequently, it has the potential to fracture due to various factors such as impact load, occlusal forces, incompatible coefficients of thermal expansion between porcelain and metal substructures, use of metal with low elastic modulus, excessive seating force during trial insertion or cementation, improper design, micro-defects within the material and trauma.[3] Besides this, the adhesive interfaces are also subjected to temperature changes, saliva, pH changes, and fatigue that can destroy the ceramic metal bond due to its low tensile strength. Therefore, failures in porcelain are fairly common and have been reported in the range of 2.3%–8%[4-7] and are said to be the second greatest cause of failure after caries.[8-11] These failures may be classified as simple (involving only porcelain body), mixed (associated with exposure of metal and porcelain) and complex (with substantial metal exposure).

It may be desirable to repair a broken retainer of a fixed prosthesis rather than to remove it and risk the possibility of destroying the entire restoration or damaging the abutment teeth.[1] Even though fractures of such restorations do not necessarily mean the failure of restoration, the renewal process is both costly, time-consuming, and remains a clinical problem.[12]

Various techniques for repair have been used as an alternative to the expensive and time-consuming procedure of remaking prostheses. Repair methods have classified into two that is, indirect methods and direct methods. Indirect repair would mean repair of the prosthesis in the laboratory using ceramic as a repair material. It is advantageous due to the esthetic ability of porcelain to match the remaining ceramic units. The drawbacks of this procedure are increased time and cost. Moreover, during removal of the prosthesis fracture of abutment tooth or porcelain veneer may take place.[7]

The direct technique uses composite for intraoral repair of the fractured porcelain. A number of systems have been developed to facilitate bonding of composite to porcelain and metal.[10] The techniques include surface preparation of ceramics and silane treatment in bonding procedure.[2] The surface treatment of porcelain and metal includes diamond roughening, air particle abrasion with metal oxide and etching with acids.[11-14] It helps in micromechanical retention. The establishment of reliable and durable chemical bonds between dental ceramics and composite resins is of paramount importance, which is due to the invention of silane coupling agents. These agents chemically bond dissimilar organic and inorganic compounds together and help in chemical retention.[2] The advantages of using composites are less chairside time, low cost and ease of application whereas disadvantages include low strength, poor wear qualities, and poor esthetic qualities.[7]

Various direct intraoral repair systems are available, and each repair system has its own guidelines for use as per the components. In this study, we have compared two commercially available intraoral porcelain repair systems. The procedure involved the evaluation of the shear bond strength of metal with porcelain in a repaired porcelain fused metal crowns when repaired using two ceramic repair systems.

## MATERIALS AND METHODS

The study was approved by Institutional Review Board (ref no: SGTU/FDS/24/465). Ninety metal discs were fabricated (8 mm in diameter and 2 mm thick) with Nickel–Chromium base metal alloy (Bella bond plus-Bego) and 1.8 mm thick ceramic layer (Ceramco 3, Dentsply) was applied over metal disc. The sample size of 90 was kept as per previous studies done in the literature. To standardize the metal ceramic discs a metal jig [Figure 1a and b] was fabricated with a circular housing of 3.8 mm depth and 8 mm diameter (2 mm + 1.8 mm) where 2 mm is metal disc thickness and 1.8 mm ceramic layering thickness. Ninety wax patterns were prepared by flowing molten casting inlay wax (Schuler-dental ULM-W, Germany) into the circular housing of metal jig. Ten wax patterns were attached at a time to the sprue former. It was then fixed to 9x size crucible former (Titec-Orotig, Verona, Italy). The wax patterns were vacuum invested were vacuum invested (Cuymxx, Germany) using 500 g of phosphate bonded investment material and 75 ml mixing liquid (Deguvest) as per manufacturer's instructions. After setting of the investment, the crucible former was separated, and the ring was placed inside the wax burnout furnace (Burnout furnace, Unident Ambassador) and subsequently casting was done with Ni-Cr metal (Bella bond plus-Bego) in induction casting machine (Ducatron). After casting the rings were allowed to cool down at room temperature and were grossly divested from the investment using blunt mechanical forces and rotary instruments, care was taken not to damage the edges of the disc. The specimens with individual sprues were separated using carborundum discs. Incomplete castings or porosities seen on surface of castings were discarded and equal number of casting specimens were added in respective groups.

The metal discs samples were prepared for ceramic application. Ceramic was applied in the thickness of 1.8 mm over one test surface of metal discs (0.2 mm opaque, 0.8 mm dentine, and 0.8 mm enamel) with an aid of a custom made metallic jig. Finally, the metal-ceramic discs samples were finished and self-glazed to achieve a uniform thickness of 3.8 mm (2 mm disc thickness + 1.8 mm ceramic thickness).

The shear bond strength test of 10 control group samples was done using Universal Testing Machine (UTM) (WDW-5E, Serial–20070802, Times Shijin Group) with a 10-kN load cell and 0.5 mm/min crosshead speed. A chisel load applicator was used to direct a parallel shearing force as close as possible to the ceramic metal substrate interface of samples. Shear bond strength for each sample was calculated using the formula ultimate force/area of the force application. The shear bond strength values were recorded in MPa.

Adhesive fracture [Figure 2] and cohesive fractures [Figure 3] were created in 80 test samples (40 each, respectively).

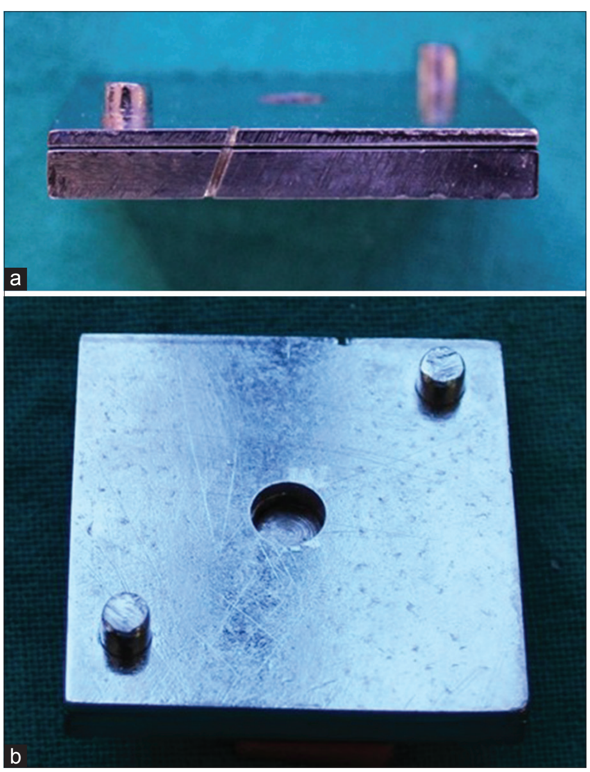


**Figure 1:** (a) Metal jig (side view), (b) Metal jig (top view)

Adhesive fractures were created in 40 test samples with the help of diamond fissure bur of 2 mm diameter (GWZ 856-018 Great White diamond bur SS white) in one-fourth of the total area of the disc sample and defect was created until the metal was exposed. Whereas cohesive fractures were created in 40 test samples to expose the body ceramic by marking depth orientation grooves (1.6 mm) and reducing them to leave a uniform thickness of 0.2 mm ceramic over the metal disc.

Forty samples with cohesive defect (ceramic substrate) were divided into 20 each and were repaired using Clearfil porcelain repair system and Shofu (P and R) repair system, respectively. Forty samples with adhesive defect (metal substrate) were divided into 20 each and were repaired using Clearfil porcelain repair system and Shofu (P and R) repair system, respectively.

### Clearfil porcelain repair system

The fractured surface of exposed metal and porcelain was roughened with a diamond point, and the sharpened areas were beveled. A layer of K etchant gel was applied for 5–10 s, thoroughly rinsed with water and dried with oil-free air. Then, a thin layer of alloy primer was applied over exposed metal surface and allowed to dry for 5 s. Thereafter, thin layer of ceramic primer was applied over exposed ceramic surface and allowed to dry. Now 0.5 mm thick layer of Clearfil ST opaque [Figure 4] was applied over the treated surface and cured for 30–40 s. The composite was placed in increments to build the fractured portion, and each increment was light-cured for 30–40 s. After the fractured portion was built, it was finished properly, and thin layer of surface coat was applied over it and light-cured for 30–40 s. The same procedure was repeated for 40 samples (20 samples with adhesive defects and 20 samples with cohesive defects).

**Figure 2:** Adhesive fractures

### Shofu (P and R) repair system

The exposed metal and porcelain surface was roughened and cleaned with diamond point. It was followed by the application of M. L primer [Figure 5] which was left for 10 s. Then the opaque paste was applied on the exposed metal surface and light-cured for 30–40 s, after it was cured, Cera Resin Bond 1 was applied, left for 10 s and followed by Cera Resin Bond 2 application which was again left for 10 s. Then the application was light-cured for 10 s.

The composite resin was built in increments, and each increment was light-cured for 30–40 s. Last of all repaired portion was finished and polished, and all of the 40 samples were repaired using the same technique.

To test the bond strength of metal and porcelain with repaired porcelain, repaired samples were fractured using UTM (WDW-5E, Serial–20070802, Times Shijin Group) [Figure 6] and the resulting shear bond strength was calculated.

### Grouping of samples

Ninety metal ceramic disc were divided into control (Group I $n = 10$), Ceramic substrate/Cohesive defect group (Group II $n = 40$) and Metal substrate/Adhesive defect group (Group III $n = 40$). The samples of ceramic substrate (Group II) and metal substrate (Group III) were further subdivided into A and B containing 20 samples each according to the repair material used (A; Clearfil porcelain repair system, Kuraray and B; P and R porcelain repair system, Shofu) [Table 1].

## RESULTS

In the present study, one-way analysis of variance (ANOVA) and *post hoc* Bonferroni test was used to find out the significance of the difference between and within groups of repair systems after utilizing in adhesive and cohesive fractures. The comparison was made between the mean shear bond strength values of Groups I, Group II, and Group III [Table 2].

**Figure 3:** Cohesive fractures


**Figure 4:** Clearfil repair kit


**Figure 5:** P and R Shofu repair kit

**Figure 6:** Testing of samples with universal testing machine machine

Table 2 depicts the shear bond strength of all three groups, Group I (control group), Group II (cohesive or ceramic substrate group) and Group III A (adhesive or metal substrate group) showing mean and standard deviation. It was found that the mean of Shear bond strength values was in the range of 45.69 to 26.56 Mpa.

Among the Groups, Group II A samples repaired with Clearfil repair system (Kuraray) showed the highest mean value (29.35 ± 1.53) for cohesive fractures Group III B showed highest mean value for adhesive fracture (27.65 ± 1.91). The statistical difference was found to be significant between the groups ($P < 0.05$) [Table 3].

The mean shear bond was significantly more among Group I compared to Group II A compared to Group III B which was significantly more than Group III A. The comparison was done using *post hoc* Bonferroni test [Table 4].

**Table 1: Grouping of samples**

| Group | Subgroups | Material used | Number of test samples | |
|---|---|---|---|---|
| | | | Number of samples | Total number of samples |
| Group I | | | 10 | 10 |
| Group II | A | Clearfil repair | 20 | 40 |
| cohesive | B | P and R repair | 20 | |
| Group III | A | Clearfil repair | 20 | 40 |
| adhesive | B | P and R repair | 20 | |

**Table 2: Descriptive analysis of shear bond strength of Group I (control group) Group II (Ceramic substrate group) Group III (Metal substrate group) using one-way analysis of variance test**

| | Shear bond strength | | |
|---|---|---|---|
| | Mean±SD | *F* | *P* |
| Group I | 45.69±4.20 | 259.788 | <0.001* |
| Group II | 28.10±1.94 | | |
| Group III | 26.56±2.35 | | |

*Significant difference. SD: Standard deviation

**Table 3: Descriptive analysis of shear bond strength of Group IIA with Group IIIA and Group IIB with Group IIIB using One-way analysis of variance test**

| | Shear bond strength | | |
|---|---|---|---|
| | Mean±SD | *F* | *P* |
| Group I | 45.69±4.20 | 143.160 | <0.001* |
| Group IIA | 29.35±1.53 | | |
| Group IIB | 26.84±2.07 | | |
| Group IIIA | 25.47±2.47 | | |
| Group IIIB | 27.65±1.91 | | |

*Significant difference. SD: Standard deviation, ANOVA: Analysis of variance

**Table 4: The intergroup comparison of mean shear bond was done using the *post hoc* Bonferroni test**

| | Mean difference | *P* |
|---|---|---|
| Group I-Group IIA | 16.34 | <0.001* |
| Group I-Group IIB | 18.85 | <0.001* |
| Group I-Group IIIA | 20.22 | <0.001* |
| Group I-Group IIIB | 18.04 | <0.001* |
| Group IIA-Group IIB | 2.51 | 0.021* |
| Group IIA-Group IIIA | 3.88 | 0.001* |
| Group IIA-Group IIIB | 1.70 | <0.001* |
| Group IIB-Group IIIA | 1.37 | 0.048* |
| Group IIB-Group IIIB | −0.81 | 0.032* |
| Group IIIA-Group IIIB | −2.18 | 0.047 |

*Significant difference

## DISCUSSION

Repair of fractured metal-ceramic restorations aims to re-establish the function and esthetics of restoration using various intraoral repair systems. For the repair to withstand functional loads, the bond between the repair material and remaining restoration must be strong and durable. Until recently, due to lack of materials with a defined and specific protocol for repair of metal-ceramic restorations, it was a common practice to use different combinations of the available adhesive systems and composite resins in conjunction with a variety of surface treatments. However, with the emergence of different intraoral ceramic repair systems in the current time, there is a need for establishing an optimum bond strength value and a standardized technique for repair of metal-ceramic restoration.

The aim of the present study compared the efficacy of two different commercially available porcelain repair systems (Clearfil repair system and P and R repair system) with respect to their shear bond strength in adhesive and cohesive fractures simulating two different clinical situations. Control group (Group I) shear bond strength values obtained were: 45.69 ± 4.20 MPa [Table 2]. These values are within the bond strength values of metal-ceramic restorations, i.e., 41–106 Mpa.[15] De Melo RM *et al*. evaluated the shear bond strength between porcelain and Ni-Cr alloys and found out to be 58.5 Mpa. Shear bond strength values of Group II and Group III were significantly lower than Group I. This difference in the shear bond strength values can be attributed to the fact that the bond between ceramic veneer 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 the type of etchant and the composition of alloy primer used in porcelain repair systems.

In intragroup comparison, the shear bond strength values of Group II A (Clearfil) were significantly higher than Group II B (P and R). This difference can be attributed to the fact that Clear fill group has 40% phosphoric acid and P and R group has no acid for chemical surface treatment. In metal substrate group, shear bond strength of Group III B was higher than Group III A. This could be attributed to the presence of adhesive primer containing 10-Methacryloyloxydecyl Dihydrogen phosphate (10-MDP) in the adhesive system. 10-MDP is a bipolar molecule with a methacrylate group at one end and an ester phosphate group at the other. The ester phosphate group chemically bonds to metallic oxides of ceramic, enhancing the bond strength.[8]

In intergroup comparison, the shear bond strength values of Group II A (Ceramic substrate Clearfil group) were significantly higher than Group III A (metallic substrate Clearfil group). Hence, it can be inferred that Clearfil is a better material for cohesive fracture. Simultaneous comparison of shear bond strength values of Group II B (Ceramic substrate P and R group) with Group III B (Metallic substrate P and R group) showed that Group III B has higher Shear bond strength value which proves better efficacy of P and R repair material for repairing adhesive fractures. The shear bond strength values 29.35 Mpa of Group II A i.e., (Ceramic substrate Clear fill group) and Group II B (Ceramic substrate P and R group) 26.84 Mpa was significantly higher than Group III A (Metallic substrate Clearfil group) 25.47 Mpa and III B (Metallic substrate P and R group) 27.65 Mpa. These results are useful in understanding that cohesive fractures are favorable fractures and can be repaired with greater efficiency compared to adhesive fractures. The decreased resistance to fracture in adhesive fractures can be attributed to the fact that adhesive failures are initiated at porcelain metal-oxide interface and proper wetting of alloy with alloy primer cannot be achieved effectively hence composite adherence to alloy is compromised.[16]

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.[11-13,17-19] Data presented in literature has shown the bond strength of ceramic to metal substrates in the range of 43–71 MPa.[20,21] and a sufficient bond for metal-ceramic has been accepted when the fracture stress is >25 MPa.[22,23] According to some authors, shear bond strength values >10 MPa indicate clinically satisfactory results, representing a better bond strength than that is necessary to provoke the clinical flaw of union between metal and ceramic.[24-28] *In vitro* evaluation is the first step of testing any material to examine the properties and potential that it possesses. The present study tested only shear bond strength of porcelain repair material to metal-ceramic, it is suggested that other aspects of the bond, such as the effect of different mechanical test designs, mode of failure and microleakage be studied for a more comprehensive evaluation of these porcelain repair systems.[29] The values evaluated/obtained from the present study are within the best range of values obtained in the studies done earlier, but further *in vitro* studies subjecting the specimens to cyclical loading and to a long period of storage in water should be explored to more closely simulate the oral environment and to provide additional information about durability of the repair systems.

## CONCLUSIONS

1. The shear bond strength values of Clearfil repair system (29.16 Mpa) and P and R repair system (27.23 Mpa) for cohesive defects showed statistically significant results ($P < 0.05$). From the present study, it can be concluded that for cohesive defects Clearfil repair system is a better material
2. The shear bond strength values of Clearfil repair system (25.74 Mpa) and P and R repair system (26.59 Mpa) for adhesive defects showed statistically significant results ($P < 0.05$). From the present study, it can be concluded that for adhesive defects P and R repair system is a better material
3. The alloy primer containing 10-MDP is essential for bonding of repair material to metal surface of metal-ceramic restoration
4. The shear bond strength for cohesive fractures was found to be more significant in both Clearfil repair system (29.16 Mpa) and P and R repair system (27.23 Mpa) when compared with adhesive fractures which were 25.74 Mpa for Clearfil repair system group and 26.59 Mpa for P and R repair system group.

Clinical implications of the study are as follows:

1. Cohesive fractures are favorable and are easier to repair compared to adhesive fracture
2. Clearfil repair material is the material of choice for cohesive fracture when compared to P and R repair material
3. P and R repair material is the material of choice for adhesive fracture when compared to Clearfil repair material.

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### Conflicts of interest

There are no conflicts of interest.

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