Bond strength of different intraoral repair systems for metal-ceramic restorations

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Abstract: When clinical fractures of the ceramic veneer on metal-ceramic prostheses can be repaired, the need for remake may be eliminated or postponed. Different ceramic repair materials are available, and bond strength data are necessary for predicting the success of a given repair system. The aim of this study was evaluation of the shear bond strength of three intra oral repair systems for metal-ceramic restorations applied on exposed metal and porcelain surface.**Material and methods**: Nickel-chromium alloy and feldspathic porcelain were used to fabricate 60 cylindrical specimens (9 × 3 mm). Specimens were embedded in a polyvinyl chloride (PVC) ring and received one of the following bonding and resin composite repair systems: indicated that the highest mean shear bond strength values among repair systems with metal surface, were recorded using CoJet repair system, followed by Bistite II DC and the lowest value were obtained for Clearfil type. On the other hand the highest mean shear bond strength values were recorded for Clearfil type, followed by CoJet and the lowest value were obtained for Bestite II DC type. **Conclusions:** In this study, CoJet repair system produced the highest shear bond strength to the exposed metal surface, while using Clearfil repair system achieved the highest shear bond strength to the exposed porcelain surface.

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1. Introduction:

Despite the development and growing of all-ceramic systems, a metal ceramic restorations are still a good option for oral rehabilitation due to their mechanical strength, Kupiec et al., (1996); Frankenberger et al., (2003); Haselton et al., (2001); Kumbuloglu et al., (2003). The use of alternative alloys for these restorations became more popular in the 1960s, after the cost of the gold alloys increased. Their mechanical properties allow for fabrication of restorations with greater rigidity and less thickness, Sced and McLean (1972). Unfortunately, metal ceramic restorations have the potential to fracture, Prado et al., (2005).

Porcelain failures have been reported as the second greatest cause of failure after the dental caries.[7] Furthermore, failures occur more frequently in regions that may compromise esthetics.[8] Fractures may result from trauma, inadequate occlusal adjustment, parafunctional habits, flexure fatigue of metal substructure, incompatibility of coefficient of thermal expansion between porcelain and metal structure, failure in adhesive bonding, inadequate tooth reduction during tooth preparation, porosities in porcelain, and inappropriate coping design, Gregory and Moss (1990); Llobell et al., (1992); Appeldoorn et al., (1993); Diaz-Arnold et al., (1993); Chung and Hwang (1997); Shahverdi et al., (1998); Leibrock et al., (1999);Latta and Barkmeier (2000); Ozcan et al., (2002); Ozcan (2003a & b).

These failures may be classified as simple (involving only the porcelain body), mixed (associated with the exposure of metal and porcelain), and complex with substantial metal exposure, Haselton et al., (2001). A number of systems have been developed to facilitate bonding of composite to porcelain and metal. Porcelain and metal surface treatments, such as diamond roughening, air-particle abrasion with aluminum oxide, and etching with acids have been studied under varying conditions in the laboratory, Beck et al., (1990); Cooley et al., (1991); Diaz-Arnold et al., (1993); Barkmeier et al., (1993); Czerw et al., (1995). Some investigators reported that the bond strength was increased when the base alloy was air abraded before placement of composite, Chung and Hwang (1997).

Repair systems such as CoJet Sand, Clearfil SE Bond, and Bistite II DC, which are indicated for repairing metal-ceramic restorations, have a defined sequence of application for the products. However, these materials lack sufficient studies proving their effectiveness. The aim of this study was therefore to evaluate the bond strength of the three tested metal-ceramic repair systems.

2. Materials and Methods

2.1.Materials:

2.1.2. Specimens preparation:

Thirty nickel-chromium and thirty feldspathic porcelain cylindrical specimens 9 mm in diameter and 3 mm thickness were constructed using a specially designed teflon mold (Fig.1). Metal specimens were prepared according to manufacturer instructions. Specimens were sandblasted with 250µm aluminum oxide particles at pressure 75 psi(ECO Dental Farm Torino, Italy), then finished using "Diadur" carbides finishers
(DFS DIAMON Company Riedenburg, Germany)

As regards the porcelain specimens, the undersurface of the mold was lined platinum foil, and then the body porcelain powder was mixed with distilled water and condensed inside the mold. Then firing was done following the recommendations of the porcelain manufacturer.

The metal and porcelain specimens were embedded in polyvinyl chloride (PVC) cylinders, 2.5 mm in diameter and 27.0 mm in height filled with polymethyl methacrylate resin(Acrostone cold cure denture base Egypt LOT NO-17338) (Fig. 2b). To ensure centralization of the specimens inside the PVC ring, a centralizing ring was used (Fig.2a) . All specimen bonding surfaces were smoothed using 120-, 220-, and 320-grit silicon carbide papers(3M do Brasil Ltd, campinas, Sao Paulo, Brazil)

The metal and porcelain specimens were then divided into 3 groups (n= 10) to receive one of the following bonding and resin composite repair systems: Clearfil SE bond / Clearfil AP-X composite resin (CL), Bistite II DC / clearfil AP-X composite resin (B), and CoJet sand / Z100 composite resin (CO)

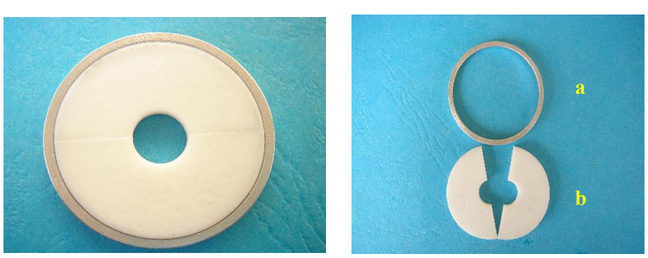

Fig.1: Assembled and disassembled teflon mold. (a) The holding ring. (b) The split parts of the teflon mold.

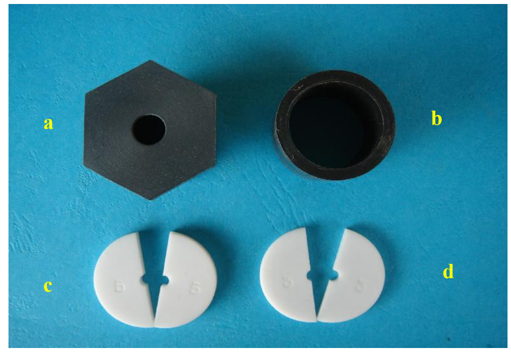

Fig.2: (a) Centralizing ring. (b) PVC ring. (c and d) Composite and opaquer teflon matrices respectively

Surface treatment was performed according to the manufacturer instructions for each type of repair system.

2.1.2. Materials used in this study:

Illustrated in table (1):

	Material	*Manufacturer*	*Lot no.*	*Symbol*
1-	3M *ESPE (CoJet System Repair)	3M ESPE, Seenfeld, Germany.	LOT # 292552	**CO**
2-	Composite material (Z100)	KURARAY MEDICAL INC. 1621 Sakazu, Kurashiki, Japan.	LOT # 20070814	
3-	Clearfil Repair Kit	KURARAY MEDICAL INC. 1621 Sakazu, Kurashiki, Japan.	LOT # 41250	**CL**
4-	Composite material (Clearfil AP-X)	KURARAY MEDICAL INC. 1621 Sakazu, Kurashiki, Japan.	LOT # 01211A	
5-	BISTITE II DC Repair System	ToKuyama Dental Corp. 38-9, Taitou 1-chome, Taitou-Ku, ToKyo, Japan.	LOT # UB535Y6	**B**
6-	Nickel Chromium alloy	Dental Future Systems GmbH Ländenstraße 1. D-93339 Riedenburg. Germany	LOT # 55345	NIADUR (DFS) (DIAMON)
7-	Feldspathic porcelain	WOHLWEND-AG FL9488 Schellenberg fürstentum Liechtenstein Germany	LOT # 1761	Vision Classic

2.2.Methods:

2.2.1.Application of repair systems:

- **Before the application of the tested repair systems**:

Metal and porcelain specimens, were subjected to airborne-particle abrasion for 20 seconds with an airborne-particle abrasive unit(ECO Dental Farm Torino, Italy) of 50µm aluminum oxide particle, at 35 psi and 10 mm distance.

-For Clearfil repair system:

Acid etching of porcelain surfaces with K-ETCHANT GEL supplied by the manufacturer, then left in place for 5 seconds before washing with distilled water and drying with oil-free air. Silane treatment for the metal and porcelain surfaces was done using ClearfilTM Se bond primer and ClearfilTM porcelain bond activator, where one drop of each was mixed immediately before application. The mixture was applied using a disposable brush tip, then left in place for 5 seconds and using a mild oil-free air stream the volatile ingredients was evaporated.

Bonding was done using ClearfilTM Se Bond Bond, applied with a disposable brush tip, then a light air stream was used to make the bond film as uniform as possible.

-Clearfil SE Bond was light-cured for 10 seconds with a visible light-curing activator blue phase(Ivoclar Vivadent Austria).

- **ClearfilTM St Opaquer**

It was applied to mask the color of metal, using custom-made teflon matrix 4.0 mm internal diameter and 0.3 mm thickness. The Teflon matrix was placed on the surface of the metal specimens using a holding ring attached to the PVC ring then light-cured for 40 seconds. Finally,ClearfilTM Ap-X composite was placed on the porcelain and metal specimens, then light-cured, according to the manufacturer's instructions.

-Bestite II DC repair system;

An adhesive promoter (Metalite) containing a thiouracil monomer was applied to the metal specimens according to manufacturer instructions, to enhance the adhesion of resins to the metal surface. Application was done using the teflon matrix and the holding ring. Resin cement pastes (PASTE A and B) formed of an adhesive promoter, silica-zirconia, and filler initiator in a dimethacrylate matrix was used. The paste A and B were mixed immediately before application on the metal and porcelain specimens using a custom made composite teflon matrix. It was then light irradiated for 30 seconds.

-Clearfil AP-X composite resin was applied on the metal and porcelain specimens surfaces and cured according to manufacturer instructions.

- CoJet repair system:

Micro blasting was done using micro etcher unit(DeDanville Engineering San Ramon.Ca,USA), filled with a CoJet sand, which is a specially developed 30 µm aluminum oxide grains coated with silicon dioxide. The air pressure was set to 30-45 psi to ensure that the energy of impact is sufficient for successful coating. Micro blasting was done from a distance of 7-10 mm and perpendicular to the surface of the metal and porcelain specimens while providing aspiration. Directly after coating, a silane solution (ESPE Sil) was applied, using a clean brush to wet the entire surface of the metal and porcelain specimens, then left to dry for 5 min. A dual curing hybrid composite system (Sinfony Opaquer) was applied to the metal specimens to mask their color. On the other hand ,bonding agent supplied by the manufacturer was mixed and applied to the silanized surfaces of the porcelain specimens, using a disposable brush, then light-cured for 20 sec.

A visible-light activated, radiopaque composite (Z 100 composite resin) was applied to porcelain surface according to the manufacturer instruction using the previous teflon matrix. The composite resin was then light-cured with visible light for 40 seconds.

Specimens were then stored in distilled water for 24 hours before thermocycling.

Thermocycling was done between 5ºC and 55ºC for 1000 cycles with a 30-seconds dwell time. After thermocycling, the specimens were stored in 37°C distilled water for an additional 8 days. Shear bond strength testing was performed using a universal testing machine(Material Test System 810;MTS Systems corp,Eden prairie,Minn) with a 10-kN load cell and a 0.5-mm/min crosshead speed.

2.2.2.Statistical analysis :

It was performed using one-way ANOVA followed by Student Newman-Keuls multiple comparison (SNK) tests to evaluate the significance within groups. Two-way analysis of variance (ANOVA) was used to examine the main effects of base (Metal vs. Ceramic), surface treatments (CoJet, Bistite and Clearfil) and the interactions between these 2 factors.

Statistical analysis was performed using Graph pad Prism-4 statistics software for Windows. P values less than 0.05 were considered to be statistically significant in all tests.

3.Results

3.1.Shear bond strength of to metal specimens:-

The mean value and standard deviation of shear bond strength after different surface treatments of metal specimens are listed in table (2) and illustrated in figure (4). From the table and figure it is obvious that the highest shear bond strength value, was recorded for CO group (7.78 ± 1.99 MPa), followed by that obtained using B repair system (5.83 ± 0.976 MPa) and the lowest value was obtained using CL repair system (4.50 ± 1.12).

Using one way analysis of variance (ANOVA) test to compare shear bond strength values of the treated metal groups revealed that the difference between the three surface treatment types was statistically significant (P< 0.0005) (Table 3).

Table (2): Summary of descriptive statistics of shear bond strength test (MPa) after different surface treatment for both metal and ceramic specimens.

	CO-metal	CO-ceramic	B-metal	B-ceramic	CL-metal	CL-ceramic
Sample size.	10	10	10	10	10	10
Minimum	4.87	6.16	4.51	3.98	2.67	8.74
Maximum	10.44	7.01	7.05	6.86	6.30	14.31
Mean	*7.78*	*6.59*	*5.83*	*5.55*	*4.50*	*10.44*
Std. Deviation	*1.99*	*0.60*	*0.97*	*1.20*	*1.12*	*2.32*
Median	7.42	6.59	6.29	5.68	4.40	9.34
Std. Error	0.70	0.42	0.36	0.60	0.37	1.03
Lower 95% CI*	6.12	1.18	4.93	3.64	3.63	7.56
higher 95% CI*	9.45	12	6.73	7.46	5.37	13.33

*Confidence interval

Table (3): One-way ANOVA test comparing metal groups after different surface treatment.

ANOVA Table	SS	df	MS	F	P-value
Between Groups	45.95	2	22.98	11.03	0.0005***
Within Groups	43.74	21	2.08		
Total	89.69	23			

SS; sum squares. df; degree of freedom. MS: mean squares. ***: very high significant (p<0.001).

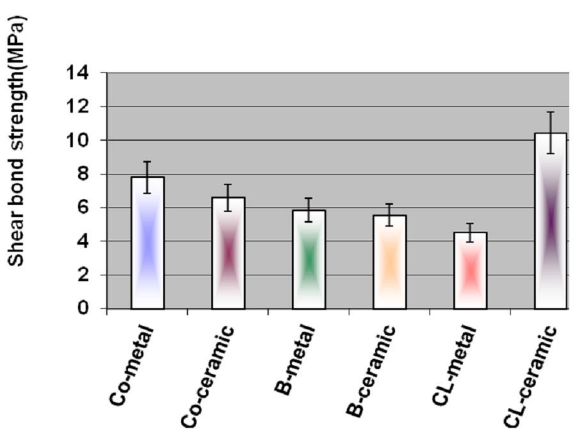

Figure (4): A column chart of shear bond strength test (MPa) after different surface treatment of metal and ceramic specimens

3.2.Results obtained from pair wise Newman-Keuls multiple comparison of metal groups :

(Table 4) revealed that the difference was significant between metal specimens treated with CL repair system and CO system (P<0.001). Results also indicated that the difference was significant between the metal specimen treated with B and CO repair systems (p<0.05), while there was no significant difference between metal specimens treated with CL and B repair systems (P<0.05).

Table (4): Pair wise Newman-Keuls multiple comparison of shear bond strength of metal groups

Pair wise Comparison	Mean Diff.	t-value	P- value	Sig.?
CL-metal vs CO-metal	3.28	6.62	P<0.001	Yes
CL-metal vs B-metal	1.33	2.58	P > 0.05	No
B-metal vs CO-metal	1.95	3.70	P < 0.05	Yes

3.3. The shear bond strength to porcelain specimens:-

The mean values and standard deviation of shear bond strength after different surface treatments of porcelain specimen are listed in table (2) and shown in figure (4).

Results indicated that the highest shear bond strength value was recorded using Cl repair system (10.44 ±2.32 MPa), followed by that obtained using Co repair system (6.59 ±0.602 MPa) and the lowest values (5.55 ±1.20 MPa) was obtained using B repair system Using the one way analysis of variance (ANOVA) test comparing the shear bond strength of the ceramic groups using different repair system, revealed that the difference between the three types of surface treatments was statistically significant (P<0.05) (Table 5)

Table (5): One way ANOVA test comparing ceramic groups after different surface treatment.

ANOVA Table	SS	df	MS	F	P value
Between Groups	57.79	2	28.90	8.808	0.0095***
Within Groups	26.24	8	3.280		
Total	84.03	10			

As regards the pair wise Neman-Keuls multiple comparison of shear bond strength of ceramic groups using different repair systems (table 6), it could be noticed that the difference was significant between ceramic specimens treated with B and CL repair system (P<0.01). The difference was also significant between specimens treated with CO and that treated with CL (P<0.005). On the other hand there was no significant difference between specimens treated with B and that treated with CO repair system (P<0.05).

Table (6): Pair wise Newman-Keuls multiple comparison of shear bond strength of the ceramic groups

Pairwise Comparison	Mean Diff.	t	P value	Sig.?
B-ceramic vs CL-ceramic	4.89	5.69	P < 0.01	Yes
B-ceramic vs CO-ceramic	1.04	0.93	P > 0.05	No
CO-ceramic vs CL-ceramic	3.85	3.59	P < 0.05	Yes

4. Discussion

Ceramic-based restorations have the potential to fracture because of the brittle nature of ceramic materials. Repairing these restorations intraoraly can increase their clinical longevity. With the introduction of many new products related to bonding porcelain and alloys, there are techniques available today to repair the fractured restorations with moderate expectations of success.

In this study; the highest shear bond strength values to metal specimens, was obtained using the CoJet system ,this may be due to the effectiveness of the mechanical and chemical bonding provided by this system, Dos Santos et al.,(2006). CoJet repair system promotes adhesion to metal surface using unique particles for air abrasion. CoJet system did not rely on acid for developing micromechanical retention but rely on silica coating airborne particles abrasion that increases surface area and promotes silane wetting so it is well suited for metal repair. CoJet sand (3M ESPE) contains a silanized silica coating on aluminum oxide particles that when used leaves a coating of silica on both metal and ceramic surfaces that enhance the bond of repair using composite resin, Latta and Barkmeier (2000).

During sand blasting, the impact energy produces a ceramic-like coating on the treated surface (tribo-chemistry). Subsequent silanization and application of the bonding agent produce a strong chemical and micro-gap-free bond between the treated surface and the restorative material.

Results obtained with Bestite II DC repair system was slightly higher than that obtained with Clearfil surface treatment with the difference being insignificant. The higher shear bond strength values for Bestite II DC may be due to the use of an adhesive promoter containing thiouracil monomer. This adhesive promoter promotes adhesion to the metal substrate as it is characterized by having an affinity for both the substrate and resin adhesive, Dos Santos et al.,(2006)

As regard the shear bond strength of repair system to porcelain specimens, the highest shear bond strength values were recorded for Clearfil repair system (10.44 MPa). This may be due to the application of K-etchant gel on porcelain surface, providing a conditioning action that increases the surface energy and provided additional micromechanical retention which when followed by silane coupling agent a reliable adhesion results.

Additionally, Clearfil bond system has more hydrophilic properties than conventional unfilled resins; it contains one or more hydrophilic resin monomers. The Clearfil porcelain bond system contains Bis-GMA, HEMA, a phosphate monomer with a silane coupling agent , Suliman et al.,(1993). High bond strengths and hydroscopically stable bonds have been reported with Clearfil bonding agents, Latta and Barkmeier(2000).

Results obtained in this study were slightly higher with CoJet repair system than that with Bestite II DC with no significant difference. This could be explained by the fact that these groups showed porcelain cohesive failure, indicating that the bond strength between the repair material and the porcelain was superior, Lacy (et al.,(1988);Gregory and Moss (1990); Berry et al.,(1999);Haselton et al.,(2001); Kumbuloglu et al.,(2003).

The lowest shear bond strength values of Bestite II DC with porcelain; may be due to the fact that Bestite II DC depend on sandblasting and using of resin cement only for bonding composite to porcelain surface, while Clearfil repair system rely on sandblasting, acid etching, silanization and the application of a bonding agent for bonding composite to porcelain surface. On the other hand CoJet repair system relies on the tribochemical effect together with silanization and the application of the bonding agent Dos Santos et al.,(2006).

Conclusions

Within the limitations of the present investigation, the following conclusions were drawn: CoJet repair system produces the highest bond strength than the other tested repair systems, when used on exposed metal surface. For the repair of metal-ceramic restorations with exposed porcelain surface, the Clearfil system achieved significantly higher bond strength among other tested repair systems.

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