ISJ

Available online at https://int-scientific-journals.com

International Scientific Journals

IJEISR

IJEISR (2019) Vol.3–no.1

https://int-scientific-journals.com/ijeisr

# The assessment of the effect of various surface treatments on the shear bond strength of three different intraoral ceramic repair methods

*Premkumari S. Sharma*
*Faculty of of Biomedical Engineering, Indian Institute of Technology (IT-BHU),Varanasi, India*
*Email: sspremkumari@gmail.com*

## Abstract

The aim of this study is to assess the shear security quality of two intra oral clay fix frameworks on metal substrate and fired substrate and to contrast among gatherings with evaluate a superior earthenware fix framework after corrosive scratching and laser surface treatment. Therefore, 40 Nickel chromium and 40 feldspathic ceramic specimens were fabricated and divided into two main groups which were further subdivided into four subgroups based on the repair systems used and surface treatments, which had ten specimens each. Hydrofluoric acid and Erbium-doped Yttrium aluminum garnet laser were used as surface treatments and two intra oral repair systems used were Bisco and Angelus. Bonded specimens were stored in distilled water for 24 hours before being thermocycled at 5°C to 55°C for 300 cycles with a 30-second dwell time. The specimens were stored for an additional 7 days before being subjected to shear force in a universal testing machine with a 10KN load cell at a crosshead speed of 0.5 mm/min. The bond strength values obtained were recorded in MPa and analyzed using independent t test. The outcomes indicate that the shear bond strength values obtained were highly significant for Bisco when compared to Angelus for both the metal and ceramic substrates. Similarly, after acid etching and laser surface treatment, Bisco proved to be better. At the end, Bisco repair system had significantly higher shear bond strength values when compared to Angelus. Hence it is the preferred choice for intraoral repair of fractured metal ceramic restorations. Er: YAG laser surface treatment is the recommended surface treatment for intraoral repair.

Doi: 10.31219/osf.io/y37cg


Keywords: Intraoral repair, Shear bond strength, metal ceramic, Composite resin, and Repair of metal-ceramic restoration.

## Introduction

The recovery of teeth with crowns and fixed incomplete dentures has expanded incredibly in the course of the most recent three decades. Metal fired reclamations are constantly considered as a highest quality level for fixed halfway rebuilding because of their capacity to satisfy the useful just as tasteful requests. Despite the esthetic appearance, biocompatibility, and color stability, these materials have some disadvantages such as reduced mechanical properties and tendency to break. Metal ceramic restorations have a potential to fracture and it may result from inadequate occlusal adjustment, traumata, parafunctional habits, flexural fatigue of the metal substructure, incompatibility of the co-efficient of thermal expansion between the porcelain and the metal structure, failures in adhesive bonding, inadequate tooth reduction during dental preparation, inappropriate coping design and intradermic defects.

Replacement of a failed restoration is ideal for the fracture, but is not necessarily the most practical solution due to replacement cost, additional trauma to the tooth and other limited factors in patients. In cases with small fracture areas intraoral repair options may provide a practical approach rather than removal of whole restoration [1].

Advances in adhesive dentistry have enabled the development of repair systems. Many intraoral repair materials and surface treatments are available to repair intraorally fractured metal ceramic restoration. Each system requires specific protocols with different combinations of adhesive systems and resins to repair ceramic fractures.

Many intraoral repair materials and surface treatments are available to repair intraorally fractured metal ceramic restoration. Hydrofluoric acid etching followed by the application of a silane coupling agent also promotes good results in the preparation of a ceramic surface, and it is commonly used in clinics due to its simplicity. Technological advances during the last decade have resulted in the increased use of lasers in dentistry. Only few studies have been performed on the surface treatments of ceramics and base metal alloys using lasers [2]. Hence the aim of this study is to evaluate and compare shear bond strengths of two ceramic repair systems after two different surface treatments.

## Methodology

This study comprised of 80 cylindrical samples which were divided into 2 main groups (Group A and Group B which were ceramic and metal substrates respectively) and 4 subgroups in each group (Group A1, A2, A3, A4 and Group B1, B2, B3 and B4) based on surface treatments and repair systems [3].

Forty cylindrical and metal specimens were fabricated (8mm in diameter and 2mm thick) from nickel-chromium base metal alloy (Bellabond plus, BEGO, Bremen, Germany) (Figure 1) and forty from feldspathic porcelain (VITA Zahnfabrik H. Rauter GmbH & Co. KG, Bad Säckingen, Germany) (Figure 2). The specimens of each substrate were divided into 4 groups (n=10), 1 for each of the repair systems tested and two surface treatments. Fabrication of the metal specimens (M) was accomplished by waxing cylindrical patterns using a circular metal matrix which was customised in stainless steel with an opening 8 mm in diameter and 2 mm thick (Figure 3). The wax pattern for metal substrates (M) was placed in a casting ring using a prefabricated wax sprue and embedded in phosphate-bonded investment (Bellavest SH, BEGO, Bremen, Germany) and invested according to manufacturing instructions [4]. The same matrix was used for constructing the feldspathic porcelain cylindrical specimens (C). Portions of body porcelain powder mixed with distilled water were condensed in the matrix. The specimens were placed in a porcelain oven that had been preheated to 600 0C, at which time the temperature was increased to 930 0C, following the recommendations of the porcelain manufacturer. After firing, the specimens were allowed to cool to room temperature [5]. The nickel-chromium and feldspathic porcelain cylinders were embedded in a polyvinyl chloride (PVC) ring (25mm diameter and 27 mm height) using polymethyl methacrylate resin in such a way that the flat surface of the metal and ceramic discs were left flush with acrylic resin, leaving the disc at a higher level to facilitate shear bond testing [6]. All specimen bonding surfaces were smoothed with silicon carbide papers (120-, 220-, and 320-grit) (Figure 6 and Figure 7).

For subgroup A1, A3, B1, B3 the surface of both the metal and ceramic substrates were treated with 9% HF acid for 90 seconds, rinsed thoroughly with water spray and then air dried until a frosted appearance was observed.

For subgroup A2, A4, B2, B4 the surface of both the metal and ceramic substrates were irradiated with Er: YAG laser (Fotona; Ljubljana, Slovenia) with 2 energy parameters.For ceramic substrates the parameters used were Er: YAG (2940nm) – 20Hz repetition rate, long pulse, 5W power and 250mJ on the porcelain surface for 20 seconds under 80% water flow and 40% air flow.For metal substrates the parameters used were Er: YAG (2940nm) – 10Hz repetition rate, long pulse, 5W power and 450mJ on the metal surface for 20 seconds under 80% water flow and 40% air flow. The laser optical fiber was placed perpendicular to the metal surface at 1mm distance and was moved in a sweeping motion by hand over an area that was 4mm in diameter. To ensure consistent energy density, distance and hand piece angle, the laser hand piece (noncontact R14, Fotona) was attached to a modified surveyor After surface treatments all the samples were repaired with 2 commercially available repair systems - Porcelain Repair Kit, Angelus, Londrina, Brazil and Intraoral Repair Kit (Figure 4), Bisco, Illinois, USA (Figure 5) according to manufacturer's instructions. Opaque resin was applied to metal specimens. The composite resin for each group was applied using a custom-made metal matrix (4.0-mm internal diameter and 2.0-mm thickness) which was placed on the surface of the specimen. The photo activation of the fluid resins of the adhesive systems, the opacifying agents (on the metal specimens), was performed for 20 seconds. The composite resin was polymerized for 60 seconds with the matrix in position and 20 seconds after removing the metal matrix. The photo activation was performed with light curing unit.

All specimens were stored in distilled water for 24 hours before thermal cycling, which occurred between 5 0C and 55 0C for 300 cycles with a 30-second dwell time. After thermal cycling, the specimens were stored in distilled water for an additional 8 days before being subjected to a shear load using a testing machine with a 10-kN load cell and a 0.5-mm/min crosshead speed. A chisel apparatus was used to direct a parallel shearing force as close as possible to the resin/substrate interface (Figure 8). The shear deboning forces were recorded in N. The failure loads (N) were divided by the bonding areas (mm2), and then the shear deboning forces were converted into MPa. The shear bond strength values were recorded in megapascals (MPa).

*Statistical Anlysis*

Statistical analysis was performed using the SPSS software. The data was collected and fed in SPSS (IBM version 23) for the statistical analysis. The descriptive statistics included mean and standard deviation. The inferential statistics included Independent t test for comparison between 2 independent groups. The level of significance was set at 0.05 at 95% Confidence Interval.

## Results

The shear bond strength values of the test specimens were determined by using a Universal Testing Machine. All the data obtained for the shear bond strength is expressed in megapascals (Mpa). When independent t test was applied to mean shear bond strength for two main groups with 4 subgroups each, the results obtained revealed highly significant differences between and within the groups and subgroups.

Descriptive statistical comparison of mean shear bond strength values between ceramic substrates (GROUP A) in table 1 revealed significantly higher mean shear bond strength values for subgroup A4 and A3 respectively. Table 1 also revealed that mean shear bond strength values of repair system II were higher when compared to repair system I for both the surface treatments. The values obtained were highly significant.

Descriptive statistical comparison of mean shear bond strength values between metal substrates (GROUP B) in table 2 revealed significantly higher mean shear bond strength values for subgroup B4 and B3 respectively. Table 2 also revealed that mean shear bond strength values of repair system II were higher when compared to repair system I for both the surface treatments. The values obtained were statistically highly significant.

When mean shear bond strength values between two repair systems under ceramic substrates were compared (SUBGROUP A1, A2, A3 and A4) in table 3 revealed highly significant shear bond strength values for repair system II for both the surface treatments. Similarly, comparison of mean shear bond strength values between two repair systems under metal substrates (SUBGROUP B1, B2, B3 and B4) in table 4 revealed higher shear bond strength values for repair system II for both the surface treatments.

Multiple comparisons between the two repair systems with two different surface treatments under ceramic and metal substrates in table 5 showed highly significant values. Under the laser surface treatment repair system II showed higher shear bond strength values for ceramic substrates while for repair system I higher shear bond strength values were obtained for metal substrates. Under the acid surface treatment repair system II showed higher shear bond strength values for ceramic substrates while for repair system I higher shear bond strength values were obtained for metal substrate (Graph 1).

*Table 1: Descriptive Statistical Comparison of Mean Shear Bond Strength Values Between Ceramic Substrates (Group A).*

| **Ceramic** | | **Mean in megapascals (MPa)** | **Standard deviation** | **T value** | **Significance** |
|---|---|---|---|---|---|
| Laser | Repair system II | 14.8530 | .94398 | 19.931 | 0.000 (H.S) |
| | Repair system I | 8.3530 | .41532 | | |
| Acid | Repair system II | 12.8860 | .42545 | 36.695 | 0.000 (H.S) |
| | Repair system I | 6.5990 | .33547 | | |

HS – Highly Significant

*Table 2: Descriptive statistical comparison of mean shear bond strength values between metal substrates (GROUP B).*

| Metal | | Mean in megapascals (MPa) | Standard deviation | T value | Significance |
|---|---|---|---|---|---|
| Laser | Repair system II | 11.8130 | .38056 | 12.254 | 0.000 (H.S) |
| | Repair system I | 9.3240 | .51746 | | |
| Acid | Repair system II | 10.5170 | .44310 | 15.391 | 0.000 (H.S) |
| | Repair system I | 7.8300 | .32931 | | |

HS – Highly Significant

*Table 3: Comparison of mean shear bond strength values between two repair systems under ceramic substrates (SUBGROUP A1, A2, A3 and A4).*

| Ceramic | | Mean in megapascals (MPa) | Standard deviation | T value | Significance |
|---|---|---|---|---|---|
| Repair system II | Laser | 14.8530 | .94398 | 6.007 | 0.000 (H.S) |
| | Acid | 12.8860 | .42545 | | |
| Repair system I | Laser | 8.3530 | .41532 | 10.389 | 0.000 (H.S) |
| | Acid | 6.5990 | .33547 | | |

HS – Highly Significant

*Table 4: Comparison of mean shear bond strength values between two repair systems under metal substrates (SUBGROUP B1, B2, B3 and B4).*

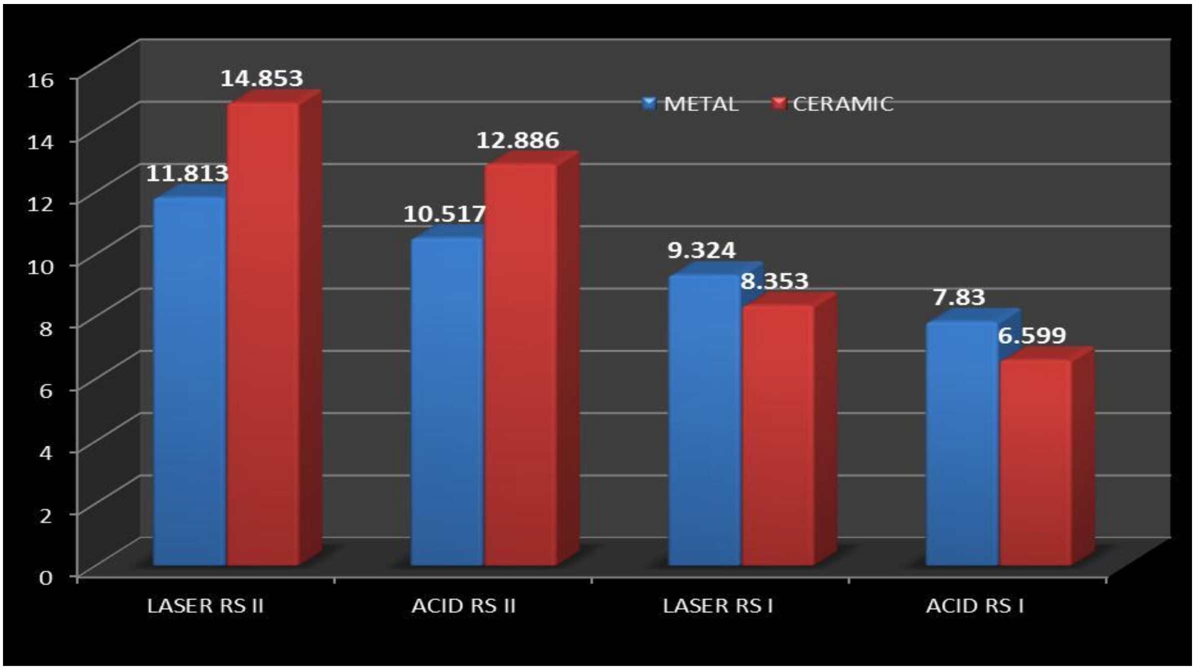
| Metal | | Mean in megapascals (MPa) | Standard deviation | T value | Significance |
|---|---|---|---|---|---|
| **Repair system II** | Laser | 11.8130 | .38056 | 7.017 | 0.000 (H.S) |
| | Acid | 10.5170 | .44310 | | |
| **Repair system I** | Laser | 9.3240 | .51746 | 7.703 | 0.000 (H.S) |
| | Acid | 7.8300 | .32931 | | |

HS – Highly Significant

*Table 5: Multiple comparisons between the two repair systems with two different surface treatments under ceramic and metal substrates.*

| | | Mean in megapascals (MPa) | Standard deviation | T value | Significance |
|---|---|---|---|---|---|
| **Laser Repair system II** | Metal | 11.8130 | .38056 | -9.445 | 0.000 (H.S) |
| | Ceramic | 14.8530 | .94398 | | |
| **Acid Repair system II** | Metal | 10.5170 | .44310 | -12.195 | 0.000 (H.S) |
| | Ceramic | 12.8860 | .42545 | | |
| **Laser Repair system I** | Metal | 9.3240 | .51746 | 4.628 | 0.000 (H.S) |
| | Ceramic | 8.3530 | .41532 | | |
| **Acid Repair system I** | Metal | 7.8300 | .32931 | 8.281 | 0.000 (H.S) |
| | Ceramic | 6.5990 | .33547 | | |

HS – Highly Significant




*Graph 1: Comparison of mean shear bond strength values among the two repair systems for both acid etched and laser surface treated surface specimens under both ceramic and metal substrates*

## Discussion and Conclusion

The main reasons for an intraoral repair are to avoid the substantial cost of interim prostheses and laboratory work [7], to minimize the time required at the clinic and laboratory [8], to avoid the possible propagation of cracks or crazing, to avoid the distortion (40 to 100 μm) that might occur during removal and additional firings of the restoration, to prevent accumulation of microorganisms and plaque on the fractured surface, and of course, to be conservative. The purpose of this in vitro study was to compare the shear bond strength of composite resin that had been bonded to a feldspathic porcelain and metal by using two commercially different porcelain repair systems after two different surface treatments. This was with a view to assessing their relative performances.

The optimum bond strength of composite resin bonded to porcelain and metal was evaluated by applying a combination of different surface treatment methods, one repair system (Bisco Inc., Schaumburg, IL, USA) was compared with another repair system (Angelus, BRAZIL) with surface treatments recommended by the manufacturer and Er: YAG hard tissue laser.

A standardized protocol for etching, salinization 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 and laser surface treatment in the testing conditions.

In this study bond strengths obtained from substrates exposed to HF acid etching were lower than those in substrates exposed to laser surface treatment. This might be because HF acid etching was not effective on ceramic surfaces or metal. Hence lower mean shear bond strength values were found for both the repair system where acid etching was the surface treatment. Laser irradiation might have led to the development of a heat damaged layer on the metal surface. This might be one of the reasons for lower mean shear bond strength values when compared to ceramic substrates.

According to the results, all bond strength values between porcelain and composite resulted in stronger bond than between metal and composite in both repair systems. This can be explained with the effect of acid roughening and silane agents on porcelain surfaces. Kupiec et al revealed that application of hydrofluoric acid, especially using it with silane agents increased bond strength. Similarly, Stangel et al reported in their study that roughening with hydrofluoric acid increases the bond strength between porcelain and composite.

The silane coupling agent used in Angelus repair kit is pre activated, solvent based on ethanol for less evaporation and the silane coupling agent used in Bisco intraoral repair kit is a two-part silane coupling agent offering additional shelf-life stability to ensure long lasting effective bonding to porcelain. The mean shear bond strengths of composite on ceramic for Bisco repair kit (laser - 14.8530 MPa, HF acid - 12.8860MPa) was higher compared to Angelus repair kit (laser -8.3530 MPa, HF acid - 6.5990 MPa). The difference in porcelain repair kits is attributed to different chemical reactions of silane in forming a bond between the substrate and resin. Evidence shows that silanes with different chemical compositions and concentrations of solvents have variable adhesions.

Based on the results, the bond strength of substrate to resin composite was significantly different among the groups with different repair methods. It could be inferred that using the Intraoral Repair Kit Bisco was helpful in repairing fractured porcelain surface, while Angelus Repair System was beneficial to restore exposed metal surface with resin composite.

The mean shear bond strengths of laser surface treated groups and acid etched group, laser surface treated groups showed better bond strengths in case of Bisco intraoral repair kit for ceramic substrates, this can be explained since more surface roughness is create by laser surface treatment and because of the silane coupling agent. But for Angelus repair system metal substrates had better mean shear bond strength values for both laser and acid etched surface groups (laser - 9.3240 MPa, acid etch - 7.8300 MPa). This might be because of poor bonding adhesive present in the kit. There are no studies available demonstrating whether Er: YAG laser irradiation modifies the surface of base metal alloys. The extent of the superficial changes on the metal surface depends on the energy density of the laser radiation as well as on the type of irradiated metal.

Each group of metal specimens displayed a unique failure mode in response to different repair methods. The metal specimens treated by the repair system I and II (Intraoral Repair Kit) after acid etching and laser surface treatment displayed adhesive failure, and also showed low bond strength. In the specimens roughened by acid, the opaque porcelain was often partially detached. Also, a greater part of the opaque porcelain failed in metal specimens treated by the repair system I (Angelus) than failed using the repair system II.

Ceramic repair system II used in this study showed higher shear bond strength values to metal substrate (laser - 11.8130 MPa, acid etch - 10.5170MPa) due to the presence of alloy primer containing MDP (10-methacryloyloxydecyl dihydrogen phosphate). MDP contains an ester phosphate group which forms a strong chemical bonding with oxide layer on the surface of the alloy for reliable bond of the resin to alloys. However, Porcelain repair system used in this study (Angelus) did not have individual alloy primer containing MDP and hence showed the least shear bond strength values for metal substrate (laser – 9.3240 MPa, acid etch -7.8300MPa) among the 2 intraoral repair systems studied.

The failure mode of the metal specimens tends to reflect the core-resin bond strength values, which demonstrated a stronger bond between the exposed metal surface and resin composite in the groups with repair system II than in the groups with repair system I for both the surface treatments [9, 10]. This can be explained because of the presence of the metal primer (Z-Prime Plus of Bisco Inc., Schaumburg, IL, USA containing MDP) in repair system II and its absence in repair system I.

The ceramic to composite and metal to composite bond is susceptible to chemical, thermal and mechanical influences under intraoral conditions [11]. Long-term water storage and thermocycling of bonded specimens are accepted methods to simulate aging and to stress the bonding interface. This study applied minimal thermal cycles to the bonded interface.

It is evident from data available in the literature that anterior metal‑ceramic restorations are more prone for fracture. 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. Unfortunately, there are no reports on the minimum shear bond strength values required for metal-ceramic restoration repair materials [12,13]. However, the ideal requirement of material should have a bond value similar to reported metal-ceramic bond strength (16–24 MPa). The average masticatory forces are reported to be between 20 and 830 N in the literature. The masticatory forces between the incisors vary between 155 and 222 N and are higher for molars up to 830 N. Since, the strength is directly proportional to the masticatory forces and inversely proportional to area (Strength = F/A), it may be assumed minimum bond strength required for intraoral repair material is 8–9 MPa.

According to this study, the bond strength values obtained for the two intraoral repair systems were higher than above assumed bond strength value (8–9 MPa) when shear bond strength values of 2 different porcelain repair kits and their restorations were compared; the values in all groups were above the acceptable values and utilizable clinically. This gives enough justification to recommend both repair systems in conjunction with acid etch or laser as a surface pretreatment used in this study for intraoral chairside repair of metal-ceramic restoration.

This study had some limitations, the application time and concentrations of acids were different. However, this study was conducted according to the manufacturer's instructions. In further studies, these factors should be controlled. In addition, thermal cycling was used as an aging procedure. To better simulate a clinical environment, thermal cycling should be combined with cyclic fatigue [14,15,16]. Further, in vivo studies would definitely give more information and clearer understanding about the clinical performance of these systems [17]. Further studies are required to evaluate the effects of different power settings and different laser applications on ceramic surfaces to obtain optimum bond strength and roughness values.

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

When the mean shear bond strength values of the two repair systems were evaluated and compared the following conclusions were drawn:

1. The mean shear bond strength of the two intra oral repair systems on metal substrates were comparatively less.
2. The mean shear bond strength of the two intra oral repair systems on ceramic substrates were significantly higher.
3. The mean shear bond strength of repair system II were significantly higher for both the metal and ceramic substrates.

When compared among the groups for both the ceramic repair systems after acid etching and laser surface treatment the following conclusion were drawn:

1. For acid etch surface treatment, the mean shear bond strength values among both the groups and the two repair systems were comparatively less.
2. For laser surface treatment, the mean shear bond strength values among both the groups and the two repair systems were significantly higher.

3. Repair system II was assessed to be a better intra oral repair system among the groups after laser surface treatment.

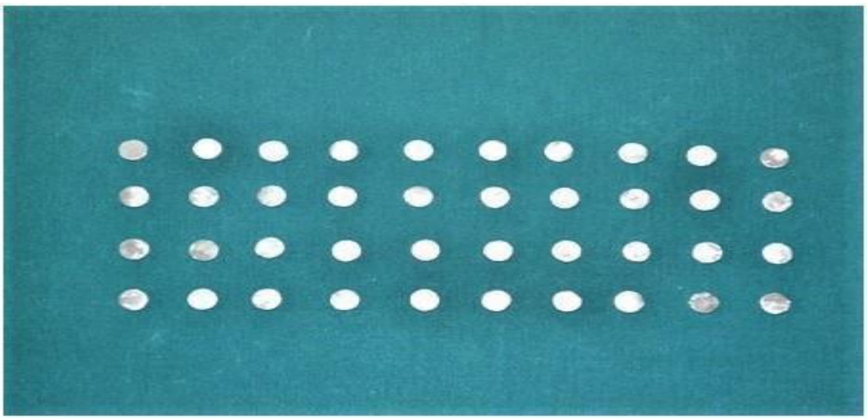


*Figure 1: 40 Nickel Chromium metal substrates*

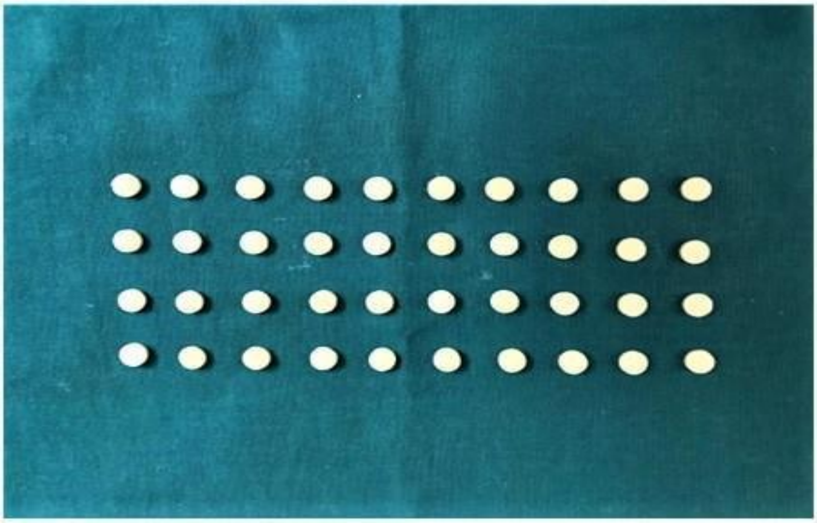


*Figure 2: 40 feldspathic ceramic substrates*

*Figure 3: Customized matrix for specimen fabrication*


*Figure 4: Repair system I*


*Figure 5: Repair system II*

*Figure 6: Ceramic substrates embedded in acrylic*

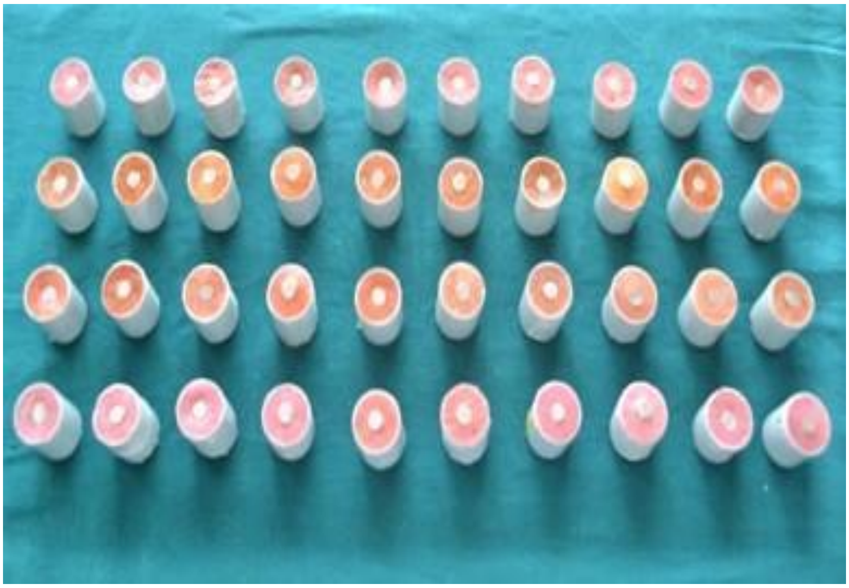


*Figure 7: Metal substrates embedded in acrylic*

*Figure 8: Shear bond strength test*

References


1. Haselton RD, Diaz-Arnold MA, Dunne TJ (2001) Shear bond strengths of 2 intraoral porcelain repair systems to porcelain or metal substrates. J Prosthet Dent 86:526–531 [Google Scholar]

2. Galiatsatos AA (2005) An indirect repair technique for fractured metal-ceramic restorations: a clinical report. J Prosthet Dent 93:321–323 [Google Scholar]

3. Libby G, Acuri MR, Lavelle WE, Hebl L (1997) Longevity of fixed partial dentures. J Prosthet Dent 78:127–131 [Google Scholar]

4. Santos DGJ, Fonseca GR, Adabo LG, Cruz DAC (2006) Shear bond strength of metal-ceramic repair systems. J Prosthet Dent 96:165–173 [Google Scholar]

5. Chung HK, Hwang CY (1997) Bonding strength of porcelain repair systems with various surface treatments. J Prosthet Dent 78:267–274 [Google Scholar]

6. Appledorn ER, Wilverding MT, Barkmeier WW (1993) Bond strength of composite to porcelain with newer generation of repair systems. J Prosthet Dent 70:6–11 [Google Scholar]

7. Thurmond WJ, Barkmeier WW, Wilweding MT (1994) Effect of porcelain surface treatments on bond strength of composite resin bonded to porcelain. J Prosthet Dent 72:355–359 [Google Scholar]

8. Cobb SD, Vargas MA, Fridrich AT, Bouschlicher RM (2000) Metal surface treatment: characterization and effect on composite-to-metal bond strength. Oper Dent 25:427–433 [Google Scholar]

9. Tulunoglu FI, Beydemir B (2000) Resin shear bond strength to porcelain and a base metalalloy using two polymerization schemes. J Prosthet Dent 83:181–186 [Google Scholar]

10. Petridis H, Garefis P, Hirayama H, Kafantaris MN, Koidis TP (2003) Bonding indirect resin composites to metal: part 1. Comparison of shear bond strengths between different metal-resin bonding systems and a metal-ceramic system. Int J Prosthodont 16:635–639 [Google Scholar]

11. Ozcan M, Sleen MJ, Kurunmaki H, Vallittu KP (2006) Comparison of repair methods for ceramic fused to metal crowns. J Prosthodont 15:283–288 [Google Scholar]

12. Suliman AA, Swift JE, Perdigo J (1993) Effect of surface treatment and bonding agents on bond strength of composite resin on porcelain. J Prosthet Dent 70:118–120 [Google Scholar]

13. Ozcan M, Neidermeier W (2002) Clinical study on the reasons and location of failures of metal-ceramic restorations and survival of repair. Int J Prosthodont 15:299–302 [Google Scholar]

14. Chung HK, Hwang CY (1997) Bonding strength of porcelain repair systems with various surface treatments. J Prosthet Dent 78:267–274 [Google Scholar]

15. Blatz BM, Dent M, Sadan A, Kern M (2003) Resin-ceramic bonding: a review of literature. J Prosthet Dent 89:268–274 [Google Scholar]

16. Ferrando PJ, Graser NG, Tallents HR, Jarvis HR (1983) Tensile strength and micro leakage of porcelain repair materials. J Prosthet Dent 50:45–50 [Google Scholar]

17. Bello AJ, Myers LM, Graser NG, Jarvis HR (1985) Bond strength and micro leakage of porcelain repair materials. J Prosthet Dent 54:788–794 [Google Scholar]