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Research Article

An *In Vitro* Evaluation of the Effect of Laser as a Metal Surface Treatment on the Bond Strength of Bonded Prostheses

Abdulelah M Binmahfooz[1] and Tarek R Abdelrehim[2]*

[1]*Assistant Professor of Prosthodontics, Faculty of Dentistry, King Abdulaziz University, KSA*

[2]*Associate Professor of Prosthodontics, Faculty of Dentistry, King Abdulaziz University, KSA*

***Corresponding Author**: Tarek R Abdelrehim, Associate Professor of Prosthodontics, Faculty of Dentistry, King Abdulaziz University, KSA.

Received: November 15, 2017; **Published:** December 02, 2017

Abstract

Preservation of natural tooth accelerated appearance of resin bonded fixed partial dentures. The most recurrent cause of failure of this restoration is debonding at the metal-cement junction. The aim was to compare the shear bond strength of three various alloy surface treatments when cemented with two different resin cements. Thirty discs of nickel chromium alloy were produced and divided according to various surface treatments into three groups. Group I sandblasted with 50 µm aluminum oxide, group II chemically etched; and group III laser treated. The 3 groups were further subdivided into subgroups A and B, according to the resin cement used. The discs were bonded to the enamel surface of extracted natural central and lateral incisors with Panavia F 2.0 and Bistite II DC resin luting cement. All bonded samples were saved in saline for 48 hours followed by thermocycling. Shear bond strength of all the specimens was measured by an Instron universal testing machine. Representative samples of each group were checked by means of scanning electron microscope (SEM). The data were analyzed by using SPSS. It can be concluded that laser has been proven as an effective tool for the metal surface treatment. The highest bond strength was recorded with laser metal surface treatment combined to Panavia F 2.0 resin cement.

Keywords: *Laser; Metal Surface; Bond Strength*

Introduction

Dental implant has the opportunity to offer patients minimally invasive fixed and potentially esthetic replacement resolution for single tooth replacement. However, implant may not be the best option for tooth replacement in many patients and they are still looking for fixed replacement [1]. Dentists frequently choose resin retained fixed partial dentures as a preservative method that enables a fixed prosthetic replacement of missing teeth. A distinguished benefit of this method is minimal tooth reduction in comparison to traditional fixed partial dentures [2]. The resin bonded retainers have been successful if the principles have been followed closely; especially metal preparations, tooth preparation with a specific metal design, and intra oral bonding steps [3].

However, previous studies recommends the use of resin cements mostly described as filled dimethacrylate –based polymers that display low solubility and high tensile strength [4,5]. Different preparation designs have been proposed by various authors, with varying claims for increasing retention and resistance forms which are essential to the success of resin bonded fixed partial dentures [6,7]. A variety of surface treatments have been employed to increase the bond strengths between the metal and the luting resin, including roughness of the metal surface, mechanical retention methods like undercuts, micro-retention methods like sandblasting, tin plating, electrolytic etching and the use of metal bonding agents and laser surface treatment [8-10].

Laser is one of the greatest inventions of the 20th century and its continued development has been an exciting chapter in the history of engineering and technology science. Initially, laser found only limited use in industrial applications, due to complexity and high cost; however, the evolutionary advances in laser technology were translated into significant improvement in the economical and performance parameters [11]. There have been much excitement and argument over the uses of laser in dentistry over the last years. Laser have been used successfully in operative dentistry for caries inhibition, detection and removal, in endodontics for disinfection of the root canals, in periodontics for scaling and curettage, in orthodontics for brackets bonding and debonding and lastly for etching laminate veneers [12].

Aim of the Study

The aim of the present investigation was to evaluate the shear bond strength of 3 different alloy surface treatment methods bonded with 2 different resin cements.

Materials and Methods

Thirty freshly extracted human maxillary anterior teeth were cleaned, pumiced and stored in 0.9% saline. A flat surface was prepared on the labial enamel surface with a new diamond disc under water. Samples were checked under 10X magnification to make certain preparation was only in enamel. Each tooth was individually mounted in cylindrical support (2.5 x 2 cm) with self curing acrylic resin up to 2.0 mm of the cement-enamel junction. The mounted prepared teeth were stored in 0.9% saline at room temperature until needed.

Thirty wax discs (7 mm diameter and 5 mm thickness) were gained from a special metallic mold. The wax patterns were invested (Bellavest SH and BegoSol, Bego, Germany) and casted in a nickel-chromium (Ni-Cr) alloy, (Wiron 99 Bego, Germany) following the manufacturer's instructions. A new metal was applied for casting using a calibrated induction casting machine (Fornax, Bego, Germany). The sprues of all cast specimens were cut off using separating disc. All discs were examined using magnifying lens, those presenting imperfections were excluded. All discs were ultra sonically cleaned in ionized distilled water for 10 minutes.

Surface treatments

All samples were divided into 3 groups for different surface treatments as following:

- **Group I (Sandblasting group):** 10 specimens were sandblast with 50 µm aluminum oxide (Al_2O_3) (Korox, Bego, Germany) in a sandblasting machine (Easy Blast, Bego, Germany), at a distance of 5 mm and under a pressure of 75 psi for 15 seconds. Resulting in a dull frosty metal surface appearance then cleaned with steamer (Triton, Bego, Germany) for 2 minutes.
- **Group II (acid etching group):** 10 specimens were chemically treated using a metal etching gel (Meta –Etch, Gresco products, Inc, Stafford, TX, USA), consists of 12% hydrochloric acid and 4% nitric acid. It was placed on the surface to be etched until the gel turns green (25 minutes), and then the discs were rinsed with tap water and cleaned ultrasonically with distilled water for 3 minutes. The manufacturer instruction was followed.
- **Group III (lased group):** 10 specimens were lased. An Nd: YAG laser system (Continuum NY 81-30 USA) at the infrared wave length (ג =1064) was used. The laser beam was reflected at 90^0 angle on the alloy disc which was fixed on a special holder having a central cavity of 7mm diameter and 1mm depth via a special flat fully reflected dielectric mirror (Melles Groit 02 MPG) held at 45^0 incident angle. The exposure power densities (210 MW/cm^2) and the number of pulses was 1800 per minute (30 pulses/second). The average power, in watt, was first measured using a power meter (Astral A 30 Scientech USA), Then the average power was divided by the repetition rate (30 pulses/sec) to calculate the energy/pulse in joules. The peak power in Mega Watt (MW) was calculated by dividing the energy/pulse by pulse duration (7 nanoseconds). The power density was calculated by dividing the peak power density by the area exposed to the laser energy. The alloy disc having a diameter of 0.7cm has an area (nr^2) equal to 0.38 cm^2. The number of pulses was calculated by adjusting the time of exposure using a stop watch. The total exposure density was calculated by multiplying the power density by the number of pulses (210 MW/cm^2 X 1800 = 378000 MW/cm^2).

The 3 groups were then subdivided into 2 subgroups (A and B). Two resin luting cements were used: Panavia F 2.0 (Kuraray America, Inc) for subgroup (A) and Bistite II DC (Tokuyama America, Inc) for subgroup (B). For each of the 3 groups, 5 specimens were bonded to extracted teeth with Panavia F 2.0 and the other 5 specimens were cemented with Bistite II DC, according to manufacturer's recommendation. A thin layer of cement was coated to the whole surface of the disc, and then bonded to the tooth. A static load of 1 Kg was applied to the specimens until polymerization was achieved. All specimens were reserved in 0.9% saline at 37OC for 48 hours before measured. Then subjected to thermocycling for 500 cycles between 5^0 C and 55^0 C with a 1 minute dwell time [13,14]. Samples were preserved in distilled water for additional 24 hours before testing. Each tooth was adjusted in order to keep the bonded surfaces of the tooth and the metal disc parallel to the direction of force created by the Instron universal testing machine (Comten Industries, USA). A shear force was utilized to each specimen using crosshead speed of 0.05 cm/minute. The force required to break the bond was recorded in Newton (N) and the shear bond strength was calculated in Mega Pascal (MPa) for each specimen according to the following equation: Shear bond strength (MPa) = Failure Load/surface area (mm^2). Representative sample of each group was examined by scanning electron microscope (Joel, Japan) to demonstrate the mode of failure of the cement of the different test groups.

The collected records were statistically analyzed using SPSS, version 21 software. Arithmetic mean and standard deviation were obtained. T-test was used to compare between the two groups. For comparison among all the groups ANOVA test was used. The level of significant was 0.05.

Results

The shear bond strength values were registered in (MPa), the mean and standard deviation was calculated and results of comparison among different groups are presented in table 1 and figure 1.

Surface treatment	Panavia F 2.0 cement	Bistite II DC Cement	t p
(Group I) Sandblasting	24.11 ± 3.06	21.66 ± 1.68	1.64 0.103
(Group II) Acid etching	27.02 ± 2.66	23.01 ± 2.03	2.72 0.011*
(Group III) Laser	36.98 ± 3.71	29.04 ± 3.62	3.11 0.001*
F	12.98	6.15	
P	0.001*	0.012*	
LSD	5.28	4.36	

Table 1: *The mean value and standard deviation of the shear bond strength (MPa) of different groups.*

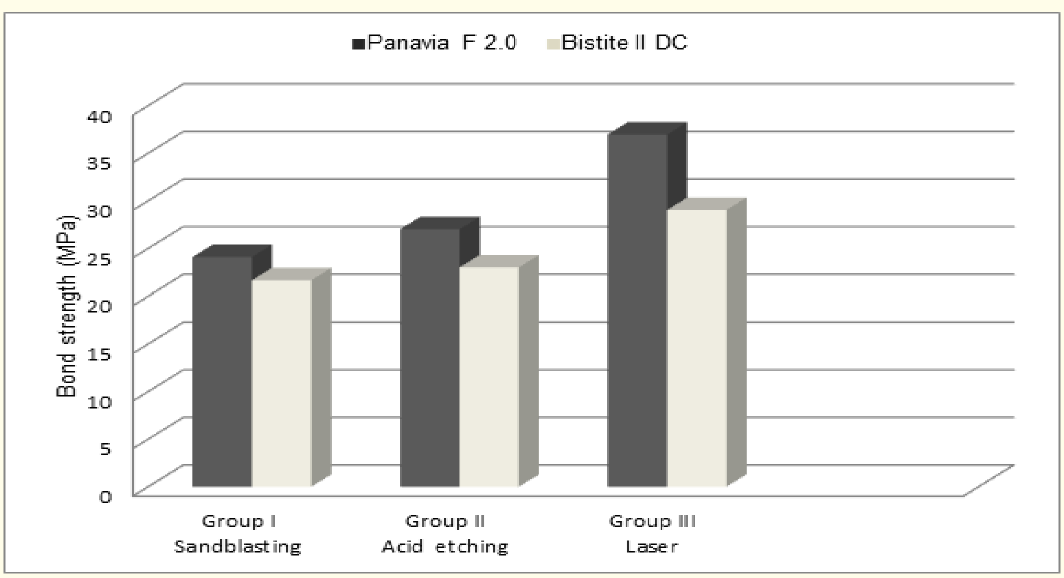

Figure 1: *Shear bond strength mean value of different groups.*

The mean shear bond strength of Panavia F 2.0 resin cement in group I (sandblasting), group II (acid etching), and group III (laser), were 24.11, 27.02, and 36.98 MPa respectively. Laser group presented higher value of shear bond strength than sandblasting and acid etching group. There was a significant difference among group III, group I and II (P = 0.001), and no significant difference between group I and II.

Furthermore the mean shear bond strength of Bistite II DC resin cement in the 3 tested groups was 21.66, 23.01, and 29.04 MPa respectively. A significant difference between shear bond strength in laser group (the highest mean value) and the two other groups (sandblasting and acid etching) was found (P = 0.012), while no significant difference between the sandblasted and acid etch group.

When comparing between the 2 resin cements, Panavia F 2.0 and Bistite II DC) in each group (sandblasting, acid etching and laser) there was a significant difference between the two resin cements in acid etching group and laser group (P = 0.011 and 0.001) respectively, Panavia F 2.0 resin cement presented higher bond strength than Bistite II DC. There was no significant difference between both resins in sandblasting group.

From the previous results the highest shear bond strength value was found with Panavia F 2.0 in laser group, followed by Bistite II DC in the same group.

Scanning electron miscopy of sandblasted, etched and laser nickel chromium alloy before bonding are displayed in (Figure 2-4) respectively. SEM displayed primary adhesive failure at the metal cement junction in sandblasted and acid etch group, while laser group (Figure 5) displayed a mixed failure mode (adhesive and cohesive).

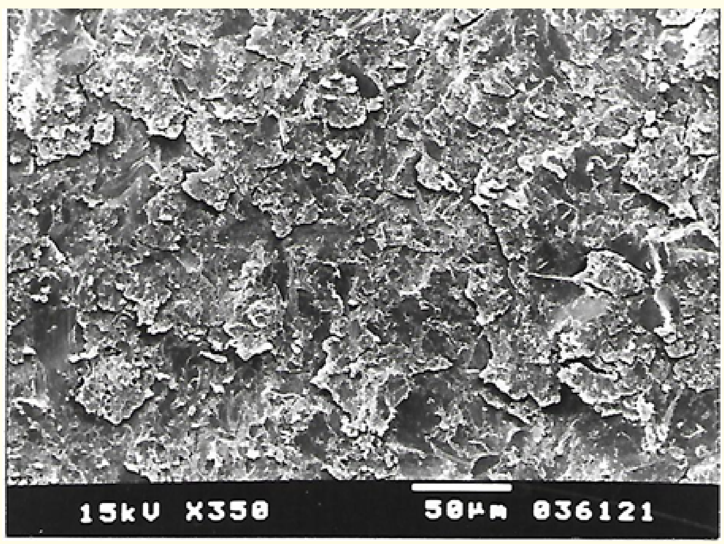

Figure 2: *Specimen of sandblasted metal surface treatment group (SEM photograph, original magnification 350x).*

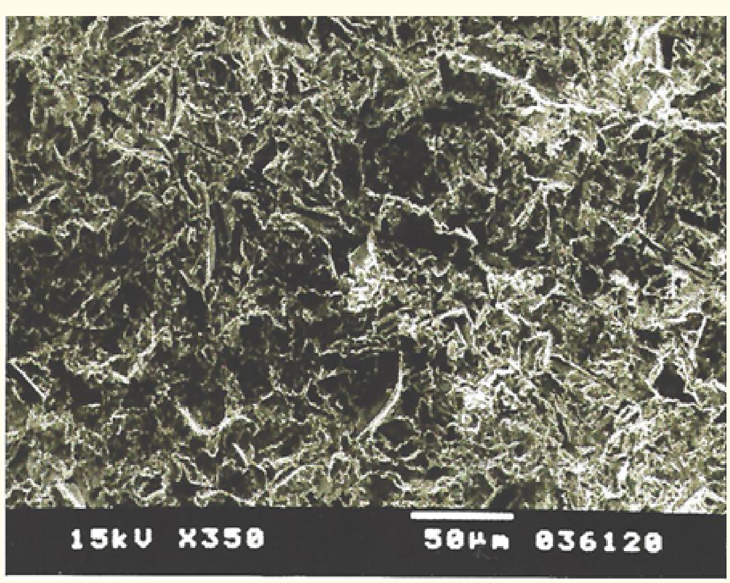

Figure 3: *Specimen of acid etch metal surface treatment group (SEM photograph, original magnification 350x).*

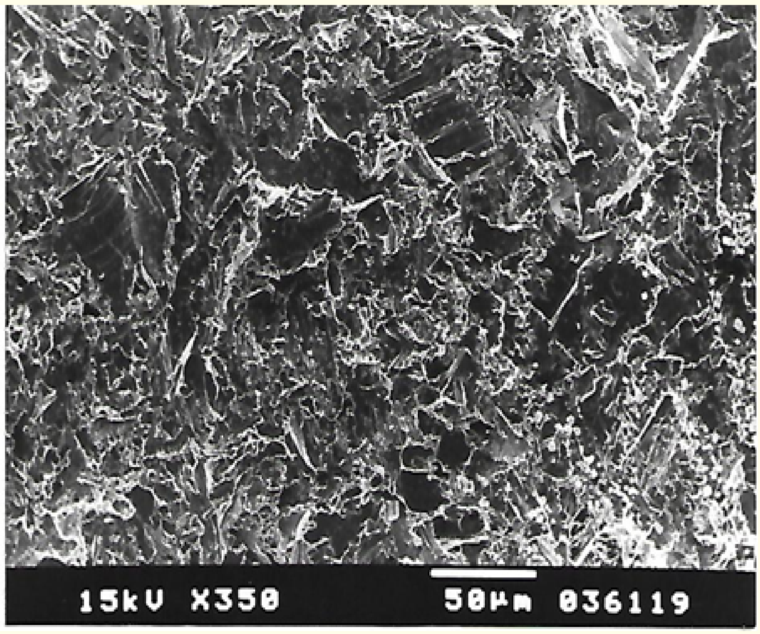

Figure 4: *Specimen of laser metal surface treatment group (SEM photograph, original magnification 350x).*

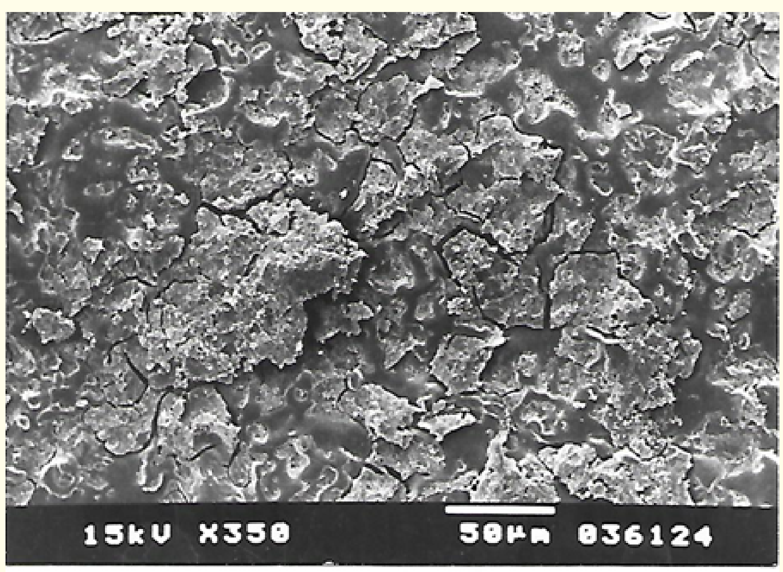

Figure 5: *Specimen in debonding presenting cohesive and adhesive failure (SEM photograph, original magnification 350x).*

Discussion

Many variables affect the success of resin retained fixed partial dentures; in this study 3 metal surface treatments were investigated to improve the micro-roughness and macro-mechanical retention. Sandblasting with aluminum oxide 50 μm and acid etching on the internal surface of the retainer are the most popular methods as metal surface treatments. Laser was described as an excellent tool for material removal. Nd:YAG laser system was chosen to be compared to these previous metal treatments and to examine the variation in the metal cement bond strength.

To simulate the clinical situation, castings were cemented to enamel in our study. This disagrees with Dixon and Antoniadon., *et al.* [15,16] who used the luting agent to form a bond between two castings. In comparison with the previous studies [17], the increased of standard deviation in the present study may be due to the variability of the enamel surface. Also the control of cementation pressure may be the cause of this variability [14].

The retention of cast restorations depends on the adhesion between the cast alloy retainer and the luting cement, the cohesive strength of the luting cement itself and the adhesions between the luting cement and tooth structure. Although successful bonding has been achieved at the latter two sites, adhesion between the alloy and the cement is relatively inconsistent and a common site of failure.

The actual mechanism of bonding between the alloy and cement is still elusive. Different theories have described the bonding mechanism as a function of mechanical, chemical or combination of mechanical and chemical factors. Chemical bonding was reported to provide good metal-cement bonding. A link is formed between the oxides formed on the alloy surface and the luting cement. Mechanical bonding between the alloy and cements proposes mechanical keying of the adhesive into the fine and minute irregularities of the substrate surface. It is of value to mention that large and deep irregularities of the alloy surface might lead to inclusion of voids at the alloy-cement junction disturbing proper wetting and subsequently reducing the bond strength. SEM surface analysis was intended as a verification of the role of the surface topography in the mechanical bonding between the alloy and the cement [18].

Sandblasting using 50 um aluminum oxide which used in this study was the same particles size as those used by many researchers [14,19]. Resin adheres to the enamel surface through the micro-mechanical engaging of resin to the hydroxyapatite crystals and rods of the etched enamel surface. The perfect bond strengths to the sandblasted base metal alloy due to the chemical communication of the resin with the oxide layer on the metal surface [20,21]. In another research done by Goswami., *et al.* [22] showed that sandblasting only produced less shear bond strength than clinically accepted.

In a study done by Al-Helou [23] he suggested the application of metal primer to increase shear bond strength to base metal and noble metal. In another study the metal primer did not promote an increase in bond strength of resin cement to nickel-chromium alloy [24].

The highest cement bond strength values recorded in the laser group, this may be related to the surface roughness with minute depressions (Figure 4) into which the cement might have flowed. The different orientations of the linear scratches and tubular arrangement shown in this group might have further helped in the mechanical retention of the cement onto the alloy. Laboratory results obtained by Shereen [12] demonstrated that the shear bond strength of lased cobalt chromium was significantly higher than acid etched specimens of the same alloy. In an investigation done by Grover., *et al.* [25], they reported that Nd: YAG laser surface treatment produced excellent surface roughness and obtained the highest bond strength values. Further support of these findings is related to Vallittu., *et al*. [26] who referred the cohesive bonding failure obtained with the sandblasted alloy surface to the numerous micro-irregularities revealed in the SEM analysis that might have offered good retention with the cement material.

The dispersing apparatus of the resin luting cement used in this study enables the dentists to always distribute correct proportion of the base and catalyst, while older brands distributed the power and liquid independently, leading to alternation in the applied measure of powder or liquid and resultant inconsistency in the quality of the mix [27]. All specimens were subjected to standardized procedure for cementation, storage and thermocycling.

It is recommended that thermocycling should be included in all studies of bonded metal restorations [28]. Thermocycling and water storage influence the mode of tensile failure of resin bonded base metal alloy [29]. Metal bonded to all metal specimens stored in water for 2 days (with or without thermocycling) demonstrated cohesive failure within the luting agent. While adhesive failure was observed after 30 days water storage (70% of thermocycled samples and 100% of non-thermocycled samples). May be the effects of thermocycling would be larger in the metal bonded to enamel situation where the resin cement would be between two materials with different coefficients of thermal expansion. In the present study one minute dwell times were used to allow the specimens to reach equilibrium in every water bath. A variety of thermocycling cycle numbers and dwell times have been recorded in the many studies [16,28,30].

Subjective evaluation of SEM at 350 power magnification reveled differences that were representative of the results reported in this study. The lased specimens (Figure 4) revealed not only more exposed surface area and deeper etched pattern but evidence of large and deeper pores. The formulation of the results obtained in this study is that laser has succeeded in enhancing the metal cement bonding of base metal alloy.

A recent study of clinical performance of resin bonded fixed partial denture prostheses up to10 year of clinical evaluation presented that it could provide acceptable clinical longevity with high patient satisfaction, and it can be considered a minimally invasive, economical and time saving treatment alternative for the other prosthetic rehabilitation for missing teeth [31].

Conclusions

Based on the results of this study, the following conclusions can be drawn:

1. Laser has been proven as an effective means for metal surface treatment.
2. Laser metal surface treatment significantly enhanced shear bond strength to base metal alloy compared to sandblasting and acid etching.
3. The highest bond strength was obtained with laser surface treatment in combination with Panavia F 2.0 resin cement.
4. Further investigation should be carried out to study the effect of different metal surface treatment on noble metal alloys.

Bibliography

1. Barwacz CA., *et al*. "Minimally invasive preparation and design of a cantilevered, all ceramic, resin bonded fixed partial denture in the esthetic zone: a case report and descriptive review". *Journal of Esthetic and Restorative Dentistry* 26.5 (2014): 314-323.
2. Petrie CS., *et al*. "A comparison of 3 alloys surface treatments for resin- bonded prostheses". *Journal of Prosthodontics* 10.4 (2001): 217-223.
3. Doukoudak A., *et al*. "A comparison of the shear strength of chemically versus electrolytically etched metal retainers". *Journal of Prosthetic Dentistry* 67.5 (1992): 614-616.
4. Tanaka T., *et al*. "M.4 META opaque resin- A new resin strongly adhesive to nickel- chromium alloy". *Journal of Dental Research* 60 (1981): 1697-1706.
5. Hussey DL., *et al*. "Performance of 400 adhesive bridges fitted in a restorative dentistry department". *Journal of Dentistry* 19.4 (1991): 221-225.
6. Arora V., *et al*. "Comparative evaluation of retentive properties of acid etched resin bonded fixed partial denture". *Medical Journal Armed Forces India* 70.1 (2014): 53-57.
7. Verzijden., *et al*. "A metal analysis of two different trials on posterior resin-bonded bridges". *Journal of Dentistry* 22 (1994): 29-32.
8. Mc Caughey AD. "Sandblasting and tinplating surface treatment to improve the bonding with resin cements". *Dental Update* 20 (1993): 153-157.
9. Abouch Y., *et al*. "Resin to metal bonds mediated by adhesion promoters". *Dental Materials* 7.4 (1991): 279-280.
10. Tjan HL and Hemetz H. "Bond strength of composite to metal mediated by metal adhesive promoters". *Journal of Prosthetic Dentistry* 57.5 (1987): 53-54.
11. Dobberstein H., *et al*. "Laser processing of dental materials: Laser in dentistry". Quintessence Publication Co. Inc, (1995).
12. Shereen AA. "Evaluation of laser treatment of different types of ceramometallic alloys". *Ph D. Cairo University* (2001).
13. Miyazaki M., et al. "Durability of enamel bond strength of simplified bonding systems". *Operative Dentistry Journal* 25.2 (2000): 75-80.
14. Dixon DL., *et al*. "Comparison of tensile bond strengths of two resin luting systems for a base metal and a high noble metal". *Journal of Prosthetic Dentistry* 72.5 (1994): 457-461.
15. Antoniadon M., *et al*. "Effect of a new metal primer on the bond strength between resin cement and two high nobel alloys". *Journal of Prosthetic Dentistry* 84.5 (2000): 554-560.
16. Imbery TA., *et al*. "Tensile strength of three resin cements following two alloy surface treatments". *International Journal of Prosthodontics* 5.1 (1992): 59-67.

17. Gates WD., et al. "Comparison of the adhesive strength of a BIS-GAMA cement to tin plated and non-tin plated alloys". *Journal of Prosthetic Dentistry* 69.1 (1993): 12-16.

18. Anusavice KJ., *et al*. "Phillips Science of dental materials". 12th Edition, WS Saunders Co (2012).

19. Tanaka T., *et al*. "Surface treatment of non precious alloys for adhesion of fixed partial dentures". *Journal of Prosthetic Dentistry* 55.4 (1986): 456-462.

20. Arnold A., *et al*. "Current status of luting agents for fixed prosthodontic". *Journal of Prosthetic Dentistry* 81.2 (1999): 135-141.

21. Aquilino SA., *et al*. "Tensile fatigue limits of prosthodontic adhesives". *Journal of Dental Research* 70.3 (1991): 208-210.

22. Goswami MM., *et al*. "Evaluation of shear bond strength of composite resin bonded to alloy treated with sandblasting and electrolytic etching". *Journal of Indian Prosthodontic Society* 14.1 (2014): 98-103.

23. Al Helou H and Sweed E. "Effect of metal type and surface treatment on shear bond strength of resin cement(in vitro study)". *Journal of Indian Prosthodontic Society* 16.1 (2016): 49-52.

24. Fonseca R., *et al*. "Effect of metal primers on bond strength of resin cements to base metals". *Journal of Prosthetic Dentistry* 101.4 (2009): 262-268.

25. Grover N and Nandlal B. "An in vitro evaluation of the effect of sandblasting and laser surface treatment on the shear bond strength of a composite resin to the facial surface of primary anterior stainless steel crowns". *Journal of Clinical and Experimental Dentistry* 7.1 (2015): 119-125.

26. Vallittu PK and Forss H. "Adhesion of glass ionomer cement to ceramometal alloy". *Journal of Prosthetic Dentistry* 77.1 (1997): 12-16.

27. Rubo JH and Pegoraro LF. "Tensile bond strength of composite resin cement for bonded prosthesis to various dental alloys". *Journal of Prosthetic Dentistry* 74.3 (1995): 230-234.

28. Ishijima T., *et al*. "Adhesion of resin to casting alloys". *Journal of Prosthetic Dentistry* 67.4 (1992): 445-449.

29. Diaz-Amold AM., *et al*. "Tensile strength of three luting agents for adhesive fixed partial dentures". *International Journal of Prosthodontics* 2.2 (1989): 115-122.

30. Thompson VP., *et al*. "Resin bonded retainers. Part I: Resin bonded to electrolytically etched non-precious alloys" *Journal of Prosthetic Dentistry* 50.6 (1983): 771-779.

31. Piemjai M., *et al*. "A 10 year clinical evaluation of resin-bonded fixed partial denture prostheses on non-prepared teeth". *European Journal of Prosthodontics and Restorative Dentistry* 24 (2016): 63-70.

Volume 16 Issue 2 December 2017