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Comparision of shear bond strength of stainless steel brackets on porcelain fused metal and zirconium crowns with different types of surface conditioning techniques: An in vitro study

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Abstract

Background: An increasing percentage of today's orthodontic population consists of adults who may need bonding to esthetic restorations such as zirconium or porcelain fused metal crowns. Bonding brackets to these crowns is complicated because of composition and surface integrity. Hence acid etching, sandblasting, and silane techniques have been investigated as methods to boost bond strength.

Methods: The sample composed of 30 Porcelain fused metal and 30 Zirconium crowns. The specimens are divided into 2 groups of 30 each and coded A & B. GROUP A – Porcelain fused metal; GROUP B – Zirconium. These were again subdivided into 3 subgroups of 10 each based on surface conditioning techniques and coded Group I to III. Group I - Sand blasting + Hydrofluoric acid + Silane, Group II - Sand blasting + Silane, Group III - Hydrofluoric acid + Silane. Stainless steel orthodontic brackets were bonded and shear bond strength was assessed.

Results: ANOVA showed a statistical difference between the three groups of Porcelain fused metal & Zirconium. Intra group comparision between Porcelain fused metal & Zirconium using post hoc tukey test showed no significant difference between Sandblasting + Hydrofluoric acid + Silane and Hydrofluoric acid + Silane.

Conclusion: Surface treatment with Hydrofluoric acid and Silane coupling agent produced highest bond strength in both Porcelain fused metal & Zirconium groups.

Keywords: Shear bond strength, Porcelain fused metal, Zirconium, Sandblasting, Hydrofluoric acid, Silane

Introduction

An increasing percentage of today's orthodontic population consists of adults who may need bonding to esthetic restorations such as zirconium or porcelain fused metal crowns. Bonding brackets to these crowns is complicated because of composition and surface integrity. Due to composition, they are relatively resistant to dilute acids and do not etch well. Surface integrity depends on the finishing procedure and whether the surface is glazed. Hence acid etching, sandblasting, and silane techniques have been investigated as methods to boost bond strength.[1] While conventional acid etching with 37% phosphoric acid is useful for enamel, this is inefficient for bonding orthodontic brackets to the porcelain surface, so strong acids like 9.6% HF are frequently used which creates surface pits by the preferential dissolution of the glass phase from the ceramic matrix.[2] The use of silane increases adhesion of composite resin bond to ceramic, by creating a chemical link between hydroxyl (OH) group of silica of the ceramic with the adhesive matrix of the composite.[3] Sandblasting can increase the surface roughness, provides micromechanical undercuts, cleans the porcelain surface, and increases the surface energy and wettability, which can improve the adhesion of the ceramics, but they are reported to provoke crack initiation and propagation within the ceramic.[4] Therefore, the present research study aims to compare the shear bond strength of stainless steel metal brackets bonded to porcelain fused metal and zirconium crowns with different types of surface conditioning techniques.

Materials and methods

The present study was conducted in the Department of Orthodontics and Dentofacial Orthopedics, Drs Sudha & Nageswara Rao Siddhartha institute of dental sciences, Chinnaoutapalli, Gannavaram, Andhra Pradesh and Virtue Metasol material solutions Balanagar, Hyderabad

Preparation of crowns

One human mandibular premolar tooth, necessary for the fabrication of Porcelain fused metal and zirconium crowns was collected & stored in normal saline after treating the tooth with 10% hydrogen peroxide for one week. Tooth preparation was done by using a diamond carbide crown cutting bur in a contra angle airotor hand piece (NSK N-75). Thirty PFM & Zirconia crowns were fabricated over this prepared tooth using CAD/CAM technique.

Procedure

The sample composed of 30 PFM and 30 Zirconium crowns (Fig 1a & 1b). The specimens are divided into 2 groups of 30 each and coded A & B.

GROUP A – PFM Crowns; GROUP B – Zirconium Crowns

These were again subdivided into 3 subgroups of 10 each based on surface conditioning techniques and coded Group I, II, III in both PFM and Zirconium Groups.

GROUP I - (SAND BLASTING + HYDROFLUORIC ACID + SILANE) (Fig 2c) Buccal surfaces of PFM crowns/ Zirconium crowns were sandblasted with Aluminium oxide particles and then etched with 9.6% HFA (Mediclus co., ltd) for 2 minutes, rinsed with a water / spray combination for 30 seconds, and dried before application of silane. Silane primer (Pulpadent Corporation Watertown, MA 02471 USA) was applied with a microbrush to the etched surface and allowed to dry for 5 minutes.

GROUP II - (SAND BLASTING + SILANE) (Fig 2d) Buccal surfaces of PFM crowns/ Zirconium crowns were sandblasted with Aluminium oxide particles; Silane primer (Pulpadent Corporation Watertown, MA 02471 USA) was applied to the etched surface with a microbrush and allowed to dry for 5 minutes.

GROUP III - (HYDROFLUORIC ACID + SILANE) (Fig 2e) Buccal surfaces of PFM crowns/ Zirconium crowns were etched with 9.6% HFA (Mediclus co., ltd) for 2 minutes, rinsed with a water / spray combination for 30 seconds, and dried before application of silane. Silane primer (Pulpadent Corporation Watertown, MA 02471 USA) was applied with a microbrush to the etched surfaces and allowed to dry for 5 minutes.

After performing respective surface conditioning techniques for each respective group,

a. Orthosolo Universal Bond Enhancer (Ormco) was applied on etched surface of PFM surface with a microbrush and cured for 20 seconds and also a thin coat of Orthosolo Universal Bond Enhancer was painted on the metal bracket base and cured for 10 seconds before applying the paste.
b. Z-Prime Plus Primer (Bisco) was applied on etched surface of zirconium surface with a microbrush and cured for 20 seconds and also a thin coat of Z-Prime Plus Primer was painted on the metal bracket base and cured for 10 seconds before applying the paste.

Later, using a syringe tip, the adhesive was applied to the mandibular premolar bracket base. The mandibular premolar brackets were used because their bases ensured optimal adaptation to glazed or unglazed porcelain surface. The brackets were then positioned at FA point on the PFM & Zirconium crowns and pressed tightly. Excess adhesive was removed with a sharp scaler. All specimens were cured for 40 seconds (20 seconds on the mesial and 20 seconds on distal). All specimens were stored in incubator for 24hrs at 37°c and shear bond strength was assessed using Universal Testing Machine (Fig 3)

Statistical analyses

Descriptive statistics, including the mean, median, standard deviation, and quartiles were calculated for each of the groups tested. One-way analysis of variance (ANOVA) and Tukey's test were used to compare the SBS of the groups. Significance for all statistical tests was predetermined at $P < 0.05$.

Results and discussion

Descriptive statistics for three groups i.e., GROUP - I: Sand blasting + HFA + Silane; GROUP – II: Sandblasting

+ Silane; GROUP – III: HFA + Silane were tabulated in tables and graphs.

Table 1 depicts Results of Shear bond strength of Porcelain fused metal Crowns, compared between the three groups. Maximum shear bond strength mean value (32 Mpa) was obtained in GROUP – III (HFA + Silane) and minimum shear bond strength mean value (26.7 Mpa) was obtained in GROUP – II (Sand blasting + Silane) (Table 1; Graph 1) Table 2 depicts Results of Shear bond strength of Zirconium Crowns, compared between the three groups. Maximum shear bond strength mean value (36.1 Mpa) was obtained in GROUP – III (HFA + Silane) and minimum shear bond strength mean value (30.24 Mpa) was obtained in GROUP – II (Sand blasting + Silane). (Table 2; Graph 2)

The rapid break through of innovative ceramic materials in dentistry have resulted in the need to properly bond orthodontic brackets to various ceramic restorations.[5]Efficient bonding to ceramic is determined by the bonding mechanisms that are controlled in part by the specific surface treatment used to promote micromechanical or chemical retention to the ceramic substrate. The micromechanical retention of the ceramic surface plays an important role for bonding with resin cement. Modification of ceramic surface morphology may be performed to increase bond strength.[5] When orthodontic brackets are bonded to the enamel surface, bonding relies on adhesive penetration into the previously etched tooth surface and on formation of resin tags. In material with artificially glazed surfaces, such as porcelain, there is no such tag formation; for this reason, it demands different types of surface conditioning such as mechanical or chemical pre-treatment of the surface.[3] To improve bond strengths, combinations of methods are recommended. It has been recommended that the methods providing sufficient bond strength with less roughening should be used to avoid microcracks on the ceramic surface.[3] Ceramic surface etching is a dynamic process and the impact is dependent on, surface topography, acid concentration, substrate constitution and etching time. In regard to the etching time, many studies have been done with different kinds of HF etchants and ceramics. Chen et al. evaluated two HFA etchants (5 and 2.5%) and 7 different etching times (180, 150, 90, 60, 30, 0 s). Etching periods above thirty seconds effectively increased the bond strength to resin. Of the two etching agents applied to the unsilanated porcelain, the buffered 2.5% HF produced higher bond strengths to resin than the 5% HF for all etching time periods, except for 180 s.[6] Guler et al. evaluated the effect of different 9.6% HF etching times (30 s, 30+30 s, 60 s, 60+60 s, 120 s, and 180 s) on porcelain and 2 adhesive systems on shear bond strengths to resin composite. The authors concluded that HF etching for 120 s provided adequate bond strength of porcelain to resin. It is known that HF etching of porcelain provides the necessary surface roughness to mechanical interlocking but overetching could have a weakening effect on the porcelain.[7] According to Abu et.al, it was found that the phosphoric acid-etched groups had similar bond strengths to those etched with HFA. This is in agreement with Nebbe and Stein (1996), Bourke and Rock (1999), Pannes et al. (2003) and Larmour et al. (2006) but in contrast to Ajlouni et al. (2005) This is in agreement with the findings of Al Edris et al. (1990) where a threefold increase in bond strength was found after the application of HFA to sandblasted ceramic surfaces.[8] Sriamporn et.al carried out a study to evaluate the surface morphology and crystal structure change of dental zirconia after hydrofluoric acid (HF) etching and it was concluded HF can etch dental zirconia ceramic, creating micro-morphological changes. Tetragonal-to-monoclinic phase transformation was induced on the etched zirconia surface. HFA is best known for its ability to dissolve glass by reacting with SiO2, the major component of most glass, to form silicon tetrafluoride gas and hexafluorosilicic acid.[9] Although Kocadereli et al. (2001) concluded that roughening the porcelain surface with a sandblaster did not increase the resistance to debonding forces but many authors have recommended using an intraoral sandblaster for surface roughening (Eustaquio et al. , 1988; Smith et al. , 1988; Wolf et al. , 1993 ; Zachrisson et al. , 1996; Chung and Hwang, 1997 ; Shahverdi et al. , 1998 ; Jost-Brinkmann and Böhme, 1999).[10] The application of a silane bonding agent resulted in higher bond strengths, and Kocadereli et al., Chung et al., Harari et al., hung et al., kao et al., wood et al. higher shear bond strengths with HFA etching followed by the application of a silane bonding agent when compared to sandblasting and HFA used without silane.[11] In contrast, Schmage et al. found no significant difference in bond strengths between HFA used with silane and HFA alone.[12] Jochen et al. & Moore et al found sandblasting prior to HFA and silane application did not significantly increase bond strengths.[11] In the present study, SBS was highest in HFA + Silane group (Group-III). This is in accordance with Turk et al. wherein their study evaluated the bond strength of brackets to ceramic surfaces with different surface preparations and noted the highest SBS following etching with 9.6% HF acid for 2 minutes and application of silane. However, Abdelnaby et al. and Karan et al. reported that the use of silane did not have any advantage.[13] kwak et. al conducted a study and in their study air abrasion was performed with 30 μm Al_2O_3 particles (used for intraoral) on the glazed zirconia, producing a randomized roughened glazing porcelain surfaces. Although alumina sandblasting produced a significantly rougher surface than Hydrofluoric acid, no increase in bond strength was observed even when silane was applied, confirming that chemical adhesion by silane treatment might have a greater effect than surface roughening.[14]

In the present study, the highest SBS was obtained with HFA and silane application in both PFM and Zirconium groups. This is because HFA facilitates micromechanical retention and silane provides a chemical link between porcelain and composite resin. The contradictory results may be described by the differences in storage conditions, bonding agents, and ceramic types. Considering the harmful and irritating effects of etching with HFA (Jochen, 1973 ; Moore and Manor, 1982), Kocadereli et al. , 2001 ; Schmage et al. , 2003 suggest silane application after sandblasting as an alternative with similar bond strengths.[3] In contrast, Zachrisson (2000) reported that silane application to sandblasted porcelain did not provide clinically acceptable bond strengths and suggested abandoning this technique. In the present study, the lowest SBS was found in the sandblasted and silane group. These results clearly showed that the most significant factor in bond strength of brackets to porcelain teeth is etching with HFA.[3]

Use of ceramic or polycarbonate orthodontic brackets is more desirable on ceramic restorations in esthetic terms. Thus the bond strength of such tooth colored brackets to ceramic surfaces should be further investigated. Although in vitro bond strength studies are useful to provide information about new adhesive materials and bonding techniques, in vitro bond strength data should be interpreted with caution. This study has some limitations that may preclude the extrapolation of the results: it is an in vitro study, which tested only resistance to shear forces, under constant load, without subjecting the sample to any simulation of the oral environment. Variations in temperature, stresses, humidity, acidity, and plaque are impossible to reproduce in the laboratory. Considering the above limitations, further researches should be conducted so that a reliable clinical protocol can be established.

Conclusion

1. Surface treatment with HFA and Silane coupling agent produced highest bond strength in both PFM & Zirconium groups.
2. No significant difference is found between HFA and Silane and Sandblasting before HFA and Silane application.
3. HFA+Silane was preffered because only two surface conditioning techniques were used, which was less time consuming and armamentarium like intraoral sandblaster can be avoided.
4. Silane application to Sandblasted porcelain provided poor results in vitro and clinical trials are needed to determine its reliability for bonding ceramic brackets to ceramic crowns.

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Legend Tables and Figures

Table 1: comparison among the three groups of porcelain fused metal

Groups	Mean±SD	F value	P value
Sandblasting + HFA+ Silane	30.65±2.57	26.6	.000*
Sandblasting + Silane	26.7±1.11		
HFA+ Silane	32±0.75		

*Statistically Significant SD - standard deviation

ANOVA test applied

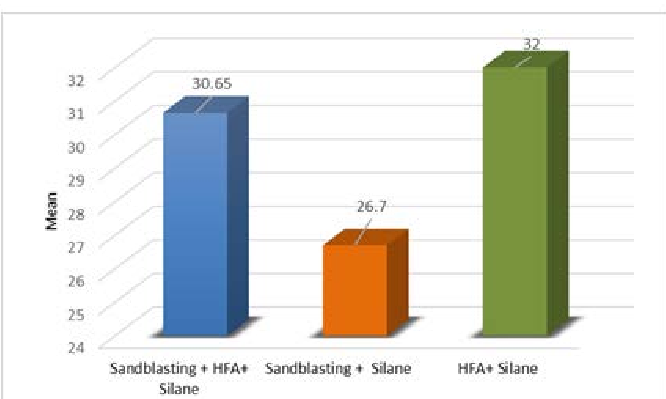
Table 2: comparison among the three groups of zirconium

Groups	Mean±SD	F value	P value
Sandblasting + HFA+ Silane	34.8±1.74	35.28	.000*
Sandblasting + Silane	30.24±1.60		
HFA+ Silane	36.1±1.57		

*Statistically Significant SD - standard deviation

ANOVA test applied

Graph 1: results of shear bond strength of porcelain fused metal crowns, compared between the three groups



Graph 2: Results of Shear Bond Strength of Zirconium Crowns, Compared Between the Three Groups

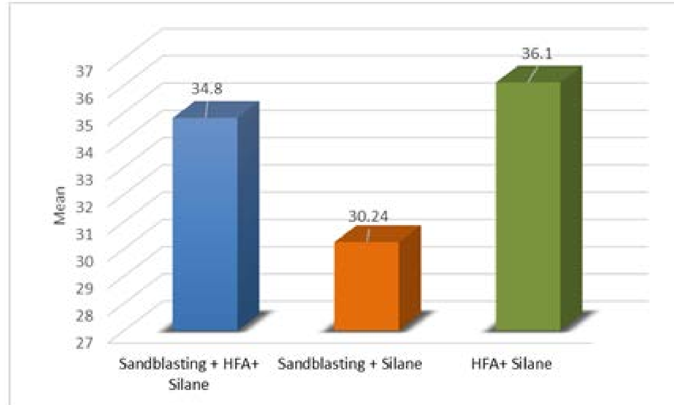


Fig 1: a) Porcelain fused metal crown, b) Zirconium crown

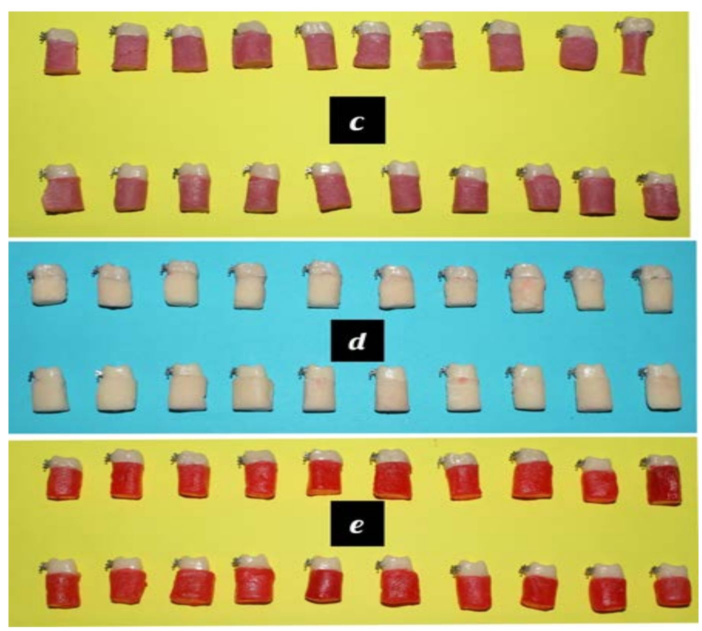


Fig 2: c) Group I - Sand blasting + Hydrofluoric acid + Silane, d) Group II - Sand blasting + Silane, e) Group III - Hydrofluoric acid + Silane

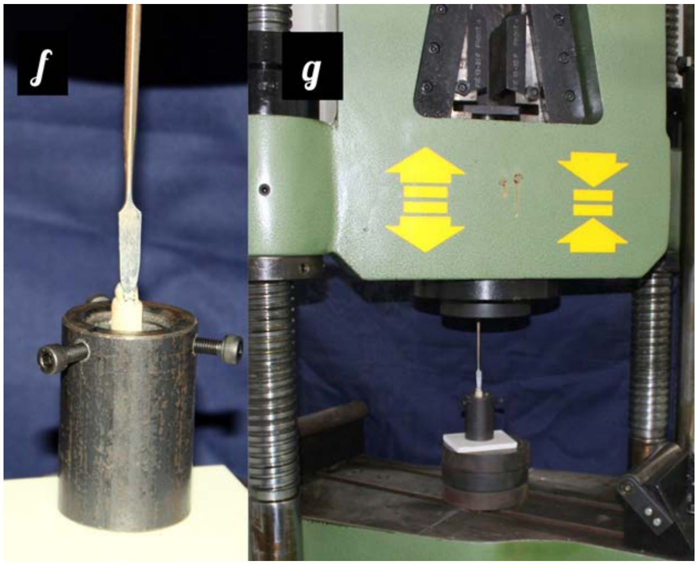


Fig 3: f) chisel end downward parallel to porcelain outer surface to apply a force in an gingivo-incisal direction of the bracket g) Universal testing machine