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ORIGINAL RESEARCH

COMPARISON OF SHEAR BOND STRENGTH OF ORTHODONTIC METAL BRACKETS TO PORCELAIN SURFACES USING DIFFERENT SURFACE TREATMENTS: AN IN-VITRO STUDY

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ABSTRACT:

Background: Bonding orthodontic brackets to porcelain/ceramic surfaces presents a higher degree of failure when compared to bonding to enamel. Hence; the present study was undertaken for comparing the shear bond strength of orthodontic brackets bonded with resin modified glass ionomer cement and composite resin on porcelain surfaces treated with hydroflouric acid and silane coupling agent. **Materials & methods:** Eighty porcelain discs are divided into 4 groups of 20 discs each. The mounted discs are surface deglazed by aluminium oxide sandblasting, rinsed with water and air dried. Group I – 20 porcelein disc surfaces were etched with 9.6 per cent hydroflouric acid gel for 120 seconds. Group II- 20 porcelein disc surfaces were etched with 9.6 per cent hydroflouric acid gel for 120 seconds. Group III –20 porcelein disc surfaces were coated with silane coupling agent according to the manufacturer's instructions and allowed to dry for 60 seconds. Group IV- 20 porcelein disc surfaces were coated with silane coupling agent according to the manufacturer's instructions and allowed to dry for 60 seconds. The shear bond strength test was conducted in the laboratory of analytical research and metallurgical laboratories. **Results:** There is a significant difference in shear bond strength of metal brackets bonded to porcelain surfaces using hydroflouric acid and silane coupling agents. There is a significant difference in shear bond strength of metal backets bonded to porcelain surfaces using resin modified glass ionomer cement and light cure composite resin. There is no statistically significant difference in the ARI scores after debonding when using hydrofluoric acid and silane coupling agent. There is no statistically significant difference in the ARI scores after debonding when using light cure composite resin and resin modified glass ionomer cement. **Conclusion:** Surface conditioning alone without silanation produced significantly low SBS. The use of silane was the single most important factor in determining satisfactory bond strength. Sand blasting followed by silanation produced favorable bond strength and might have the potential to replace alternative methods.

Key words: Bond, Strength, Orthodontic

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INTRODUCTION

Orthodontics in the early days started with the practice of cementing metal bands with brackets to teeth with cements and a procedure to overcome this tedious banding would have been a significant advancement in orthodontics in those days. With the advancement in orthodontics and esthetic dentistry treatment needs have given an opportunity for adult patients to opt for orthodontic treatment. Since adult orthodontics is becoming increasingly popular and has introduced additional complexities to bonding orthodontic attachments.[1-4] The dentition is often restored with composites, alloys and ceramics in the form of fillings, veneers and crowns resulting in markedly different bonding requirements. Demand for esthetics has increased significantly and ceramic-based materials are the most common option for restoring large crown losses in both anterior and posterior teeth. Because of this, it has become increasingly frequent that orthodontists face the challenge of bonding brackets and other accessories to porcelain instead of enamel.[5]

This has encouraged orthodontists to test several different protocols with respect to bonding brackets to different dental restorations (specifically porcelain/ceramic restorations). Introduction of dental porcelain brought with it new challenges for orthodontist to deal with the problem of placing brackets on teeth restored with them, as the conventional acid etching techniques were not sufficient for effective mechanical retention of orthodontic attachment to non enamel surfaces.[5-9]

Bonding orthodontic brackets to porcelain/ceramic surfaces presents a higher degree of failure when compared to bonding to enamel. Many a times this is because of porcelain type and surface conditioning methods, bracket material (base design), properties of the bonding adhesive, and the light-curing source, as well as the skill of the clinician.[5-9]

A variety of surface preparation techniques have been advocated, including the use of acids, air particle abrasion, various adhesives, and chemical couplers such as silane.[10] A wide variety of adhesive materials now exist for the bonding of orthodontic brackets to the non enamel surface; these include conventional light and chemically cured composite resins cements and resin modified glass ionomer cements. [11] Hence; the present study was undertaken for comparing the shear bond strength of orthodontic brackets bonded with resin modified glass ionomer cement and composite resin on porcelain surfaces treated with hydroflouric acid and silane coupling agent

MATERIALS & METHODS

- Eighty porcelain discs are divided into 4 groups of 20 discs each.
- The mounted discs are surface deglazed by aluminium oxide sandblasting, rinsed with water and air dried

Porcelain discs were prepared on metal surfaces as the porcelain samples. Eighty identical Porcelein discs (Ivoclar-Vivadent, Leicester, UK) were divided randomly into four groups of 20 discs each. The discs were then bonded with 0.022 inch pre-adjusted edgewise brackets (roth – ortho organizers).

Bonding procedure:

- Before bonding the porcelein discs were cleaned with pumice and water slurry with a dental rotary hand piece and brush for 5 seconds, then thoroughly rinsed with a stream of water for 10 seconds and then dried with oil free compressed air. The discs were surface deglazed by sandblasting with a Microetcher II with 50 microns aluminium oxide from a distance of approximately 5 mm for 5 seconds. It was then rinsed with water and air dried.

Group I –	**20 porcelein disc surfaces were etched with 9.6 per cent hydroflouric acid gel for 120 seconds. All specimens were washed and rinsed thoroughly to remove the residual acid and then air-dried. A light cure resin modified glass ionomer cement paste was then applied to the 20 bondable bracket bases and was placed on the disc surface with the help of a bracket holding forceps and light cured for 40 seconds from each side i.e. mesial, distal, occlusal and gingival.**
Group II-	20 porcelein disc surfaces were etched with 9.6 per cent hydroflouric acid gel for 120 seconds. All specimens were rinsed thoroughly to remove the residual acid and then air-dried. A small amount of Transbond XT primer was applied to disc surface (Fig 8) and cured for 20 seconds (Fig 9). Transbond XT composite resin paste was then applied to the 20 bondable bracket bases and was placed on the disc surface with the help of a bracket holding forceps and light cured for 40 second from each side i.e. mesial, distal, occlusal and gingival.
Group III –	20 porcelein disc surfaces were coated with silane coupling agent according to the manufacturers instructions and allowed to dry for 60 seconds. A light cure resin modified glass ionomer cement paste was then applied to the 20 bondable bracket bases and was placed on the disc surface with the help of a bracket holding forceps and light cured for 40 second from each side i.e. mesial, distal, occlusal and gingival.
Group IV-	20 porcelein disc surfaces were coated with silane coupling agent according to the manufacturers instructions and allowed to dry for 60 seconds. A coat of Transbond XT primer was applied to disc surface (Fig 8) and cured for 20 seconds (Fig 9). Transbond XT composite resin paste was then applied to the 20 bondable bracket bases and was placed on the disc surface with the help of a bracket holding forceps and light cured for 40 second from each side i.e. mesial, distal, occlusal and gingival.

The prepared porcelein samples with the bonded brackets were mounted on the prepared metal jig after subjecting them to the thermocycling procedure before being tested. The mounted samples with the bonded brackets were then arranged for testing in the Instron Machine (fine universal testing machine) model-TFUC -10.

Testing apparatus: The shear bond strength test was conducted in the laboratory of analytical research and metallurgical laboratories pvt ltd, electronic city, bangalore. An instron universal testing Machine (FINE TESTING MACHINE-Model TFUC-10) was used in this study to record the shear bond strength with a load cell attached to the machine. A crosshead speed of 1 mm/minute was used to debond the brackets.

For measuring the shear bond strength, the prepared porcelein discs with bonded brackets on it were fixed to the metal Jig which in turn was positioned in the lower cross head, with the long axis of the bracket base parallel to the direction of force load applied. A stainless steel rod was gripped in the upper jaw (cross head) and under the gingival tie wings by adjusting the cross head. The cross head moved at a uniform speed of 1mm/min. The load was progressively applied till the bracket got detached from the tooth surface and the reading was recorded in Kilograms force for every specimen and then converted into Megapascals (MPa) by using following formula.

$$\text{Shear Bond Strength in MegaPascals} = \frac{\text{Force in Kgs}}{\text{Surface Area of buccal tube in mm}^2}$$

The surface area of the brackets used was 12.56 mm2.

Adhesive Remnant Index (ARI):

After the bond failure of the brackets, the surface of the porcelain discs were examined under the stereomicroscope (Fig 18) to assess the Adhesive Remnant Index (ARI), which describes the amount of composite adhesive that remains on the surface of the porcelain. (Fig 19 A,B).The artun and burgland method of scoring ARI scores was used according to the following criteria:

0 = No adhesive left on the tooth surface

1 = Less than one third of the tooth surface covered by adhesive

2 = More than one third but less than two third of the tooth surface covered by adhesive

3 = More than two third of the surface but less than the whole of tooth surface covered by adhesive.

RESULTS

In this experimental study, two factors were influencing the maximum load viz. the effect of the type of adhesive and the effect of different surface treatments used. The factorial ANOVA was carried out to find the significance of the difference in the values obtained. The results are as shown in the following Table. Higher mean load at failure was recorded in light cure composite compared to RMGIC and the difference between them was statistically significant ($P<0.05$).

Table 1 Description of shear bond strength in Group 1

Group 1- Hydrofluoric Acid + Resin Modified Glass Ionomer	Mean	Standard Deviation
Shear strength	3.5495	0.674517

Table 2- Description of shear strength in Group 2

Group 2- Silane +Resin Modified Glass Ionomer	Mean	Standard Deviation
Shear strength	5.565	0.999

Table 3- Description of shear strength in Group 3

Group 3- Hydrofluoric Acid +Light Cure	Mean	Standard Deviation
Shear strength	4.4925	0.4318

Table 4- Description of shear strength in Group 4

Group 4- Silane + Light Cure Composite	Mean	Standard Deviation
Shear strength	8.8924	1.1166

Table 5-Analysis of shear strength
***ANOVA TEST(P<0.05 SIGNIFICANT)**

	Mean	Standard Deviation	F Value	P Value
Group 1- Hydrofluoric Acid + Resin Modified Glass Ionomer	3.5495	0.674517	150.3212	0.0000*
Group 2- Silane +Resin Modified Glass Ionomer	5.565	0.999		
Group 3- Hydrofluoric Acid +Light Cure	4.4925	0.4318		
Group 4- Silane + Light Cure Composite	8.8924	1.1166		

Table 6- Analysis of shear strength between group 1 & group 2
***T-TEST(P<0.05 SIGNIFICANT)**

	Mean	Standard Deviation	Difference	95% CI	P Value
Group 1- Hydrofluoric Acid + Resin Modified Glass Ionomer	3.5495	0.674517	2.0155	1.3099 to 2.7211	0.0000*
Group 2- Silane +Resin Modified Glass Ionomer	5.565	0.999			

Table 7 - Analysis of shear strength between group 1 & group 3
***T-TEST(P<0.05 SIGNIFICANT)**

	Mean	Standard Deviation	Difference	95% CI	P Value
Group 1- Hydrofluoric Acid + Resin Modified Glass Ionomer	3.5495	0.674517	0.9430	0.2374 to 1.6486	0.0041*
Group 3- Hydrofluoric Acid +Light Cure	4.4925	0.4318			

Table 8 - Analysis of shear strength between group 1 & group 4
***T-TEST(P<0.05 SIGNIFICANT)**

	Mean	Standard Deviation	Difference	95% CI	P Value
Group 1- Hydrofluoric Acid + Resin Modified Glass Ionomer	3.5495	0.674517	5.3429	4.6373 to 6.0485	0.0000*
Group 4- Silane + Light Cure Composite	8.8924	1.1166			

Table 9- Analysis of shear strength between group 2 & group 3
***T-TEST(P<0.05 SIGNIFICANT**

	Mean	Standard Deviation	Difference	95% CI	P Value
Group 2- Silane +Resin Modified Glass Ionomer	5.565	0.999	-1.0725	-1.7781 to -0.3669	0.0008*
Group 3- Hydrofluoric Acid +Light Cure	4.4925	0.4318			

Table 10- Analysis of shear strength between group 2 & group 4
***T-TEST(P<0.05 SIGNIFICANT)**

	Mean	Standard Deviation	Difference	95% CI	P Value
Group 2- Silane +Resin Modified Glass Ionomer	5.565	0.999	3.3274	2.6218 to 4.0330	0.0000*
Group 4- Silane + Light Cure Composite	8.8924	1.1166			

Table11 - Analysis of shear strength between group 3 & group 4

	Mean	Standard Deviation	Difference	95% CI	P Value
Group 3- Hydrofluoric Acid +Light Cure	4.4925	0.4318	4.3999	3.6943 to 5.1055	0.0000*
Group 4- Silane + Light Cure Composite	8.8924	1.1166			

Table 12 - Adhesive remnant index scores
ARI SCORES

	0	1	2	3
GI(HFL+RMGIC)	2	7	6	5
GII(Silane + RMGIC)	1	4	7	8
GIII(HFL+LC)	0	3	8	9
GIV(SILANE+LC)	0	2	4	14

SCORE 0 – No adhesive left on the porcelain
SCORE 1 – Less than half of the adhesive left on the porcelain
SCORE 2 – More than half of the adhesive left on the porcelain
SCORE 3 – All adhesive left on the porcelain, with distinct impression of the bracket mesh.
The ARI scores that were obtained in the study were compared and analysed by the Chi Squared test. The results of the ARI scores obtained in the all the groups are shown in the tables.

ARI SCORE	GI(HFL+RMGIC)	GII(Silane + RMGIC)	GIII(HFL+LC)	GIII(HFL+LC)
0	2	1	0	0
1	7	4	3	2
2	6	7	8	4
3	5	8	9	14
Chi square analysis	Group 1 vs group 2	P value	0.581	
		Chi square value	1.923	
	Group1 vs group 3	P value	0.713	
		Chi square value	1.364	
	Group 1vs group 4	P value	**0.023***	
		Chi square value	9.441	
	Group 2 vs group 3	P value	0.283	
		Chi square value	3.783	
	Group 2 vs group 4	P value	0.24	
		Chi square value	4.121	
	Group 3 vs group 4	P value	0.45	
		Chi square value	2.632	

The Chi Squared test showed no significant association between ARI scores of light cure composite and resin modified GIC,(P>0.05) and no significant association between ARI scores of HFL and silane ,(P>0.05) from the above table. Adhesive remnant index (ARI): the artun and bergland test was used to describe the amount of composite adhesive that remains on the porcelain surface. Chi square analysis was used to determine the statistical differences between the groups. The results obtained showed statistically significant difference in ARI scores between all the groups as shown in table. The most significant difference was observed between group 1 and group 4 compared to all other groups.

DISCUSSION

Porcelains are commonly used as restorative material in veneers, crowns and bridges because of their highly aesthetic appearance, their outstanding biocompatibility and also their mechanical properties. The increase in demand for adult orthodontic treatment, results in the necessity for orthodontics to attach the brackets and the tubes on porcelain surfaces. However, the difficulty of bonding the bracket is its semipermanent nature. Bond strength should always be high enough to resist accidental debonding during treatment but also low enough to remove the bracket from the porcelain without generating excessive amount of forces which may damage the restoration or the periodontium. The present study intended to determine and compare the shear bond strength of orthodontic brackets bonded with resin modified glass ionomer cement and composite resin on porcelain surfaces treated with hydroflouric acid and silane coupling agent and was aimed to find the most re liable method for bonding brackets to porcelain surfaces.[12-15]

Shear Bond Strength

For the purpose of bonding orthodontic attachments, an ideal shear bond strength of 6-8 MPa has been suggested[16]. This number has been challenged by the successful clinical performance of glass ionomer cements with in vitro SBS outcomes in the 3-4 MPa range.[17, 18] Traditionally, orthodontic adhesives do not perform with a static SBS value, but rather, dynamically change over time. Light photons initiate radical formation and the hardening, by means of cross linking unreacted monomers, of light cured resins. This reaction continues until there is no further monomer available to react. Complete maturation is not instantaneous but progresses hours to days following the initial set. This is evident with higher SBS values being obtained after 24 hours than those obtained immediately following the initial cure. Once complete maturation has been achieved, degradation of the bond begins with water sorption, or other means, and gradually decreases in SBS. This is enhanced by thermal exposure with expansion and contraction of the adhesive interfaces. This process is replicated in the laboratory by thermocycling the samples. Furthermore, the acquisition of the SBS value can vary depending on the testing parameters used. Interpretation of both the mean shear bond strength value and the range expressed of an orthodontic adhesive in an experiment are important for study comparison.

In the present study, Transbond XT and Resin Modified GIC was used to bond the porcelain surface.

The mean bond strength of

Group 1 was 3.5495

Group 2 was 5.565

Group 3 was 4.4925
Group 4 was 8.8924
In this study the highest bond strength achieved was with the Transbond XT conditioned with silane coupling agent group (group 4).
The results of the present study indicate that adequate bond strength to porcelain surface should theoretically be possible with different types of approaches. After deglazing of the porcelain surface by sandblasting and

1) Etching with either hydrofluoric acid and or
2) Coating with silane coupling agent and application with Transbond XT primer
3) Bonding with RMGIC and Transbond XT Adhesive.

In clinical situation , it is impossible for an orthodontist to differentiate between various types of porcelain and brands of porcelain. Commercially available porcelains despite being similar in chemical formula, still represent the differences in constituents, particle size , sintering, crystalline structure and micrography by etching.[19-22]

Removal of surface glaze

Deglazing of the porcelain surface still remains controversial. Several studies indicate that it is possible to achieve adequate bond strength to silane -treated glazed porcelain.[22-24] Several methods have suggested strengthening the bond strength between porcelain surface and brackets:
Previously, it was described to roughen the porcelain with green stones, diamond burs, or different abrasive disks.
Some studies described to get more retention by cutting a retention cavity in the porcelain surface. Nevertheless, all these procedures usually damage the glazed porcelain surface. Another method of roughening the surface of porcelain is to do sandblasting or apply different acids to the porcelain surface before bonding. Calamia suggested to use strong acids to roughen the pocelain surface ,eg : acids like orthophosphoric and hydrofluoric acid(9.6%). Hydrofluoric acid with 9.6 per cent is able to create a series of pits on the surface by preferential dissolution of the glass phase from the porcelain matrix . Hydrofluoric acid is an acid which is extremely dangerous and harmful because of its corrosive characteristics and the danger of causing severe trauma to tooth substance and soft tissues .For this reason ,the present study also included silane coupling agent .
Silane molecules, after being hydrolyzed to silanol is able to form a polysiloxane network or hydroxyl groups to cover the surface of the silica. Monomeric ends of silane molecules react with the methacrylate groups of the adhesive resins by free radical polymerization. The results of the present study showed that surface conditioning alone without silanation produced significantly low SBS. The use of silane coupling agent was the single most important factor in determining satisfactory bond strength. It was not necessary to use HFA which is highly toxic and corrosive, to achieve satisfactory bond strength. Sandblasting followed by silanation produced favorable bond strength. The ARI scores measured in the present study confirm this conclusion.
Additionally, the use of hydrofluoric acid seems not to be justifiable anymore for preparing the surface of dental ceramic restorations before bracket bonding. The danger in handling hydrofluoric acid is extreme, because skin and corneas of the eyes could be severely damaged by contact. Owing to its toxicity and handling issues HFA is less preferred for chairside application.
Another important factor to be taken into consideration is the kind of bond failure. Cohesive failures within the porcelain surface indicate that the composite resin-ceramic compound was stronger than the ceramic layer itself. Cohesive failures occur when SBS is higher than 13 MPa. An ARI score of, is reminiscent of the fact that there was no cohesive failure in the study. In clinical practice the incidence of porcelain damage while debonding the brackets are stated to be very low, since peeling forces are predominant and are different from shear testing in laboratory. Hence, sandblasting followed by silanation produced favorable bond strength and might have the potential to replace alternative methods. This is an in-vitro study, and care should be taken to interpret the results to those that may be obtained in the oral cavity.[25-28]

CONCLUSION

There is a significant difference in shear bond strength of metal brackets bonded to porcelain surfaces using hydroflouric acid and silane coupling agents. There is a significant difference in shear bond strength of metal backets bonded to porcelain surfaces using resin modified glass ionomer cement and light cure composite resin. There is no statistically significant difference in the ARI scores after debonding when using hydrofluoric acid and silane coupling agent. There is no statistically significant difference in the ARI scores after debonding when using light cure composite resin and resin modified glass ionomer cement. Also there was significant difference in chi square value between group-1 (HFL with RMGIC) and group-4 (SILANE with LC). Sandblasting with 50 µm aluminium oxide and the use of silane coupling agent seems to prepare the surface of ceramic restoration sufficiently before bracket bonding. Hydrofluoric acid seems not to be justifiable anymore for preparing the surface of dental ceramic restorations before bracket bonding. It was not necessary to use HFA which is highly toxic and corrosive, to achieve satisfactory bond strength. The results indicated that surface conditioning alone without silanation produced significantly low SBS. The use of silane was the single most important factor in determining satisfactory bond strength. Sand blasting followed by silanation produced favorable bond strength and might have the potential to replace alternative methods.

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