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Comparison of Shear Bond Strength of Orthodontic Brackets Bonded to Zirconia Surfaces Underwent Different Surface Treatments Using Different Primers: An In Vitro Study

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ABSTRACT

Purpose: The purpose of this study is to compare the shear bond strength of metallic orthodontic brackets bonded to zirconium surfaces by using various surface preparation methods and also with application of different adhesive primers and to determine which primer is more effective on prepared zirconium surfaces.

Materials and Methods: Twenty seven zirconia blocks with 90 zirconium surfaces were divided into three groups of 30 surfaces each; group 1(9.6% Hydrofluoric acid, HF), group 2 (Sandblasting, SB) and group 3 (Sandblasting + Hydrofluoric acid i.e., SHF). Each group was separated into three subgroupsof ten surfaces each;(a) Silaneprimer, (b) Bisphenol A Diglycidylether Dimethacrylate (Bis-GMA)primer and (c) Silane+10-methacryloyloxydecyl dihydrogen phosphate (SMDP) primer. After surface treatment, Maxillary central incisor metal brackets were bonded with light cure composite to zirconium surfaces. The shear bond strength values were measured bya universal testing machine with a crosshead speed of 1 mm/min. The data was analyzed using one-way ANOVA and Post hoc tests.

Results: Highest shear bond strength was observed in SHF group with SMDP primer (14.50 ± 0.7 MPa) and the lowest shear bond strength was observed in HF group with Silane primer (4.60 ± 0.9 MPa). The results showed that there was a statistical significant difference between all groups ($p < 0.05$).

Conclusion: Therefore, it can be concluded that the combination of Sandblasting and Hydrofluoric acid surface preparation with application of Silane + 10-methacryloyloxydecyl dihydrogen phosphate primer is a suitable choice for bonding a metal bracket to zirconium crown.

Keywords: Shear bond strength, Metal brackets, Zirconia, Hydrofluoric acid, Sandblasting, Silane primer, Bis-GMA primer, SMDP primer.

INTRODUCTION

Over the last decade, thesustained demand of patients for esthetic and metal free restorationsresulted in the increased use of all ceramic restorations by the clinicians. These restorations in dentistry are widely used for the restoration of damaged teeth and the replacement of missing teeth. Moreover, dental ceramics became a successful alternative in most of the cases owing to esthetics and biocompatibility.[1]If they were used appropriately, they provide excellent fit, function and esthetics, and can be reasonable substitutes for metal- ceramic restorations.[2]Even though abundance of all ceramic systems were available, many clinicians preferred using lithium disilicate and zirconium crowns due to their color stability, biocompatibility, high flexural strength, wear resistance, relatively low elastic modulus and high fracture toughness.[3,4]Advancements like CAD/CAM technology further enhanced the use of zirconium, made it most interesting materials in dentistry.[5]

Table 1: Classification of study groups

Groups (Surface treatment)	Adhesive primer (Sub- groups)		
	a	B	c
Group 1: Hydrofluoric Acid (Clear)	Silane adhesive primer (Magenta)	Bis-GMA primer (Blue)	Silane + MDP primer (Green)
Group 2: Sandblasting (Pink)	Silane adhesive primer (Magenta)	Bis-GMA primer (Blue)	Silane + MDP primer (Green)
Group 3: Hydrofluoric acid + sandblasting (Yellow)	Silane adhesive primer (Magenta)	Bis-GMA primer (Blue)	Silane + MDP primer (Green)

With recent improvements like Y- ZTP (yttria-stabilized tetragonal zirconia polycrystal) which improves the natural tooth like opacity and techniques of precise machining, the clinical application of full- contour zirconia crowns have been actively pursued.[6]However, due to increased clinical application of zirconia, the orthodontists frequently encountered issues while bonding orthodontic brackets to the zirconia surfaces. Literature evidence suggested for alternative approaches such as mechanical, chemical or combination in order to alter the surface characteristics of porcelain to provide sufficient bond strength and thereby withstanding orthodontic forces.[7]It has been recommended that methods which provide proper bond strength with less roughening should be used in order to avoid micro-cracks on zirconium surfaces.[8]

During orthodontic bonding, the use of primer is highly recommended by manufacturers as it ensures enamel adhesion by mechanical interlocking between the etched enamel prisms and the polymerized liquid primers.[9] Many commercial zirconia primers are available, among them porcelain primer could be used to treat glazed zirconia surfaces for bracket bonding, as it creates a strong bond by increasing the wettability of the ceramic surface for bonding of resin cement.[10]

The aim of the present study is to compare the shear bond strength of metallic orthodontic brackets bonded to zirconium surfaces which underwent different surface pre-treatment methods. This study also tested different adhesive primers in order to find out which primer would provide the more effective surface treatment for orthodontic bracket bonding.

MATERIALS AND METHODS

Specimen (Zirconia block) preparation

Disc shaped Y- ZTP zirconia specimens (VITA Zahnfabrik H. Rauter GmbH & Co. KG, Germany) of size 98 mm × 12 mm were used in this study. After the design was completed with Exocad Software (Exocad GmbH, Germany) the zirconia blocks were CAD/CAM milled to an area of 10 × 10 mm^2 shaped size (n = 27). The blocks were then coloured with A2 shade Vita colouring kit (dipping each block in the colouring liquid for 3 min, according to manufacturer's instructions) and sintered in a furnace for zirconia (Mihm-Vogt GmbH & Co. KG; Germany) by firing at 1,600˚C for 8 hours.

A glazing liquid (Vita akzent plus, vita, Germany) was applied

Table 2: Comparison of values of shear bond strength among groups using One- way ANOVA analysis

Groups		N	Mean	± SD	p-value
HF	S	10	4.600	0.9238	0.000*
	Bis-GMA	10	6.420	0.8600	
	SMDP	10	8.500	0.8602	
SB	S	10	5.480	0.8456	0.000*
	Bis-GMA	10	8.730	0.6750	
	SMDP	10	12.520	0.7757	
SHF	S	10	6.710	0.9735	0.000*
	Bis-GMA	10	10.360	0.7905	
	SMDP	10	14.500	0.7803	

*The mean difference is significant at the 0.05 level.

with a brush on the zirconium surface of each block to prepare the glazed surface, before refiring at 900^0c for 15 minutes in a glaze furnace (Ivoclor P 300, Ivoclor vivadent, Lichenstein). This step was performed in order to reproduce the surface state of zirconium crowns in clinical practice. To ensure consistency throughout the procedure i.e., the specimen preparation and the glazing process, all the steps were carried out by a single dental technician in accordance with the manufacturer's recommendations.

Table 3: Mean difference of shear bond strength among groups (Post hoc test).

Groups			Mean Difference (I-J)	p-value
HF	S	Bis-GMA	-4.56	0.000**
	SMDP	S	9.7703	0.000**
	Bis-GMA	SMDP	-5.407	0.000**
SB	S	Bis-GMA	-9.49	0.000**
	SMDP	S	-19.399	0.000**
	Bis-GMA	SMDP	-11.6500	0.000**
SHF	S	Bis-GMA	9.204	0.000**
	SMDP	S	19.744	0.000**
	Bis-GMA	SMDP	-11.786	0.000**

*The mean difference is significant at the 0.05 level.

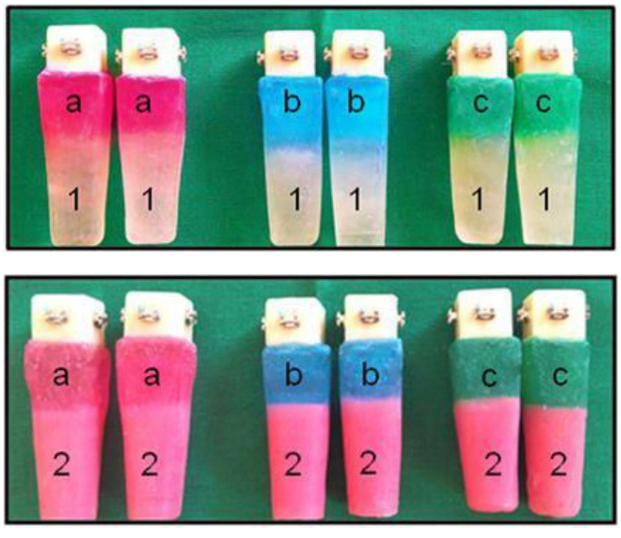
A total of 27 zirconia blocks were embedded in auto-polymerizing (self- cure) acrylic resin (DPI-RR Products Ltd) for use in shear bonding strength test. For differentiation of each group, the blocks were embedded in acrylic blocks with different color codings: group 1 (clear acrylic) treated with Hydrofluoric acid, group 2 (pink acrylic) treated with sandblastingand group 3 (yellow acrylic) treated with combination of Hydrofluoric acid and sandblasting. Each group was again divided into three sub groups (color- coded) based on the type of adhesive primer; Subgroup (a)- Silane adhesive primer- Magenta acrylic, Subgroup (b)-Bis-GMA primer- Blue acrylic and Subgroup (c)-Silane + MDP primer - Green acrylic. (Table 1 &Figure 1).

Surface treatment

A 27 zirconia blocks with 90 zirconium surfaces were divided into three groups of 30 each: in group 1, zirconia surface is treated with 9.6% Hydrofluoric acid (HF) (Porcelain etch, Ultradent, USA) for 2min and washed with gentle flow of water for 10 seconds and air dried for 10 seconds. In group 2, the zirconia surface was sandblasted (S) with 110 µm aluminium oxide particles at 80 Psi pressure for 5 seconds. In group 3, zirconia surface is treated with combination of Sandblasting + Hydrofluoric acid (SHF).

Bracket bonding with primers and resin cement

After surface preparation each group is divided into three subgroups of 10 surfaces each. In first subgroup, Silane primer (Silane, Ultradent, USA) is applied as a thin coat with applicator brush and left for 10 sec. In second subgroup,Bisphenol A DiglycidyletherDimethacrylate primer (Bis-GMA) (Orthosolo, Ormco, USA) is applied with applicator tip and left for 10 seconds. In third subgroup, Silane + 10-methacryloyloxydecyl dihydrogen phosphate primer (SMDP) (Clearfill ceramic primer, Kuraray, Japan) is applied with applicator tip and left for 10 seconds. Similarly, a thin layer of respective primer was then applied on bracket base in each subgroup.



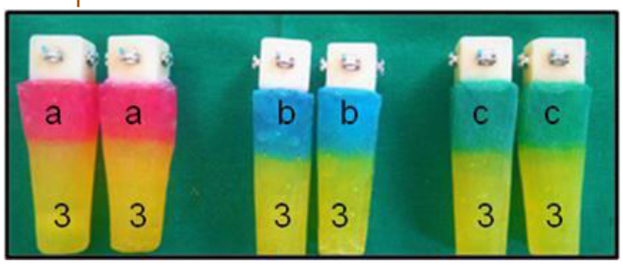


Figure 1: Color coding of the study groups underwent different surface pre- treatments and sub- grouping based on the type of adhesive primer used (Groups 1 to 3 & Sub- groups a to c)

A stainless- steel metallic bracket for the maxillary central incisor (Mini 2000 Ormco Corp., Glendora, California, USA) was bonded to the prepared and primed surfaces with light cured resin cement (Ormco Enlight, USA). After the excess resin around the bracket was removed, the resin adhesive was cured with a Light Emitting Diode (Ledition, Dentsply India) for 20 seconds. After bonding, the specimens were stored in distilled water at room temperature until testing.

Shear- bond- strength test

All the specimens were subsequently tested for evaluation of shear bond strength with a universal testing machine, (AGS-10kNG, Shimadzu Inc. Japan) (Figure 4, 5). The values of failure loads were recorded in Megapascals (MPa).

Statistical analysis

Statistical analysis was carried out using SPSS 17.0 for Windows (SPSS Inc., Chicago, IL, USA). One- way ANOVA analysis and multiple comparisons using Tukey honest significant difference test was carried out to determine the differences in shear bond strength between the surface pretreatment groups and also the type of primer used. The level of significance was set at p= 0.05 for all statistical analysis.

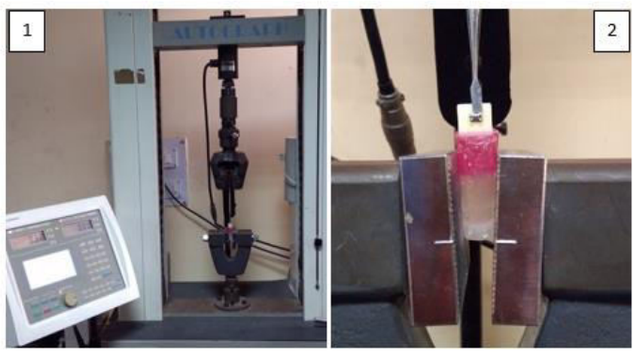


Figure 2: Universal testing machine for testing the shear- bond strength (1) and the schematic illustration showing the specimen being tested on the machine (2)

RESULTS

The mean bond strength values and standard deviations for each surface pretreatment group is presented in Table 2. Group 1 treated with HF, showed significantly lower mean shear bond strength values for different adhesive primers compared to other groups ($p<0.05$). On the other hand, group 3 treated with combination of HF and sandblasting on zirconium surface showed higher shear bond strength values with statistical significance between the adhesive primers ($p<0.05$). In group 3, highest shear bond strength was observed for SMDP primer (14.50 ± 0.7 MPa), followed by Bis-GMA primer (10.36 ± 0.7 MPa) respectively.

Multiple comparisons among groups were done by means of post hoc test as shown in Table 3, which revealed that among HF group, there was a significant difference between Silane and Bis-GMA primer (p= 0.000), Silane and SMDP primer (p= 0.000), SMDP and Bis-GMA primer (p= 0.000). Similarly, among SB group, there was a significant difference between Silane and Bis-GMA primer (p= 0.000), Silane andSMDP primer (p= 0.000), SMDP and Bis-GMA primer (p= 0.000). And also, for the SHF group, there was a significant difference between Silane and Bis-GMA primer (p= 0.000), Silane andSMDP primer (p= 0.000), SMDP and Bis-GMA primer (p= 0.000) respectively.

DISCUSSION

Zirconia crowns are among the best types of dental crowns and are commonly used in areas where esthetics is as important as strength.[11]In orthodontics, the brackets in general are bonded to the enamel surface using adhesives. However, the bonding of orthodontic brackets to ceramic restorations remained a challenge for clinicians. To increase the adhesiveness of brackets to different crown types, with zirconia being the most commonly used crown type, different methods were introduced for surface treatment of zirconia crowns. In the present study, the shear bond strength of metal brackets bonded to various zirconium blocksafter different surface treatments. And also, different primers were tested in order to verify which primer was more suitable for bonding orthodontic brackets to the zirconia blocks.

Among bond strengths, shear bond strength refers to the measurement of how well one material bonds to the other. In orthodontics, the bond strength of orthodontic brackets should be high enough to resist accidental detachment during treatment and low enough so that excessive force need not be applied during debonding.[12] To avoid bond failure, bond strength of 6 to 8 Mpa between the bracket and enamel surface was recommended.[12,13]In present study, except for the zirconium surfaces (irrespective of type of surface treatment) applied with silane adhesive primers, the shear bond strengths of metal brackets to zirconium surfaces fell within 6- 8 Mpa range or

exceeded, indicating for further consideration in clinical applications.

Previously various methods such as mechanical (diamond bur, abrasive discs) and chemical (orthophosphoric acid, hydrofluoric acid or silane) were used for the treatment of zirconium surfaces.[11]Studies have shown increased shear bonding strength in glazed porcelain surfaces that have been etched and sandblasted following the application of porcelain primer.[14,15]On the contrary, results from the study by Schmage et al.,[16]showed that porcelain primer has no significant effect on bonding strength. In present study, we tested the shear bond strength of different adhesive primers on prepared zirconium surfaces. Our results showed that in sandblasted zirconium surfaces, the application of Silane + MDP adhesive primer produced shear bond strength of 12.52 Mpa, while the application of same primer in zirconium surfaces treated with SHF showed shear bond strength of 14.5 Mpa. This showed the variation in shear bond strength with respect to the type of primer and method of surface treatment.

Evidence from literature suggested that the shear bond strength of ceramic brackets was higher than the bond strength of metallic brackets.[17-19]In the present study, when metallic orthodontic brackets were used, treated using hydrofluoric acid and sandblasting methods with different adhesive primers, shear bond strength values up to 14.5 Mpa were recorded. This showed that the results of present study were in accordance with the findings of Mehmeti et al.,[5,20]showed that metallic brackets in comparison with ceramic brackets produced better bond strength with zirconia restorations.

CONCLUSION

The purpose of this study was to compare the shear bond strength of zirconium blocks underwent different surface treatments, using different primers. The results are summarized as follows:

1. In group 1, surface treated with HF, the shear bond strength varied between 4.6 to 8.5 Mpa according to types of adhesive primers with statistically significant difference between them ($p<0.05$).
2. In group 2, surface treated with sandblasting, the shear bond strength varied between 5.4 to 12.52 Mpa. Sandblasted zirconium surface applied with Silane + MDP adhesive primerproduced bond strength of 12.52 Mpa. And also, statistically significant difference between the adhesive primes was seen ($p<0.05$).
3. In group 2, surface treated with combination of HF and sandblasting, the shear bond strength varied between 6.7 to 14.5 Mpa. SHFzirconium surface applied with Silane + MDP adhesive primer produced bond strength of 14.5 Mpa. And also, statistically significant difference between the adhesive primes was seen ($p<0.05$).
4. Based on our results, we conclude thatthe combination of Sandblasting + Hydrofluoric acid surface preparation with application of Silane + 10-methacryloyloxydecyl dihydrogen phosphate primer is a suitable choice for bonding a metal bracket to zirconium crown.

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