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SHEAR BOND STRENGTH OF CERAMIC BRACKETS BONDED TO GLAZED LITHIUM DISILICATE USING DIFFERENT BONDING PROTOCOLS.

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Abstract

Objectives: *To evaluate the shear bond strength (SBS) of ceramic brackets to lithium disilicate using different bonding protocols.*

Materials and methods: *Forty five lithium disilicate discs were embedded into acrylic resin. and randomly assigned to three equal groups (n=15), according to bonding protocol into: (A)Air abrasion with 50µm aluminum oxide particles + Assure Plus, (B) air abrasion with 50µm aluminum oxide particles + silane + Assure Plus (C) air abrasion with 50µm aluminum oxide particles + hydrofluoric acid etching + silane + Transbond XT Primer. Ceramic brackets were then bonded to the lithium disilicate discs using light cure-composite resin. Following thermocycling (500 cycles, 5° - 55° C), shear bond strength(SBS) testing was performed with a universal testing machine. After bracket debonding Failure mode and Adhesive Remnant Index were assessed under a stereomicroscope.*

Results: *No significant differences were found among the three groups regarding SBS, Group B showed the highest SBS values. Most specimens in Group B and Group C showed a failure at the bracket adhesive interface. Specimens in Group A showed a mixed cohesive-adhesive failure pattern*

Conclusion: *All 3 groups exhibited shear bond strengths within the clinically acceptable level, samples recieving Air abrasion + Assure plus only displayed better debonding characteristic.*

Introduction

In recent years , there has been an increase in demand from adult patients seeking orthodontic treatment[1–3].The emotional and psychological effects of severe malocclusion on adult patients' lives has a direct effect on patients' self-esteem, especially patients who require fixed prosthodontics treatment.[4] Adults considering treatment now have a choice in the type of fixed appliance design available whether conventional metallic or ceramic, with more and more adults choosing ceramic brackets due to their higher esthetic properties.

With the advances in the esthetic field of dentistry, new challenges arise in direct bonding to the orthodontist on a daily basis. Orthodontists treating adult patients are tackling bonding to not only sound teeth but are often met with the task of bonding brackets and attachments to a vast array of esthetic dental restorations,(5)

Recently Lithium Disilicate, a silica based ceramic restoration material, has been introduced and is among the most esthetic of the restoration materials currently available. Their increased light transmission and diffusion make them a popular choice for anterior fixed restorations. [6,7] Bonding ceramic brackets to porcelain, specifically lithium disilicate may necessitate special steps. These steps are taken to insure that bond strength is high enough for adequate clinical performance during orthodontic treatment.

In order to enhance adhesion of resin cements to ceramic surfaces mechanical and chemical

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conditioning methods, or a combination of both have been suggested(8).

Due to the clinical difficulty in distinguishing between lithium disilicate, zirconia and other glass ceramics to the orthodontist, a universal bonding protocol that achieves a good bond strength would be of great benefit.

As a universal solution to bonding brackets to any restorative material, primers containing 10-methacryloxydecyl dihydrogen phosphate (MDP) have been introduced. Up to our knowledge, little studies investigated bonding ceramic brackets to glazed lithium disilicate with primers containing MDP.

There is paucity of information in the literature regarding bonding ceramic brackets to glazed lithium disilicate with primers containing MDP. The null hypothesis assumes that that there is no difference in the shear bond strength of ceramic brackets to glazed lithium disilicate regardless of the bonding protocol employed.

Therefore, the aim of this study is to evaluate different bonding protocols of ceramic orthodontic brackets to glazed lithium disilicate.

Materials and methods

Lithium Disilicate blocks (IPS E-max, Ivoclar, Vivadent, Liechtenstein) were sectioned horizontally using Isomet 4000 precision saw (Buehler Ltd ,Lake Bluff, IL, USA) under water coolant into 45 discs measuring 10x10x2 mm. The Discs were then subjected to a crystalization firing at a temperature of 850 ^{o} C according to manufacturer instructions. Following firing, discs were then embedded into metallic molds filled with clear auto polymerizing acrylic resin (Acrostone Dental & Medical Supplies) and flushed with the surface using a glass slab to create a single level plain.[7–11] The acrylic resin was allowed to set before removal of the metal rings.

All specimens underwent prophylaxis cleaning administered with a low-speed rotary instrument with a rubber cup and oil-free pumice, followed by rinsing and drying with a portable hair dryer until the surface was completely clean and dry. Air abrasion with an intra-oral sandblaster (Bio-art Microjato- Bio-Art Equipamentos Odontológicos Brazil) using 50 µm Al_2O_3 used at 40 psi for 5 seconds at a distance of 5mm from the specimen surface. A 5 mm orthodontic wire was secured to the tip of the airblaster to insure reproducibility of distance.

Specimens were then randomly assigned to three groups (n=15) according to the following bonding protocols:

- **Group A:**

A single layer of Assure Plus (Reliance Orthodontics Products, IL, USA) was applied with a micro-brush, compressed with air, then light cured using a light-emitting-diode light curing unit (Radii plus- SDI Limited, Bayswater Victoria AU) for 15 seconds mesially and distally.

- **Group B:**

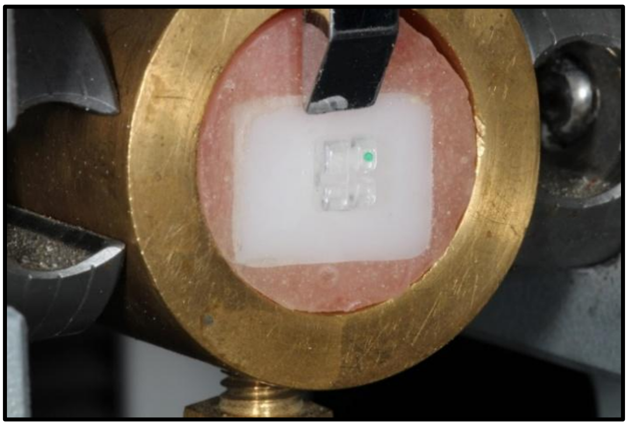
Silane ((Reliance Orthodontics Products, IL, USA) was applied in two layers with a micro-brush, compressed with oil-free compressed air, then left to dry for 90 seconds. This was then followed with one layer of Reliance Assure Plus applied in the same aforementioned manner.

- **Group C:**

Hydrofluoric Acid (HF) (Porc-Etch, Reliance Orthodontics Products, IL, USA) was applied for 4 minutes, rinsed for 15 seconds, then air dryed using with oil-free compressed air. This was followed by application of silane as previously described. A layer of Transbond XT Primer (3M Unitek, Monrovia, CA, USA) was then applied with a brush, compressed with air, then light cured using a light-emitting-diode (LED) light curing unit for 15 seconds.

Monocrystalline Central incisor ceramic brackets (Perfect Clear II Sapphire, Hubit Products Co. Ltd., Dongan-gu, Republic of Korea)) were then handled with orthodontic tweezers and adhesive paste (Transbond™ XT Paste-3M Unitek, Monrovia, CA, USA) was applied to them. They were then placed on the surface of the discs. Excess material was removed using the tip of a sharp examination probe. Samples were then light cured for 15 seconds on the mesial and distal sides of the bracket. All Specimen were stored at 37°C in Distilled water for 24 hours. Specimens were then subjected to thermocycling, for 500 cycles in water between 5°C and 55° C.

Shear bond strength was then tested on the Universal Testing Machine (Model 3345, Instron, Norwood, MA, USA) at a 1mm/min crosshead speed and cell load of 500 N. The load at which failure occurred was recorded for each specimen. The specimens were oriented so that the stainless steel blade of the universal testing machine was parallel to the bracket base. **(Fig 1)**



(Fig. 1)

Following shear testing all samples were examined under a stereomicroscope (Olympus SZ1145TR, Japan) at 10x magnification and photographed using a mounted digital camera (ToupCam, XCAM1080PHB, Japan)

Mode of failure was measured at the site of bond failure and categorized as following: [10]

1. Adhesive Failure between lithium disilicate and resin cement
2. Adhesive failure between resin cement and bracket base
3. Complex adhesive and cohesive failure

While the amount of bonding resin remaining on the lithium disilicate surface was determined using Adhesive Remnant Index Score (ARI)[12].

This scale ranges from 0 to 3

Score 0 = No adhesive remaining on the tooth in the bonding area

Score 1 = Less than half the bonded area covered by the adhesive

Score 2 = More than half the bonded area covered by the adhesive

Score 3 = All adhesive remaining on the entire bonded area

Statistical analysis

Sample size

G Power computer software (Universität, Kiel, Germany·)was used to calculate the sample size.[13] Using an independent sample t-test, at α = 0.05 and 95% power of mean difference of 3 MPa,[14] and a standard deviation of 2.5 MPa.[14] The minimum required number of specimens per Group was 15. No adjustment was deemed necessary for drop-out.

Data was collected and summarized. The statistical analysis was performed using Statistical Package for Social Sciences software, version 25(SPSS Inc., Illinois, Chicago, USA). Normality of the shear bond strength was detected using descriptive statistics, plots (histogram and box plot) and Shapiro Wilk test. Qualitative data was presented using count and percent while quantitative was presented using Mean±SD. One Way ANOVA was applied to compare between the groups regarding SBS. Differences in the ordinal ARI was assessed using Kruskal Wallis Test that followed by post hoc comparisons. Mode of failure was compared by Monte Carlo modification of Chi Square test. Significance level was set *p* value of 0.05.

Results

The mean and SD of the SBS of the different groups are shown in **Table 1**. The highest mean shear bond strength was found in Group B , and the lowest in Group A. One-way ANOVA showed no statistically significant differences (P=0.112, $P < 0.0001$) among the study groups with regards to SBS.

Table 2 shows the frequency of ARI scores among the study groups. Kruskal Wallis Test showed a statistically significant difference between the Groups (<0.0001). The predominant ARI score in Group A was score 1, in Group B it was a score of 3 and in Group C score 3.

Regarding failure mode, Group A failure mode was mixed adhesive failure at the bracket-adhesive interface and complex cohesive-adhesive failures, whereas in Group B and Group C failure mode was predominantly presented by failure at bracket-adhesive interface. Monte Carlo modification of Chi Square test showed a statistically significant difference among the study Groups ($P < 0.0001$). Pair wise comparisons regarding failure modes among the study Groups showed a statistically significant difference when comparing Group A with Group B (P=0.013), a significant difference was also found when comparing Group A with Group C (P=0.002). No statistically significant difference was found when comparing Group B with Group C (P=0.309)

	Group A (n=15)	**Group B (n=15)**	**Group C (n=15)**
Mean (SD)	10.27 (1.35)	11.63 (1.79)	11.49 (2.46)
***P* value**	0.112		

Table 1

	Group A (n=15)	Group B (n=15)	Group C (n=15)
	n (%)		
Score 0	1 (6.7%)	0 (0%)	0 (0%)
Score 1	6 (40%)	0 (0%)	0 (0%)
Score 2	3 (20%)	1 (6.7%)	0 (0%)
Score 3	5 (33.3%)	14 (93.9%)	15 (100%)
***P* value**	<0.0001*		

Table 2

Discussion

This study evaluated the SBS of monocrystalline brackets bonded to glazed lithium disilicate using 3 different bonding protocols. In Group A, only air abrasion and Assure Plus were used as a method of surface alteration this was in accordance to manufacturers recommendations when bonding to lithium disilicate. In Group B silane was added as a priming agent in an attempt to increase the bond strength. The classical bonding protocol (AA +HF+ Silane) for boding brackets to lithium disilicate was chosen for the assessment of the outcome of the other experimental groups.

The use of Silane has been promoted to be used during orthodontic bonding to ceramics as a method of enhancing bond strength.(15–18) According to **Lung et al.,**(19) silanization alters the hydrophilic surface of the ceramic to become hydrophobic which in turn allows the composite to optimally wet the ceramic surface. However, glazed ceramic surfaces are not amenable to resin penetration for successful orthodontic bonding. Studies conducted on bonding to ceramic surfaces confirmed that the use of silane alone with no prior surface roughening does not provide adequate bond strength and that silane coating should be combined with surface roughening, mechanical or chemical removal of the glazed surface has been proven to be essential to obtain mechanical interlocking.(15,20–22)

When bonding orthodontic brackets to ceramic, there needs to be a balance between a bond strength that is high enough to withstand chewing and orthodontic forces applied during treatment and at the same time not be too high as to fracture the dental substrate during bracket removal. According to **Reynolds**(23), a shear bond strength of 6-8 MPa is thought to be clinically acceptable for orthodontic bonding, a maximum bond strength limit of 13 MPa has also been suggested above which risk of ceramic fracture increases.(24) Based on the results of the current study all three Groups reported shear bond strengths above the clinically acceptable limits.

In a study by **Lyons et al.,**(25) surface preparation with air blasting followed by use of Assure Plus was tested showing similar but slightly higher (12.2 MPa) to the results obtained in Group A. Contrarily, **Naseh et al.,**(26) tested SBS of brackets bonded to lithium disilicate using Assure plus after surface preparation with hydrofluoric acid and air abrasion. Although the protocol was similar to Group A, results showed a higher SBS value of 20.52 MPa, this discrepancy in the results could be attributed to the use of 9.6 %

hydrofluoric acid etching as a method of surface preparation in addition to Air abrasion. This hypothesis is supported by **Abu Alhajja et al.,**(5) in a study conducted to compare the effects of HFA and air abrasion on the SBS of orthodontic brackets bonded to ceramic surface, showing a significantly higher bond strength achieved with HFA compared to air abrasion.

The same protocol used in Group B of the current study was also tested by **Bayoumi et al**(100) Although results of their study showed similar SBS values to the ones obtained in the present study comparing SBS values may not be as straightforward, as 2 different 10-Methacryloyloxydecyl dihydrogen phosphate (MDP) containing universal bonding systems (One Coat 7 universal and G-Premio Bond).Each MDP primer has a different chemical composition according to the manufacturer which may affect the performance of the bond in question.

Similarly, **Reichheld et al.,**(27) displayed results showing higher SBS values (15.3 ± 2.5 MPa) when compared to results from the current study, this could be attributed to the effect of lack of thermocycling performed on the samples. Bonding materials are consistently exposed to thermal changes in the oral cavity, which may cause stresses to the adhesive, leading to a weaker bond strength. The complexity of the oral environment and the difficulty of simulation in vitro owing to the presence of several variables intraorally , make it important to use aging protocols when conducting in vitro studies.(28)

Previous studies have assessed the effect of thermocycling and water storage on Shear Bond Strength (SBS), showing a significant decrease on SBS after thermocycling.(29–31) However, according to **Gale and Darwell,**(32) there is a difficulty in predicting the temperature changes in the oral cavity as there are discrepancies between different subjects and within the same person according to the position in the oral cavity. Due to the lack of agreement in literature on the standards for thermocycling,(32) a standardised protocol by the International Organization for Standardization (ISO) **(ISO/TS,2015),** with the criteria of thermocycling at 500 cycles between 5° - 55°C with a dwell time of 30 s, was suggested as a method of universal standardisation. This protocol was chosen for this study and was in accordance with several studies conducted on SBS testing of orthodontic brackets.(34–37)

In vitro testing has the objective of gathering data to predict the subsequent clinical outcomes as close as possible. In this study, the choice of shear bond testing over other methods of bond-strength tests was due to its low technique sensitivity and the lack of further specimen processing required after bonding. It has also been proven to show the closest stress distribution during orthodontic bracket removal.(38) SBS testing has the advantage over tensile bond strength tests in that factors such as wire loop harness adaptation, frictional resistance and specimen placement are eliminated thus simplifiying the process.(39,40) These advantages make SBS testing one of the most popular methods used, as it has been reported to be used in 26 % of scientific papers reporting bond strength.(40) In this study 15 samples were chosen for each intervention group, a minimum of 10 specimens is recommended to perform SBS testing.(41)

The conventional protocol for bonding to glass ceramics was chosen for Group C. Following surface preparation with hydrofluoric acid, silane primer was applied. **Mehmeti et al.,**(42) conducted a study on ceramic brackets bonded to lithium disilicate surfaces with the same bonding protocol as in Group C, results of this study showed a mean SBS value of 10.31 MPa similar to the results obtained in the current study. This is also in agreement with **Abu Al Hajja et al.,**(5) and **Naseh et al.,**(26) who also conducted a similar test. Conversely, results obtained by **Karan et al.,**(43) showed a decrease in bond strength when applying silane after surface preparation with HF and air abrasion in comparison with samples that did not receive silane application, it was hypothesized that the silane completely filled the surface porosity created by HF acid on the ceramic surface, which could explain the drop in bond strength seen.

The bonding sites of the samples in this study comprised of three surfaces and two interfaces. The three surfaces involved the surface of the lithium disilicate, the composite and the ceramic bracket base. While the two interfaces were present between the lithium disilicate surface and the adhesive, with the second being between the bracket base and the adhesive.

When assessing ARI scores in the current study, samples in Group A showed significantly lower ARI and Failure mode scores when compared with samples in both Group B and Group C, while no statistical significant difference was found between samples of Group B and C. However, it should be noted that ARI scores might not be an exact representation of bond strength. According to **O'Brien et al.,**(44) several factors affect ARI scores, including bracket base design and the type of adhesive used. Hence, predicting mode failure based solely on bond strength values can prove difficult.

Specimens in Group A (SB+ Assure Plus) showed mixed cohesive-adhesive bond failure patterns with lower ARI scores compared to the other groups. The lower overall ARI scores obtained in the group and the reduced residual composite left on the surface of the ceramic could be clinically beneficial. Studies have promoted using adhesives which show lower ARI index scores which reflect easier and quicker removal of the residual composite left on the ceramic after debonding.(45,46) Applying a similar bonding protocol results by **Naseh et al.,**(26) were comparable to results from the present study, with majority of samples showing ARI scores of 0 and 1.

Failure modes in both Groups B and Group C were predominantly adhesive failures between the bracket base and the adhesive, this pattern of failure mode could show that the chemical bond strength between the lithium disilicate and the adhesive was more than bond strength achieved by the ceramic bracket base, leaving all the adhesive remaining on the ceramic surface. The ceramic brackets used in this study were made of monocrystalline sapphire with a base design consisting of retentive beads spread at the centre of the bracket base, it could be hypothesised that this design played a role in the failure modes seen as the area for micromechanical interlocking of the composite is only situated centrally, according to the manufacturer this design is to facilitate easy debonding.

Assure Plus is a universal adhesive which is marketed to be used for various types of restorations. It was found when used with air abrasion only, to be advantageous over the other methods of surface treatments. The use of hydrofluoric acid etching could be eliminated. Hydrofluoric acid can produce toxic vapours and burn skin and mucous membranes,[120] potentially harming both the patient and practioner. Further, the step of silanization could also be eliminated when using the bond, reduction in steps during bonding would reduce clinical chair time leading to a simpler bonding procedure. According to the current study its use can be advocated as a viable alternative when bonding ceramic brackets to glazed lithium disilicate surfaces.

Conclusion

Within the limitations of this *in vitro* study, the following conclusions were drawn:

1. Assure Plus bonding agent can be used adequately when bonding ceramic orthodontic brackets to lithium disilicate, producing clinically acceptable shear bond strengths.
2. No significant differences were found in shear bond strengths obtained with the three bonding protocols when bonding to lithium disilicate.
3. Air Abrasion as a method of surface preparation prior to application of Assure Plus bonding agent produced clinically acceptable shear bond strengths, thus eliminating the possibility of using hydroflouric acid etchant.
4. Adhesive Remnant Index scores showed significant differences among the study groups. The use of Air abrasion alone without silane prior to application of Assure plus produced more favorable debonding characteristics which could lead to an easier and safer debonding procedure.

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