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A COMPARISON BETWEEN THE EFFECT OF DIFFERENT PRESSURES OF AIR PARTICLE ABRASION BEFORE AND AFTER SINTERING WITH AND WITHOUT ZIRCONIA LINER ON BOND STRENGTH OF RESIN TO ZIRCONIA SURFACE

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zirconia, sintered, ceramic liner, air particle abrasion

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Abstract

This study aimed to compare the effect of different pressures of air particle abrasion 2 and 4 bars before and after sintering with and without zirconia liner on SBS of resin to zirconia Surface. Materials and Methods: 54 zirconia cuboids 8×8×3 mm were milled and divided into 6 equal groups (N=9) according to surface treatment; sintered with ceramic liner application and 2 bars pressure (SL2) and with 4 bars pressure (SL4), sintered with no ceramic liner and 2 bars pressure (SN2) and 4 bars pressure (SN4), unsintered with no ceramic liner and 2 bars pressure (UN2) and 4 bars pressure (UN4). Specimens underwent thermocycling (1000 cycles) between 5˚ and 55˚ Celsius with dwell time of 10 seconds, and submitted to SBS test. Data was statistically analysed. Results: All 4 bars APA groups showed higher SBS than 2 bars groups with significant difference between SL4 group (4.7±2.07) and SL2 group (2.58±1.94). Groups with APA before sintering (12.42±2.56) showed significantly higher SBS than APA after sintering (6.35±3.7). SL2 group showed least SBS with significant difference (2.58±1.94) compared to UN2 (11.83±3.35) and SN2 (7.87±2.12). SL4 group (4.7±2.07) showed the least SBS compared to the UN4 (13±1.38), and SN4 (10.24±2.94) groups. Conclusion: It was found that APA of zirconia surface before sintering yielded superior performance than APA after sintering, also 4 bars APA pressure application showed higher SBS than 2 bars pressure, application and firing of ceramic liner onto zirconia surface didn't enhance SBS.

Keywords

zirconia, sintered, ceramic liner, air particle abrasion

1. INTRODUCTION

Dentistry is art and science that demands both versatility and readiness to adapt from today's practitioners (Mechanic et al, 2012). Due to its biocompatibility, chemical and dimensional stability, and excellent mechanical properties, zirconia is highly recognized by modern esthetic dentistry and widely employed in oral rehabilitation (Maciel et al., 2020). "Monolithic restorations", made of single layered zirconia restorations, are being used to combine high strength properties with high esthetics but it still elicits the question of how to properly cement and bond it (Ahn et al, 2015). The drawback of debonding of zirconia to dental luting cements has raised discussions regarding their clinic durability (Blatz et al 2018).

Unlike other ceramic prothesis, zirconia can't form stable bonds with resin-based luting agent due to its polycrystalline structure. Thus, researchers have set out to find new surface treatment methods to strengthen the bond (Jo et al, 2018).

Airborne particle abrasion (APA) aids in increasing the surface area for micro-mechanical interlocking, alters surface energy, increases wettability, cleans and removes impurities from the surface of zirconia, thus permitting the flow of resin cement into the micro-retentions and creates a stronger interlock (Moon et al, 2015). Thus APA promotes additional retention to zirconia's surface (Monteiro et al., 2020). APA is applied to the surface of zirconia after sintering before cementation using Al_2O_3 particles (Moon et al, 2015). Air abrasion can be performed before the zirconia sintering, that is, before the material exhibits high hardness. This alteration in the surface morphology and roughness enhances adhesive bonding at the zirconia–cement interface without affecting zirconia's mechanical strength (Abi-Rached et al, 2015).

Acid-sensitive ceramics are easily etched creating a micromechanically retentive surfaces. Thus ceramic liner fired onto the surface of zirconia and then surface treated by etching and the application of silane, produces a high bond to cement (Cheung et al., 2014).

Air particle abrasion to sintered and unsintered zirconia (He et al., 2014) provides micromechanical interlocking, and 10-methacryloyloxydecyl dihydrogen phosphate (MDP) resin cement or (MDP)-base primers use strengthens the bonds (Chuang et al, 2017) and (Lima et al, 2019). Shear bond strength test is widely used to evaluate adhesive material bond strength. (Braz et al, 2010).

The null hypothesis of this study would be no significant difference whether the air particle abrasion is applied before or after sintering with or without application of liner in zirconia bonding.

The aim of this study is to compare the effect of different pressures of air particle abrasion 2 and 4 bars before and after sintering with and without zirconia liner on SBS of resin to zirconia surface.

2. MATERIALS AND METHODS:

A total of 54 zirconia blocks (3D cuboids 8×8mm length and 3mm thickness) were fabricated from high translucency zirconia block (UPCERA Shenzhen, China) using CAD-CAM technology. The specimens were divided into the following groups:

SL group: 18 zirconia blocks were sintered, ceramic liner (VITA VM EFFECT LINER) was applied, and divided into two equal subgroups receiving APA at 2 bars pressure (SL2) and 4 bars pressure (SL4). Hydrofluoric acid (BISCO porcelain etchant 9.5% HF) was applied for 20 sec, then silane (BISCO porcelain primer) was applied to the surface (Cheung et al., 2014) (Cheung et al., 2015).

SN group: 18 blocks were sintered without ceramic liner application, they were then divided into two equal subgroups and received APA at 2 bars pressure (SN2) and 4 bars pressure (SN4). Ceramic primer was applied to the sandblasted surface (iTENA C-RAM BOOSTER).

UN group: 18 blocks unsintered specimens without ceramic liner application, were divided into two equal subgroups and received APA at 2 bars pressure (UN2) and 4 bars pressure (UN4), then those specimens were sintered. Ceramic primer was applied to the sandblasted surface (iTENA C-RAM BOOSTER).

A total of 54 Cuboids of composite (Filtek universal 3m) (4×4 mm and thickness of 3mm) were fabricated by being compacted into specially fabricated plexi frames.

All composite cuboids were cemented to zirconia blocks using self etch – self adhesive resin cement (iTENA TOTALCEM) under 5kg pressure for 6 minutes aided by the application of light cure. After cementation, the specimens were placed into cold cure acrylic resin that acts as a base for the specimens.

For the SEM analysis, additional zirconia specimen from each group were obtained. The specimens were mounted on metallic stubs and analysed under a high-resolution field emission scanning electron microscope (Quanta FEG 250, FEI Company, USA), which operated at 1000× magnification.

An addition silicone mold was fabricated by pressing into its mix a base plate wax cube of 2.4x2.4 cm with a thickness of 8mm. The wax cube was removed after the final setting of the addition silicone, into which cold cure acrylic resin was poured and the specimen was lowered in the center. The specimen took the shape of a larger cube so that it could be mounted later onto the universal testing machine.

The specimens were placed in distilled water for 24 hours. Then they were placed into a thermocycler (JUBLABO GmbH) and underwent 1000 cycles between 5 degrees and 55 degrees Celsius with dwell time of 10 seconds.

The specimens were then subjected to shear bond strength testing. The load was vertically applied by the chisel head to the composite-zirconia interface, at a cross speed of 0.5mm/min (Fig 1). SBS was calculated as follows Eq. (1):

Eq. (1) $$SBS\ (MPa) = \frac{load(N)}{Area(mm2)}$$

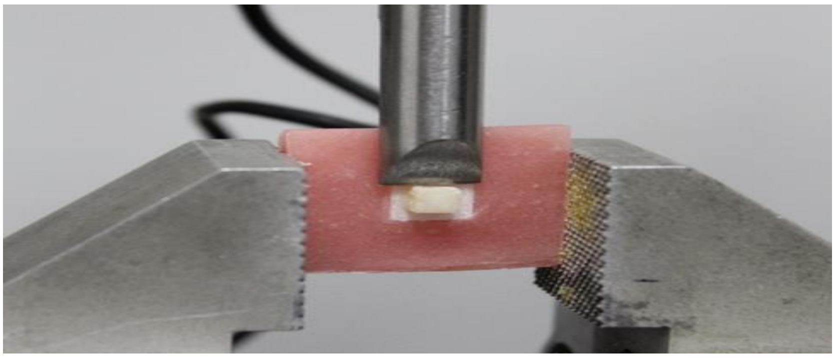

Fig.1: Chisel of Universal Testing machine applied composite/zirconia interface during testing of SBS.

Statistical analysis was performed with IBM SPSS Statistics Version 25 for Windows. Data were explored for normality by checking the data distribution using Kolmogorov-Smirnov and Shapiro-Wilk tests. P value ≤0.05 is considered significant.

3. RESULTS:

3.1 Shear Bond Strength:

It showed that the ceramic liner group with 4 bars pressure (SL4) (4.7±2.07) showed significantly higher SBS compared to ceramic liner group with 2 bars pressure (SL2) (2.58±1.94) (as indicated in Table 1).

Group APA before sintering showed significantly higher SBS results (U) (12.42±2.56) than APA after sintering (S) (6.35±3.7) (as indicated in Table 2).

The ceramic liner group with 2 bars pressure (SL2) (2.58±1.94) showed a significant difference in SBS results compared to the other two groups; the group before sintering (UN2) (11.83±3.35) and the group after sintering (SN2) (7.87±2.12) (as indicated in Table 3).

For ceramic liner group with 4 bars pressure (SL4) (4.7±2.07) showed a significant difference in SBS results compared to the other two groups; before sintering group (UN4) (13±1.38), and after sintering group (SN4) (10.24±2.94) (as indicated in Table 4).

Table 1: Comparison of SBS between SL2 and SL4.

Group	SL2	SL4	P value
SBS (N)	2.58±1.94	4.7±2.07	0.034*

*: Significant difference at P = 0.034 < 0.05

Table 2: Comparison of SBS between S and U.

Group	S	U	P value
SBS (N)	6.35±3.7	12.42±2.56	<0.001*

*: Significant difference at P < 0.001 <0.05

Table 3: Comparison of SBS between SL2, SN2 and UN2.

Group	SL2	SN2	UN2	SN2 vs SL2	UN2 vs SL2	UN2 vs SN2
SBS (N)	2.58±1.94	7.87±2.12	11.83±3.35	0.001*	<0.001*	0.009*

*: Significant difference at P = 0.009 < 0.05, P<0.0.1

Table 4: Comparison of SBS between SL4, SN4 and UN4.

Group	SL4	SN4	UN4	SN4 vs SL4	UN4 vs SL4	UN4 vs SN4
SBS (N)	4.7±2.07	10.24±2.94	13±1.38	<0.001*	<0.001*	0.038*

*: Significant difference at P = 0.038 < 0.05, P<0.001

3.2 Scanning Electron Microscope:

The SEM images (as shown in Fig 2) of zirconia surfaces were observed. Morphological differences between samples after surface treatments. Comparison of all groups between the 2 bars pressure and 4 bars pressure showed that the 4 bars pressure groups showed deeper scratches and more randomly oriented pits (as shown in Fig 2; B, D, F). While comparing the different surface treatments the sintered groups (as shown in Fig 2; A, B, C, D) showed more parallel scratches compared to the unsintered group (as shown in Fig 2; E, F). The unsintered group (as shown in Fig 2; E, F) showed deeper irregularities and more surface roughness. The comparison of SN2 to SN4 showed that SN4 (as shown in Fig 2; B) has more grooves and irregularities compared to SN2 (as shown in Fig 2; A). While the comparison of SL2 to SL4 showed that both groups contained almost equal parallel scratches (as shown on Fig 2; C, D) but with SL4 (as shown in Fig 2; D) having additional striations and pits. For the last two groups comparison, UN2 to UN4 (as shown in Fig 2; E, F) the SEM showed almost the same result.

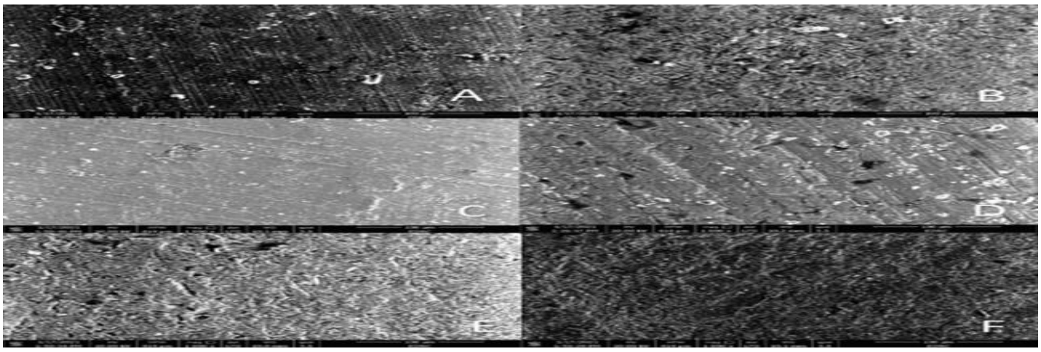

Fig.2: (A): SN2; (B):SN4; (C): SL2; (D):SL4; (E): UN2; (F):UN4.

4. DISCUSSION

Nowadays, high strength zirconia ceramics are being widely used in dentistry. Since conventional surface treatment has no effect on zirconia restorations (Blatz et al 2018), studies are being conducted to find the most efficient surface treatment for zirconia ceramics. Dental restorative materials are intended to mimic the visual nature and function of the original teeth. Monolithic zirconia material is being used to restore esthetics and function (Ahn et al, 2015). For this reason, high translucency zirconia is our choice for this study.

To secure the integrity of the results in this study, the utilized high translucency zirconia blocks were fabricated using CAD/CAM machine, which in turn increases the control over the production process.

To escape complications linked to the use of natural tooth structure were each has its own condition, we fabricated composite blocks. Since it is bonded to tooth structure on daily basis and has nearly the same modulus of elasticity of dentin (Benetti et al., 2014).

In this study APA surface treatment of Al_2O_3 (50 µm) was used, which assists with micromechanical interlocking between the resin cement and zirconia surface (Yue et al., 2019), in conduction with Özcan et al (2013) who subjected zirconia specimens to different air particle abrasion protocols and surface roughness was the highest with 50 µm Al_2O_3. In addition, Amaral et al (2006) indicated that 110 µm alumina sandblasting particles had no effect in increasing the micro-tensile bond strength of zirconia to resin cement. On the contrary Hallman et al (2012) found no difference between 50 µm and 110 µm alumina airborne particles, and Su et al (2015) confirmed that SBS was significantly increased by increasing the size of alumina powder from 50 µm to 110 µm.

In our study, zirconia blocks were treated using two different APA pressures (2 bars and 4 bars). It was evident that 4 bars (4.7±2.07) APA application showed higher SBS, especially in the sintered group with ceramic liner application, than 2 bars (2.58±1.94). These findings were consistent with scanning electron microscopy images where 4 bars pressure groups had deeper scratches and more randomly oriented pits, while the other two subgroups showed higher SBS with 4 bars with no significant difference. This was consistent with Moon et al (2016), who concluded that in bonding with resin cement, the highest SBS after thermocycling was obtained by the abrasion with 50 µm particles at 4 bars. Contrary to our results, Su et al (2015) concluded that sandblasting at 0.2 MPa with alumina particles was endorsed in dental applications to improve bonding. This may be because different zirconia material was used (Commercial grade 3% mol Y-TZP zirconia powder which was pressed, sintered, and diamond-polished into discs).

In this in-vitro study, the SBS was tested on zirconia blocks with APA treatment before and after sintering. The results showed a significant increase in SBS of the air abraded zirconia blocks before sintering (6.35±3.7) rather than after sintering (12.42±2.56). During the SEM testing, the un-sintered group showed deeper irregularities and more surface roughness, whereas the sintered group showed more parallel scratches; these results aligned with Kurtulmus-Yilmaz et al (2020), as deeper scratches in SEM images were observed in pre-sintered groups. This is because when zirconia is in its green stage which is in a state of lower zirconia hardness, permits more roughness during APA inconvenient with the pressure applied. Similar results were found by Skienhe et al (2018), who studied the effect of different types of abrasive surface treatment before and after sintering and found that the highest significant SBS value was when APA was applied before sintering. On the contrary, Kurtulmus-Yilmaz et al (2020) concluded that surface treatments performed at postsintering stage had a satisfactory effect on the flexural strength of specimens. This might be the result of having used different strength test in our study.

Other studies reported no significant differences among APA before and after sintering (Moon et al., 2011). Despite having recorded statistically higher or similar SBS (He et al., 2014) in the comparison of pre and post sintering, the use of air-abrasion with alumina particles before sintering would be more interesting for two reasons: (1) the sintering procedure may trigger the reverse transformation of the monoclinic phase content (Abi-Rached et al., 2015) (He et al., 2014) resulting from the air-abrasion step; (2) the sintering shrinkage of the Y-TZP ceramic may contain or even seal the microcracks created by the air-abrasion.

In the current study, SL group was treated with silica-based ceramics through high-temperature firing which is an internal coating system. The SBS test showed the lowest values for this group (2.58±1.94, 4.7±2.07). In a study taken out by Cheung et al (2015), similar results were shown in the group that was treated with ceramic liner, APA, hydrofluoric acid etching and silane compared to the other groups. On the contrary, Jo et al (2018) had different results, where the liner groups showed significantly higher tensile bond strength because the test applied was tensile bond strength test not a SBS test.

In our study, APA applied to zirconia blocks before and after sintering and treated with MDP containing zirconia primer showed higher bond strength than the samples of zirconia treated with APA, ceramic liner, hydrofluoric acid and silane. Chuang et al (2017) confirmed this in his study, he stated that the use of MDP-base primer functions in enhancing resin–zirconia bonding. Similar results were established by Yoshida et al (2012), that 10-MDP molecules make the adhesive interface more resistant to biodegradation due to forming chemical bonds with the residual hydroxyapatite crystals. This explains the documented favorable clinical longevity of bonds produced by 10-MDP-based adhesives.

Shear bond strength is also affected by thermocycling used to simulate the aging of specimens Sousa et al (2016). The number of cycles used in this study was 1000 cycles corresponding to short term aging and between 5℃ and 55℃.

The null hypothesis for the present study was rejected. Different APA pressure on zirconia surface affects the SBS as application of 4 bars pressure showed higher SBS than 2 bars. APA applied before zirconia sintering showed SBS. In addition to ceramic liner, application is not effective in increasing SBS for high translucent zirconia.

5. CONCLUSION

Within the limitations of the present in-vitro study, the following could be concluded:

A. Micromechanical and chemical surface treatment is a must for a durable bond with zirconia ceramics.

B. Air particle abrasion of zirconia surface before sintering showed a significant advantage over air particle abrasion after sintering, especially with 4 bars pressure that showed a significant difference in SBS over 2 bars pressure.

C. The application and firing of ceramic liner onto zirconia surface didn’t enhance SBS.

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