Comparison of Shear Bond Strength of Metal Brackets Bonded to LAVA Esthetic Zirconia Using Duragreen® DIA Burs and Sandblasting as Surface Modification

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ABSTRACT

The purpose of this study was to compare the initial shear bond strength between metal orthodontic brackets and LAVA Esthetic zirconia after sandblasting and grinding. Ten LAVA esthetic (3M, ESPE) specimens were divided into 2 groups; Group 1 was sandblasted with 50 µm Al₂O₃ particles (n=5), Group 2 was ground by Duragreen® DIA burs (n=5). After surface modification, all specimens were measured roughness value and subjected to shear bond strength testing (SBS) after bonding to the metal bracket. Adhesive remnant index (ARI) and failure mode were determined under a stereomicroscope (20x). SBS, ARI, and failure mode were analyzed by t-test and Chi-square, respectively.

There was no significant difference in shear bond strength between these groups (P>0.05). It can be concluded that the Duragreen®DIA can be used as and surface modification method to increase the surface roughness before bonding an orthodontic bracket.

Keywords: Zirconia, Surface modification, Shear bond strength

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Introduction

Zirconia has become widely used in dentistry due to increasing in esthetic demands and its high strength (Zhang, Lawan, 2018). Orthodontists have a greater chance to see this type of restoration that needs bonding to orthodontic brackets (Trakyali et al., 2009). Currently, highly translucent zirconia for dental prosthetic restorations has increased due to their exceptional translucency and esthetic properties compared to conventional translucent monolithic zirconia (Harada et al., 2016; Flinn et al., 2017; Putra et al., 2016; Inokoshi et al., 2018; Pereira et al., 2018; Ueda et al., 2015). LAVA Esthetic zirconia is highly translucent zirconia that contains higher yttrium content to introduce an optically isotropic cubic (c) phase into tetragonal (t) zirconia (Kim et al., 2011). But, changing from c-phase diminishes the stress-induced transformation toughening of zirconia, resulting in decreased strength and toughness (Kasraei et al., 2014).

Previous studies of shear bond strength bonded on the zirconia surface frequently use both ceramic brackets and metal brackets tested with traditional monolithic zirconia (Ju et al., 2019). Because zirconia is a non-etchable restoration, the resin bonded to zirconia needs to improve by surface treatment. So, several studies suggested to the modified surface with sandblasting combined with specific primer to achieve durable bonding brackets to zirconia surface. A previous report of the literature showed that zirconia bonding was durable when air abrasion and a 10-MDP (10-methacryloxydecyl dihydrogen phosphate) component was combined, but this report was less informative with regard to the new surface modification (Trakyali et al., 2009; Byeon et al., 2017; Kwak et al., 2016; Lee et al., 2018; Kim et al., 2017).

In clinically, sandblasting procedure is difficult to do intraorally. Compared to sandblasting, grinding intraorally to increase surface roughness is easier and safer. Due to LAVA Esthetic zirconia is the highly translucent monolithic zirconia that mechanical properties different from traditional monolithic zirconia and the practical method that use to modified this zirconia surface to bond orthodontic metal brackets are still unknown.

In recent, there is no report that whether Duragreen®DIA burs can be used as a mechanical surface modification for providing optimal bonding strength bonded to orthodontic brackets. Also, no study reveals the effect on LAVA Esthetic zirconia after sandblasting with 50 µm. Al₂O₃ particles 40 psi. The purpose of this study is to compare the Shear Bond Strength (SBS) of metal brackets bonded to LAVA Esthetic zirconia after surface sandblasting with 50 µm. Al₂O₃ particles 40 psi., grinding surface by Dura-green®DIA burs and evaluated whether a grinding with Duragreen®DIA burs is suitable as a method of surface modification for bonding orthodontic brackets. The null hypothesis was tested that there is a difference between the shear bond strengths of the groups tested. Analysis of adhesive remnant index and surface roughness is also reported.
Objectives of the study

The objective of this study was to compare the initial shear bond strength between orthodontic brackets and zirconia after surface modification by grinding with Duragreen®DIA or sandblasting with 50 µm Al₂O₃ particles 40 psi.

Materials and Methods

Preparation of specimens

Preparation LAVA Esthetic blocks in this study were followed by manufactured instructions. Pre-sintered LAVA Esthetic disc was cut in a cylindrical shape (6 mm in diameter and 4 mm in tall) using a low speed cutting machine at 500 rpm (Low speed saw, Buehler, USA.). The pre-sintered LAVA Esthetic (n=10) were sintered at 1500°C for 65 minutes according to the manufacturer’s instructions. After sintering, all specimens were glazed by GLAZE LT powder (VITA Zahnfabrik H. Rauter GmbH & Co. KG, Germany) and also sintered at 850°C for 90 minutes. All specimens were embedded in acrylic resin (Epoxy resin; Wilhelm Julius Teufel GmbH, USA) with a diameter of 20.0 mm PVC pipe. All specimens were immersed in a distilled water with ultrasonic vibration (5210, BRANSONIC, Germany) for 10 minutes and dried before modified surface using shear bond strength testing.

Surface modification

For each specimen in the sandblasting group, the bonding surface was abraded with 50 µm Al₂O₃ particles 40 psi for 10 seconds (Basic Guattro, Germany). The tip end of the sandblasting machine was over 5 mm from the surfaces. In the grinding group, the bonding surface of zirconia blocks was ground with Duragreen®DIA burs under constant water cooling using a Micromotor (NSK ultimate 500, Japan) at 20,000 rpm for 10 seconds. Direction for grinding was set only single direction forward movement from the right end to the left end.
Measurement of Surface Roughness

Following sandblasting and grinding, all specimens were cleaned in an ultrasonic device with water for 10 minutes and dried. All specimens were compared to the surface roughness. They were analyzed surface roughness using a non-contact surface roughness tester (Infinitefocus, Alicona, Tokyo, Japan). The surface roughness tester was used with the polarizing light to capture the surface and quantify surface roughness by its program. The roughness parameter evaluated were average surface roughness ($R_a$) as the average of five readings.

Bracket placement

A Metal bracket with slot 0.018” x 0.025” for right maxillary central incisors (Tomy®-omni arch) was placed on the center of the bonding surface of LAVA Esthetic zirconia block. The single bond universal adhesive was applied to the zirconia surface, blow the gentle air until there was no extra bonding left on the surface and lightening as the manufacturer’s instructions (20 seconds). The composite resin (Transbond® XT) was pasted on the base of the right maxillary metal brackets (bonding surface area of 4 x 3 mm2) in a place with 300 grams of force. The excess composite was removed with a fine explorer. Finally, Ortho curing light (Mini LED III, SATELEC®, Acteon) was used for lightening 10 seconds at each margin (totally 40 seconds).

Shear bond strength testing

After bracket placement, all the samples ($n=10$) were kept in a 37°C incubator for 24 hrs. Initial shear bond strength was tested with the universal testing machine (EZ-S, SHIMADZU, Japan), with a load applied parallel to the LAVA Esthetic zirconia-bracket interface in a gingival- occlusal direction. Using the knife-edged rod at rate 1 mm/min, 50 N until failure occurs. The force required to debond the brackets was recorded in Newton and the values were calculated to MPa.

ARI Score and types of failure

After measuring the SBS, the bonded surfaces were analyzed using a light microscope (SZ61, Olympus, Japan) at a magnification of 20x to determine the ARI score of each specimen (Table 1.) and examine the failure modes between the LAVA Esthetic specimens and orthodontic metal bracket. The failure modes were then classified into adhesive failure between metal bracket base and resin, mixed (adhesive + cohesive) failure, and adhesive failure between LAVA Esthetic surface and resin composite, and the percentage of the failure modes were calculated.
Table 1 Adhesive remnant index (ARI) score and criterion described by Artun, Bergland (1984)

<table>
<thead>
<tr>
<th>ARI Score</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No adhesive remaining</td>
</tr>
<tr>
<td>1</td>
<td>Less than half of the adhesive remaining</td>
</tr>
<tr>
<td>2</td>
<td>More than half of the adhesive remaining</td>
</tr>
<tr>
<td>3</td>
<td>All adhesive remaining</td>
</tr>
</tbody>
</table>

Statistical analysis

All data were analyzed with SPSS (version 22, statistic software) at a level of significance of $\alpha = 0.05$. The Kolmogorov-Smirnov test was applied to ascertain that the SBS and $R_a$ data had a normal distribution. The $R_a$ and SBS data were planned analyzed by independent sample $t$-test. If the data did not accept the hypothesis of the normality test, the Mann-Whitney test was used to analyze the data. The ARI scores were tabulated and analyzed using the Chi-square test.

Results

According to the normality test, the roughness value and the shear bond strength (SBS) were in the normal distribution. The result of roughness average (Table 2) in the sandblasting group was lower than grinding with the Duragreen®DIA group with a significant difference ($p<0.05$). The representative of surface morphology was showed (Figure 3).

Table 2 $R_a$ surface roughness ($\mu m$) after surface modification

<table>
<thead>
<tr>
<th>Surface modification</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandblasting</td>
<td>5</td>
<td>0.57</td>
<td>0.06</td>
</tr>
<tr>
<td>Grinding with Duragreen®DIA</td>
<td>5</td>
<td>1.18</td>
<td>0.10</td>
</tr>
</tbody>
</table>

$t$-test showed a significant difference in mean $R_a$ value among the groups ($p < 0.001$)
The representative image of a captured area that non-contact profilometry evaluated roughness parameters and reported as $R_a$ (Roughness Average).

The mean shear bond strength (SBS) of the sandblasting group was not significantly different from grinding with Duragreen®DIA group ($p>0.05$). The mean shear bond strength of the sandblasting group was 10.37±0.40 MPa, while the mean shear bond strength of grinding with the Duragreen®DIA group was 10.76±0.03 MPa. (Figure 4)

The frequency distribution of ARI scores shown in Table 3. Statistical analysis in the form of a Chi-square test was conducted on the variable “ARI score”; there was no statistically significant difference between the groups ($p > 0.05$). ARI distribution by surface treatment was shown in Figure 5, as it is evident that distributions were identical. One hundred percent of failure mode happened at the adhesive layer between the bracket base and resin composite.

<table>
<thead>
<tr>
<th>Name of the group</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandblasting group</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>Grinding with Duragreen®DIA group</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5</td>
</tr>
</tbody>
</table>

Figure 3: Image showing a captured area evaluated for roughness parameters.

Figure 4: Shear bond strength of all groups.

Table 3: Frequency distribution of adhesive remnant index (ARI) scores.
Discussion and Conclusion

As a result of this study, the shear bond strength of orthodontic bracket and LAVA Esthetic zirconia in different two surface treatments were not significant differences. Iwasaki et al. (2016) reported the shear bond strength of traditional zirconia surfaces treated with MDP primer following 110 μm Al₂O₃ sandblasting and the resin cement was measured 9.6 MPa that was not different from the shear bond strength measured in this study. In clinically the bond strength required for bonding between a tooth and a bracket was 6–8 MPa. (Raynolds, 1975). Hobson et al. (2001) defined the lowest acceptable shear strength for routine clinical use as being no less than 5.9 to 7.5 MPa. The result of this study exceeds the required bond strength. To achieve the durable bonded to zirconia, the previous study tested no surface treatment on zirconia bonded to orthodontic brackets showed a relatively lower bonding strength than surface treatment on the sample (Lee et al., 2015). Thus, the research design of this study was not testing any no surface treatment samples.

In this study, the mean roughness surface of Duragreen®DIA group was a little bit higher than the sandblasting group, while the mean shear bond strength of the orthodontic bracket on LAVA Esthetic zirconia was not significantly difference. Adhesive remnant index and failure mode have shown adhesive failure between the orthodontic bracket and resin adhesive at the same between groups. It is possible to argue that sandblasting and grinding with Duragreen®DIA can be used as the surface treatments. Although, previous studies have reported the effect of grinding burs on crystallographic phases change on traditional zirconia, but a small amount of monoclinic phase after surface grinding with Dura-green®DIA was observed and there was no significant difference in flexural strength between Dura-green®DIA and the control group (Lee et al., 2016).

LAVA Esthetic zirconia has a three-point bending strength of 800 MPa (3M ESPE, 2018). When debonding the bracket on LAVA Esthetic zirconia, the risk of causing fractures is so small. However, the strength of this bond depends on several factors, including the type of primer used and also surface pre-treatment on
the zirconia surface before bonding. Qeblawi et al. (2010) evaluated the shear bond strength of zirconia after sandblasting, hand grinding, or other surface treatments and found that the result is significantly higher bond strength values when compared to no mechanical surface treatment. Tzanakakis et al. (2015) reported that airborne-particle abrasion and tribochemical silica coating are reference pretreatment methods for durable adhesion to zirconia. Special adhesive monomers are necessary for chemical bonding to zirconia. Thus, the right balance must be found to avoid fracturing crown attached to the bracket. The studies have been considered on this issue and have not given any exact maximum strength limit for zirconia crowns (Montasser et al., 2009).

Within limitations, we can conclude that metal orthodontic brackets have a great shear bond strength when bonded to zirconia after surface modification. No statistically significant difference in shear bond strength between sandblasting and grinding with Duragreen®DIA as surface modifications. As regards the ARI score, the sample groups did not appear to have any statistically significant differences. So, sandblasting with 50 µm Al2O3Particles and grinding with Duragreen®DIA can increase the bond strength between resin and zirconia surface. Further studies modifying bracket base, grinding with other burs, using different specific primer would be useful for successfully bonding brackets to zirconia.

Acknowledgements

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