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

Kunpreeya Wiriyaamornchai (กุลปรียา วิริยะอมรชัย)* Dr.Paiboon Techalertpaisarn
(ดร.ไพบูลย์ เตชะเลิศไพศาล)**

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 Al_2O_3 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

บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อเปรียบเทียบค่าแรงยึดติดแบบเฉือนระหว่างแบรกเกตจัดฟันโลหะกับผิวลาวาเอสเทติกเซอโคเนีย เมื่อมีการปรับสภาพพื้นผิวก่อนยึดติดด้วยการเป่าผงอะลูมินากับการกรอบนพื้นผิวด้วยหัวกรอดูรากรีน โดยเตรียมชิ้นงานลาวาเอสเตทิกเซอโคเนียจำนวน 10 ชิ้นแบ่งเป็น 2 กลุ่มเท่ากัน กลุ่มที่1 ชิ้นงานจะถูกเป่าด้วยผงอะลูมินาออกไซด์ขนาด 50 ไมครอน กลุ่มที่ 2 ชิ้นงานจะได้รับการกรอบริเวณพื้นผิวด้วยหัวกรอเซอโคเนียดูรากรีน ทุกชิ้นงานจะถูกวัดค่าความหยาบของพื้นผิวหลังการปรับสภาพพื้นผิว ทำการยึดติดแบรกเกตจัดฟันและทดสอบค่าแรงยึดติดแบบเฉือนและระบุความล้มเหลวของการยึดติดผ่านกล้องจุลทรรศน์เสตอริโอ วิเคราะห์ข้อมูลโดยการทดสอบทีและการทดสอบไคสแควร์ตามลำดับ จากการวิเคราะห์ผลการศึกษาพบว่าไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติของค่าความแข็งแรงยึดติดเฉือน (p>0.05) และไม่มีความแตกต่างกันอย่างมีนัยสำคัญของดัชนีส่วนเหลือสารยึดติดและความล้มเหลวของการยึดติด (p>0.05) ระหว่างกลุ่มเป่าทรายกับกลุ่มที่กรอด้วยหัวกรอเซอโคเนียดูรากรีน จึงสรุปได้ว่าการกรอพื้นผิวเซอโคเนียด้วยหัวกรอดูรากรีนแบบหยาบสามารถใช้เป็นวิธีในการเพิ่มความหยาบผิวของเซอโคเนียก่อนยึดติดกับแบรกเกตจัดฟันเพื่อเพิ่มแรงยึดติดได้

Keywords: Zirconia, Surface modification, Shear bond strength
คำสำคัญ: เซอโคเนีย การปรับสภาพพื้นผิว แรงยึดติดแบบเฉือน

**Student, Higher graduated Program in orthodontics, Department of Orthodontics, Faculty of Dentistry, Chulalongkorn University*
***Associate Professor, Department of Orthodontics, Faculty of Dentistry, Chulalongkorn University*

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. Al_2O_3 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. Al_2O_3 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. Al_2O_3 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 1500o 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 850o 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 Al_2O_3 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.

Figure 1 Duragreen®DIA bur that use in this study.

Figure 2 Shear bond strength testing after surface modification with the load apply 50 N, 1mm/min to the interface.

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 20× 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)

ARI Score	Criterion
0	No adhesive remaining
1	Less than half of the adhesive remaining
2	More than half of the adhesive remaining
3	All adhesive remaining

Statistical analysis

All data were analyzed with SPSS (version 22, statistic software) at a level of significance of α = 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 (μm) after surface modification

Surface modification	n	Mean	SD
Sandblasting	5	0.57	0.06
Grinding with Duragreen®DIA	5	1.18	0.10

t-test showed a significant difference in mean R_a value among the groups ($p < 0.001$)

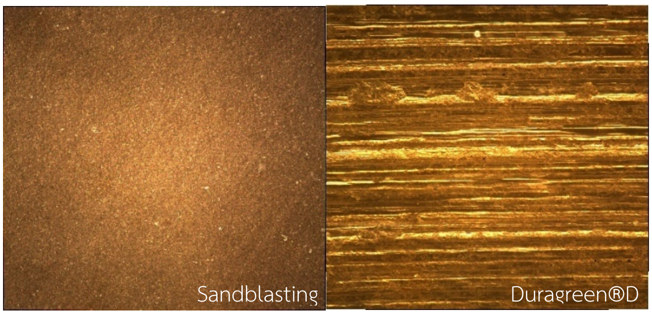

Figure 3 The representative image of a captured area that non-contact profilometry evaluated roughness parameters and reported as R_a (Roughness Average)

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±1.03 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.

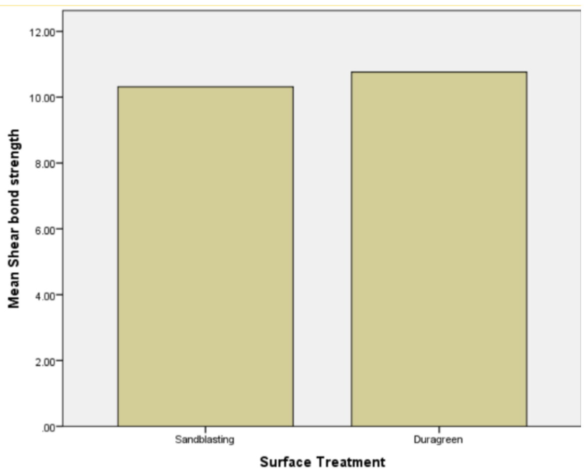

Figure 4 Shear bond strength of all groups

Table 3 Frequency distribution of adhesive remnant index (ARI) scores

Name of the group	0	1	2	3
Sandblasting group	-	-	-	5
Grinding with Durageen®DIA group	-	-	-	5

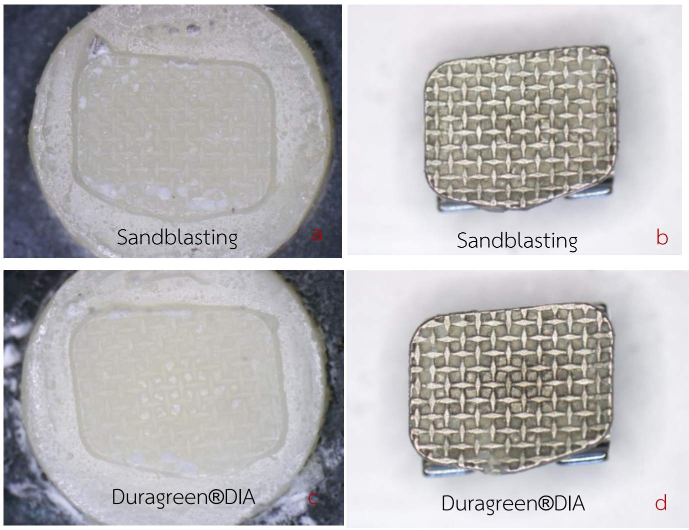

Figure 5 The representative stereomicroscope images identified the failure mode of sandblasting group and grinding with Duragreen®DIA group

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 Al_2O_3 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 crytallographic 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

This study was granted by Faculty of Dentistry (DRF63011), Chulalongkorn University, Thailand

References

Amaral M, Belli R, Cesar PF, Lohbauer U. The potential of novel primers and universal adhesives to bond to zirconia. J Dent 2014; 42: 90-98.

Artun J, Bergland S Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. Am J Orthod 1984; 85(4): 333-340.

Byeon SM, Lee MH, Bae TS. Shear Bond Strength of Al_2O_3 Sandblasted Y-TZP Ceramic to the Orthodontic Metal Bracket. Materials (Basel) 2017; 10(2).

Flinn BD, Raigrodski AJ, Mancl LA, Kuykendall T. Influence of aging on flexural strength of translucent zirconia for monolithic restorations J Prosthet Dent 2017; 117: 303-309.

Harada K, Raigrodski AJ, Chung KH, Flinn BD, Mancl LA. A comparative evaluation of the translucency of zirconias and lithium disilicate for monolithic restorations. J Prosthet Dent 2016; 116: 257-263.

Hobson RS, Ledvinka J, Meechan JG. The effect of moisture and blood contamination on bond strength of a new orthodontic bonding material. Am J Orthod Dentofacial Orthop 2001; 120(1): 54–57.

Inokoshi M, Shimizu H, Nozaki K, Minakuchi S. Crystallographic and morphological analysis of sandblasted highly translucent dental zirconia Dent Mater 2018; 34: 508-518.

Iwasaki T, Komine F, Fushiki R, Matumura H. Shear bond strengths of an indirect composite layering material to a tribochemically silica-coated zirconia framework material. Dent Mater J 2016;35: 461-469.

Ju GY, Oh S, Lim BS, Chung SH. Effect of Simplified Bonding on Shear Bond Strength between Ceramic Brackets and Dental Zirconia. Materials (Basel) 2019; 12(10).

Kasraei S, Rezaei-Soufi L, Heidari B, Vafaee F. Bond strength of resin cement to CO_2 and Er:YAG Laser-treated zirconia ceramic. Restor Dent Endod 2014; 39: 296-302

Kim J, Park C, Lee JS, Lee Y. The effect of various types of mechanical and chemical preconditioning on the shear bond strength of orthodontic brackets on zirconia restorations. Hindawi 2017; 2017: 01-10.

Kim MJ, Kim YK, Kim KH, Kwon TY. Shear bond strengths of various luting cements to zirconia ceramic: surface chemical aspects. J Dent 2011; 39: 795-803.

Kwak JY, Jung HK, Choi IK, Kwon TY. Orthodontic bracket bonding to glazed full-contour zirconia. Restor Dent Endod 2016; 41(2): 106-13.

Lee JH, Lee M, Kim KN, Hwang CJ. Resin bonding of metal brackets to glazed zirconia with a porcelain primer. Korean J Orthod. 2015; 45(6): 299-307.

Lee JY, Ahn J, An SI, Park JW. Comparison of bond strengths of ceramic brackets bonded to zirconia surfaces using different zirconia primers and a universal adhesive. Restor Dent Endod 2018; 43(1).

Lee KR, Choe HC, Heo YR, Son MK. Effect of different grinding burs on the physical properties of zirconia. J Adv Prosthodont 2016; 8(2): 137-43.

Montasser MA, Drummond JL. Reliability of the adhesive remnant index score system with different magnifications. Angle Orthod 2009; 79(4): 773-776.

Qeblawi DM, Muñoz CA, Brewer JD, Monaco EA Jr. The effect of zirconia surface treatment on flexural strength and shear bond strength to a resin cement. J Prosthet Dent 2010; 103(4): 210-20.

Pereira GKR, Guilardi LF, Dapieve KS, Valandro LF. Mechanical reliability, fatigue strength and survival analysis of new polycrystalline translucent zirconia ceramics for monolithic restorations J Mech Behav Biomed Mater 2018; 85: 57-65.

Putra A, Chung KH, Flinn BD, Kuykendall T, Raigrodski AJ. Effect of hydrothermal treatment on light transmission of translucent zirconias J Prosthet Dent 2017; 118: 422-429.

Reynolds IR. A review of direct orthodontic bonding. Br J Orthod 1975; 2: 171-178.

3M™LAVA™Esthetic Esthetic Fluorescent Full-Contour Zirconia Technical product profile [online] 2018 [cited 2020 Jul 23]. Available from: http://multimedia.3m.com/mws/media/15870120/3m-lava-esthetic-zirconia-technical-product-profile.pdf

Trakyali G, Malkondu O, Kazazoglu E, Arun T. Effects of different silanes and acid concentrations on bond strength of brackets to porcelain surfaces. Eur J Orthod 2009; 31: 402-406.

Tzanakakis EG, Tzoutzas IG, Koidis PT. Is there a potential for durable adhesion to zirconia restorations? A systematic review. J Prosthet Dent 2016; 115(1): 9-19.

Ueda K, Guth JF, Erdelt K, Beuer F. Light transmittance by a multi-coloured zirconia material Dent Mater J 2015; 34: 310-314.

Zhang Y, Lawn BR. Novel zirconia materials in dentistry. J Dent Res 2018; 97: 140-147.