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THE EFFECACY OF DIFFERENT SURFACE CONDITIONING ON SHEAR BOND STRENGTH OF ORTHODONTIC BRACKET BONDED TO LITHIUM DISILCATE CROWNS; AN IN VITRO STUDY

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ABSTRACT

Background and objective: Lithium disilicate widely used, and it is important to correctly bond orthodontic brackets to such materials. This study aimed to assess the impact of various types of surface conditioning methods on the shear bond strength (SBS) of orthodontic metal brackets to lithium disilicate crown.

Materials and methods: In this in vitro study, 30 lithium disilicate specimens were prepared based on the type of surface conditioning into three surface conditioning groups (n=10 for each group). First group the semi-crowns surface was conditioned with 10% hydrofluoric acid etching, the second group was micro-etched with sandblast particles (50 um aluminum oxide particles) and the last group was conditioned with ultrasonic scaler. Valo light cure was utilized with 3200mw/cm2 light intensity. SBS was measured using a universal testing machine. The findings were statistically examined.

Result: The results showed significant difference among the three groups where the sandblasting group had the higher mean of SBS, while the hydrofluoric acid etching group had the lower value and in between, the mean of ultra-sonic intermediate.

Conclusions: Although the means of the three types of surface conditioning were significantly different, shear bond strength was positively affected by all of them and subsequently all types may be considered recommended techniques for reliable shear bond strength.

KEYWORDS: Lithium disilicate ceramics; Sandblasting; Metal bracket; Shear bond strength; Surface conditioning.

INTRODUCTION

The increasing need for better facial aesthetics in adult patients has added to the demand for adult orthodontics (Lee et al., 2015). Porcelain crowns are also increasingly being used to repair damaged or missing teeth. However, unless the surface properties of the ceramic are adjusted prior to bonding, orthodontic brackets bind poorly to ceramic surfaces (Bilgic et al., 2013). Because orthodontic bracket bonding to crown materials differs from adhering to the tooth enamel surface, orthodontists encounter a challenge when bonding to diverse crown surfaces (Buyuk & Kucukekenci, 2018). There are two main concerns in this regard. The first challenge is achieving a bond strength of 6 to 10 megapascal (MPa) to decrease bracket bond failure during treatment (Whitlock et al.,1994). The second challenge is maintaining the outstanding appearance and functionality of ceramic restorations after debonding.

Lithium disilicate glass ceramic is one of the all-ceramic material, known as (E-max), that provides extremely good mechanical capabilities with great aesthetic outcomes, which can be created as CAD or Press (Denry & Holloway, 2010; Guess et al., 2010; Mobilio et al., 2015). Ceramic is an inorganic material that does not chemically bind to any of the bonding resins now available (Abu Alhaija et al., 2010). As a result, orthodontic brackets bind weakly to ceramic surfaces unless the surface properties of the ceramic are adjusted prior to bonding (Bilgic et al., 2013). Surface conditioning of the ceramic crown categorized into three main methods: mechanical, chemical, or a mix of the two. Chemical conditioning can be achieved by hydrofluoric acid (HFA) to increase bond strength and mechanical one either by Sandblasting with aluminium oxide particles (Kocadereli *et al.*, 2001; Harari et al.,2003; Abu Alhaija et al., 2010) or could be done by the ultra-sonic scaling (Yoon et al., 2017)

Surface preparation prior to bonding has two goals: to eliminate surface impurities and to expand the substrate's surface area. Marshall et al. (2010); Lung and Matinlinna (2012) By eliminating the glassy matrix, HFA etching produces a porous surface (Lee et al., 2015) Zarif Najafi et al. (2019) employed sandblasting as a mechanical retention method. Since several studies have evaluated changes in surface roughness following ultrasonic scaling (Vigolo & Motterle, 2010; Checketts et al., 2014; Yoon et al., 2017; Nakazawa et al., 2018), ultrasonic scaling will be introduced as a new method of surface conditioning in the current study, hopefully providing a better method of surface conditioning. Consequently, the question arises about the best method(s) of surface conditioning that may be used for bonding orthodontic brackets to lithium disilicate crown.

MATERIALS AND METHOD

Sample preparation and crown fabrication

The 30 units of semi crowns with uniform shape and size (Naseh et al., 2018) produced using a multilayer Lithium-disilicate (YUCERA, Shenzhen Yurucheng, China) CAD CAM made from ingot then heat treated at 840°C according to manufacture instruction. After fabrication, the crowns then were glazed, according to the manufacturer's directions by a skilled technician using (CAD CAM), then the samples will be visually inspected. All the teeth were examined under routine surgery light conditions to assess suitability for inclusion. Pronounced cracking was designated as those teeth with cracks detectable by direct visual inspection (Zachrisson et al., 1980).

Lithium disilcate semi-crown molding preparation

1 -Semi crowns teeth were held vertically in the center of cubic plastic boxes of approximately 1.6x1.6 cm height, width, and 1 cm depth, containing a self-cure acrylic resin in such a way that they were embedded in acrylic till the cervical line and crown from the cervical line was exposed, then each group embedded in cube and coded by engraving specific words on the side of the cube.

2-A dental surveyor (dentalfarm-Torino, Italy) was used to align teeth in an acrylic mold with the buccal surface perpendicular to the bottom. As a result, it will be parallel to the force exerted during the debonding technique. (Goswami and colleagues, 2014)

3-The lithium disilicate semi-crowns will be split into three groups: those treated with 10 percent hydrofluoric acid, those treated with ultra-sonic scaler and those treated with sandblasting as shown in the diagram bellow figure (1)

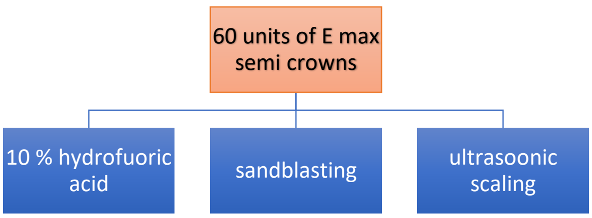

Fig (1) Diagram showing the different group distribution

Surface conditioning and bonding procedure

The first group (HF) was conditioned with condac porcelena 10% hydrofluoric acid (condac porcelana, FGM, Brasilian) for one minute then washed for one minute, and air-dried (Girish et al.,2012).

While the second group (Sa) was sandblasting with 50 µm Al_2O_3 powder (Pureblast White No. 100-3954, Henry Schein, Melville, NY) with an intraoral air-abrasion device, applied 45 degrees to the sample surfaces from a distance of 10 mm for 10 seconds in circling motions at 2.5 bar pressure (Grewal Bach et al., 2014).

The last group (USc) was prepared by measuring the 4 mm × 4 mm area on the testing surface of each crown was designated for the scaling conditioning. An ultrasonic scaler (woodpecker, china) with stainless steel tip (P type) was used with sufficient cooling water.

The scaling was conducted for 20 seconds in a reciprocal motion (Yoon et al., 2017). The angle between the surface of each crown and the scaler tip was maintained at 0°, according to the protocols of the previous study. (Oliveira, et al.,2016)

After that Specimen surfaces were coated with a thin layer of Universal Primer (Monobond Plus, Ivoclar Vivadent; Schaan, Liechtenstein) that was left for 60 s to allow it to react, and then gently air dried to evaporate the solvent.

Then, one coat of orthodontic adhesive primer (Transbond XT Primer, 3M Unitek; Monrovia, CA, USA) was applied with a microbrush, gently air dried, and light curd for 4 seconds using a Valo (Ultradent Products) light cure unit (1000 mW/cm2 intensity. (Bavbek et al., 2016)

4- Mandibular incisors edgewise stainless steel brackets with 0.022x 0.028-inch slot (3M unitek) bonded to the center of the semi-crowns' surface with an adhesive paste (3M Unitek Transbond XT) and a force of 200 gm was applied using a pressure gauge (Recen et al.,2022). After removing bond excess from all around the bracket base by the dental probe, Valo light-curing device will be used to cure the bracket adhesive in a way that cured with 3 seconds at 90 degrees with (3200 mw/cm^2) according to the manufacture and the light cure tip as much as possible close to the bracket as in (figure 2 j). (Cacciafesta et al.,2005)

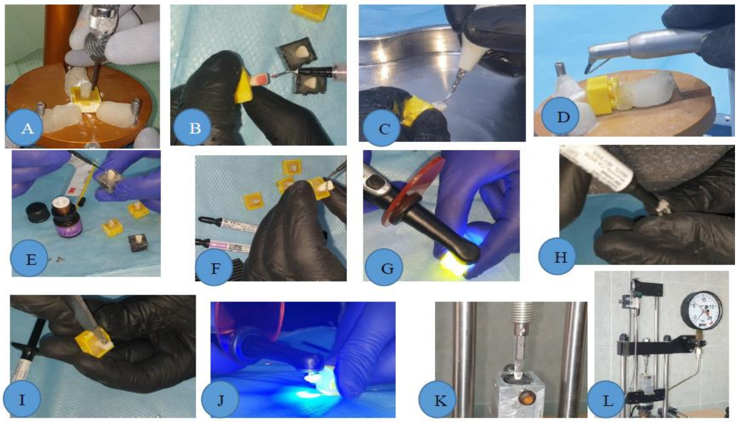

Fig (2): Step by step bonding procedure(A)

A dental surveyor (dentalfarm-Torino-Italy) was used to align teeth in the acrylic mold(B) the specimens were conditioned with condac porcelena 10% hydrofluoric acid (C) scaling treatment with an ultrasonic scaler. (D) sandblasting with 50 μm Al_2O_3 powder. (E) Specimen surfaces were coated with a thin layer of Universal Primer (momobond). (F) orthodontic adhesive Primer (G) 4 seconds light-curing with (Valo) and (1000 mw/cm^2). intensity (H) adhesive paste put on the edgewise brackets (I) bonding bracket to the center of the crowns' surface with adhesive paste (3M Unitek Transbond XT). (J) curing with 3 seconds and (3200 mw/cm^2) intensity. (k) debonding measuring by universal testing machine(L) universal testing machine

Storage

Following bracket bonding, the specimens will be stored in into dark plastic recipients containing distilled in water for 24 hrs at 37°**C** temperatures. before undertaking the shearing bond strength test. (Sachdeva et al., 2012)

Debonding Procedure

Shear bond strength was tested with WP300 Universal testing machine (G.U.N.T. Geratbau GmbH /D-22881 Barsbuttel/Germany) with a load applied parallel to the buccal surface of the crown in an occlusal- gingival direction, using a knife-edged rod as shown in figure (3). The chisel tip will be positioned to merely contact the bracket base at a speed of 0.5 mm/min. The force required to debond the brackets was recorded in Newton, and the values were converted to MPa.

Fig (3): Debonding of orthodontic bracket

RESULT

The Descriptive statistics value of different lithium disilicate semi-crown surface conditioning are listed in the table (1)

The findings of the present study showed that sandblasting (Sa) group gave rise to the higher mean SBS while the hydrofluoric acid etch (HF) group gave rise to lower mean value of SBS. The ultrasonic scaling (USc) group distributed on statistical levels between the higher and lower level of means.

Table (1): Descriptive Analysis* (Mean, standard deviations, standard error, minimum and maximum values) of shear bond of lithium disilicate crown with different surface conditionings

group	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Hydrofluoric acid (HF)	10	7.37	1.76	0.56	5.00	10.00
Sandblast (Sa)	10	18.25	3.91	1.24	15.00	25.00
Ultrasonic scaling (USc)	10	15.25	3.19	1.00	10.00	18.00
Valid N (listwise)	10					

* Measurement unit in mega Pascal (MPa)

The analysis of variance (ANOVA) for three methods of surface conditioning used in lithium disilicate semi crown crowns showed a significant difference ($P<0.001$) among them as in (table 2)

Table (2): One-way ANOVA analysis for shear bond strength of lithium disilicate crown

Source of variation	Sum of Squares	Degree of Freedom	Mean Square	F test	Sig.
Between Groups	631.06	2	315.53	33.17	P<0.001
Within Groups	256.88	27	9.51		
Total	887.94	29			

The results of Duncan multiple range test table (3) showed that group (Sa) had the highest shear bond strength among the different surface conditioning, with a significant difference ($P\leq0.05$).

On the other hand, (HF) group showed the lowest level of shear bond, with significant difference from other methods.

(USc) group is distributed on statistical levels between upper (Sa) group and the lower (HF) group mean level.

Table. (3): Duncan's test for the shear bond strength among different surface conditioning groups of lithium disilicate crown.

Method	Mean* ± SE	Duncan groups**
HF	7.37 ± 0.56	A
USc	15.25±1.00	B
Sa	18.25±1.24	C

***** The mean in MPa measurement.
****** Different letters mean significant different at $p \leq 0.05$

DISCUSSION

Because of the fast advancement of new ceramic materials in dentistry and the growing demand for adult orthodontics, it is now necessary to correctly glue orthodontic brackets to diverse ceramic restorations. Despite the increasing demand for an aesthetic facial appearance, which has led to an increase in the number of adult orthodontic patients with ceramic restorations, there is still no agreement on the most efficient ceramic conditioning procedure for achieving optimal bond strength, as demonstrated by several studies such as (Alakus Sabuncuoglu & Erturk (2013), Lee et al (2015) and Faltermeier & Reicheneder (2016).

The present study attempted to determine the most reliable way for attaching metal brackets to lithium disilicate (E max), as well as the best surface conditioning approaches.

The ideal bond strength of orthodontic brackets was reported to be 6-10 MPa in a study by Barceló Santana et al (2006) and Endo et al (2008) suggested that bond strengths of 6 to 8 MPa are sufficient for orthodontic bracket bonding; however, it should be noted that the applicability of these values to the clinical setting is restricted because the bond of orthodontic brackets to crown is affected by several environmental factors (Schmage et al., 2003).

The existing study's findings indicated that among the surface condition groups, the (Sa) group had the higher mean shear bond strength, while the (HF) group had the lower. However the group (USc) was statistically dispersed between higher and lower mean levels, and mean ranged from higher to lower (Sa,USc,HF) sequentially.

The findings of the Erdur and Basciftci (2015) study concurred with the current investigation, demonstrating that the SBS between the metal bracket and the lithium disilicate surface is greater in sandblasted surface conditioning than in HF acid treated surfaces. Furthermore, the current study results go beyond earlier studies by Cevik et al (2017), who reported that sandblasting with Al2O3 particles leads in greater SBS between metal bracket and (e max) crown as compared to hydrofluoric acid. In contrary to our study, the previous studies by Guarda et al (2013), zdemir & Alada (2017) found that sandblasting resulted in lower SBS than HF acid etching since etching the ceramic surface with 10% HF promoted dissolution in the glassy matrix of the specimens to the depth of a few microns, enabling the lithium disilicate crystals to protrude from the glass matrix. Elongated crystals and shallow irregularities were clearly observed according to Guarda et al (2013), The change in the surface morphology treated with 10% HF increased the surface area and facilitated the penetration and retention of resin cement into the microretentions of the treated surface according to (Spohr et al., 2003).

It is worth noting that the study of Bebsh et al (2021) revealed that sandblast with 50 m Al2O3 produced a higher surface roughness for lithum disilicte (E max) crown while hydrofluoric acid etching (HF) with 5% hydrofluoric acid produced a lower surface roughness compared to sandblast surface treatments.

Based on a previous study by Ramakrishnaiah et al (2016), HF etching of the lithium disilicate crowns alters the surface roughness from 0.16 to 0.65 m Ra and the etched surfaces were irregular and characterized by the presence of numerous micro porosities, grooves, and striations as a result of the dissolution of the glassy phase.

Similarly, Cevik et al. (2017) indicate that surface treatment of E max with (HF) and (Sa) surface conditioning transformed the surface from 0.85 m Ra to 1.27 m Ra and 2.20 m Ra Sequentially. It was also noted that even after multi-step polishing, the roughened surface of lithium disilicate was not properly altered back to its previous smooth conditioning. The surface roughness of lithium disilicate was changed by ultrasonic scaler from 2.35 m Ra to 28.54 mRa, according to Yoon et al (2017).

According to Bayoumi et al. (2019), shear bond strength is influenced by surface roughness, which is then controlled by surface treatment techniques.

Even though SBS of lithium disilicate semi crown using ultrasonic scaling indicated an average mean between acid and sandoblast, anybody may detect an appropriate range of SBS. As a result, the suitable SBS within the acceptable range of HF acid may be explained by the capacity of HF acids to attack the glassy phase of the ceramic, dissolving the surface to a few micrometres depth, and thereby protruding a lithium disilicate crystal from the glassy matrix. (2016, Chen et al., 1998; Prochnow et al., 2017) and the resultant-altered topography increased the surface area for micromechanical bonding with resin composites (Chen, et al., 1998; Ramakrishnaiah et al., 2016) sandblasting groups more effectively remove the glazed layer that negatively influences the bond strength which revealed a more roughened surface than those of the other groups.

Both authors Augusti et al (2015) and Kurtulmus et al (2019) indicated that significant irregularity generated by sandblasting contributes to an increase in surface free energy, which increases bond strength. Roughened E max surfaces resulted in greater shear bond strength values in this investigation.

Keshvad and Hakimaneh (2018) said that surface roughening increased the surface area, allowing for more possible retention sites in which the adhesive paste may readily be interlocked to operate efficiently and improving shear bond strength. The bifunctional groups in silane coupling agents stimulate chemical contact between the silica in the glass phase of ceramics and the methacrylate groups of the resin via siloxane bonds, which improves durability and moisture resistance. Türkkahraman and Küçükesmen (2006); Lung and Matinlinna (2012)

CONCLUSIONS

It is concluded from this study that all types of surface conditioning used in this study were significantly affected the values of SBS of metal bracket, and they were in the following ascending order of SBS means; Hf acid group then ultrasonic scaler group and finally sandblasting one. Although Hf gave rise lower mean of SBS but it is still within an acceptable range. The newly used surface conditioning (ultrasonic scaler) was effectively influenced the value of SBS. Finally, all types of surface conditioning used within the range of optimal bond strength in orthodontic point of view and may consider as a recommended technique for reliable shear bond strength.

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