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3D Slot Roughness Evaluation of Novel Orthodontic Brackets With Two Commercial Brackets (An In-Vitro Study)

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Abstract:
The purpose of the study is to evaluate the roughness of the new E-max brackets with two commercially available ceramic brackets in the markets. The bracket roughness of three different types was compared. The brackets were divided into three groups: (1) E-max brackets (IPS E-max press, Ivoclar, Germany), (2) Gemini clear brackets (Unitek, 3M, USA), and (3) Discovery pearl ceramic brackets (Dentaurum, Germany). The roughness of each bracket was tested through a 3D laser microscope (VK-X1100, Keyence, Germany). The Gemini clear showed a uniform surface significantly smoother than both E-max and Discovery pearl brackets with the latter having the highest roughness parameter. As a result of the noticeable tested brackets, E-max material is now and will continue to be a common choice for modern, aesthetically pleasing brackets, despite having a rougher surface than Gemini Clear but less than Discovery Pearl. To reduce roughness, the E-max brackets could benefit from better polishing and finishing. Hence, to lessen friction.

Keywords: *Ceramic Brackets; IPS E-max Press; Orthodontic.*

1. Introduction

The progress in orthodontics is crucial just like in contemporary dentistry; to fulfill the increased strength, durability, and wear resistance, silicate glass ceramics have been recently introduced as machinable materials [1]. The ceramic brackets that were first introduced in the 1980s served only as an alternative to metal brackets as they were more esthetically pleasing; however, the currently available ceramic brackets are almost entirely composed of aluminum oxides and, therefore, display high strength, chemical stability, and biocompatibility [2]. The demand for aesthetic orthodontics has become the main target due to the enhancement of ceramic bracket performances [3].

One of the crucial physical properties of ceramic brackets can be related to the extremely high hardness of aluminum oxide, which gives both monocrystalline and polycrystalline ceramic brackets a significant advantage over stainless steel brackets. In fact, they are nine times harder than stainless steel brackets or enamel, and consequently, if there is contact between the teeth and ceramic brackets, severe enamel abrasion might rapidly occur [4]. The esthetic performance of ceramic brackets is determined by the optical properties of the teeth of patients due to their esthetic ability to imitate tooth color with translucency close to a natural tooth, which was described as one of the primary elements in controlling esthetics, all-ceramic materials are well known as ideal dental restoration materials [3, 5].

The clinical problem in which the sliding of the archwire through the bracket becomes slow – due to the high friction that results from the roughness of the bracket interface could be controlled by using ceramic brackets that have smoother slot surfaces, such as; by adding metal slots and by strengthening the anchorage requirements [4].

Lithium disilicate material IPS E-max system (Ivoclar Vivadent AG, Schaan, Liechtenstein) is a representative glass-ceramic material that exhibits greater resistance to fracture toughness and flexural strength [6] and enables dental technicians to customize dental restorations in terms of shape and aesthetics using heat-pressing or machining technology.

The esthetic brackets, especially ceramic brackets, are considered as one of the main brackets that the patients seek for treatment. However, no reports of using lithium disilicate in orthodontics have been found as of yet, the research tries to overcome some disadvantages of commercially available brackets, by creating and evaluating a bracket from a new one.

Therefore, the goal of this project is to provide a revolutionary method for standardizing the manufacture of customized ceramic orthodontic brackets with an aesthetic appearance. This method will use heat-pressing technology, lithium disilicate materials, and bracket duplication. The roughness of the surface was assessed in comparison to ceramic bracket products that are readily accessible on the market.

2. Literature Review

2.1 Esthetic Orthodontic Brackets

2.1.1 Plastic Brackets

Plastic brackets, consisting primarily of unfilled polycarbonate, were used in orthodontic therapy in the early 1970s and significantly enhanced esthetics [7]. However, they exhibited a number of issues, such as tie-wing fracture and slot distortion due to lack of strength and stiffness, increased slot roughness, staining, and odor due to the adsorption of oral fluids [8]. In order to solve these problems, efforts were made to improve mechanical strength by employing new polymers with increased stiffness [7], incorporating smooth metallic slots[8], and reinforcing polymer with glass fibers [9].
Unfortunately, when the common esthetic plastic brackets are used, the effect of friction in mechanics must be of major concern because these brackets generate higher friction values than metallic brackets [10].

Metallic slots were inserted within the contemporary esthetic plastic brackets based on the removal of friction values. The part of the bracket that is responsible for friction during the sliding of the archwire is its slot. A specific factor that might influence friction is the roughness of the slot surfaces. Recent research has raised slot roughness in the archwire /slot-produced friction [11], but further research has to be done on this issue using more sophisticated and detailed methods.

An undesirable side effect of plastic brackets is their discoloration in the oral cavity after a short period. It has been found that the resin matrix composition and conversion influence the water absorption of polymers [12]. In addition, filler size and the distribution of the filler particles might also affect the water uptake of composites [13].

Self-ligating aesthetic brackets are a further recent development. In vitro study has shown that Polycarbonate self-ligating brackets generate significantly greater static and kinetic frictional forces than stainless steel self-ligating brackets but are comparable to conventional stainless-steel brackets [14].

One of the efforts done by orthodontic companies was to reduce friction through the addition of metallic slots due to their smoother slot surfaces, metal slot inserted into a plastic bracket could be the best option among plastic brackets for low frictional resistance and to prevent damage from the sliding movements of the archwire [10].

2.1.2 Ceramic Brackets

In the mid-1980s, monocrystalline sapphire and polycrystalline ceramic materials were introduced in the orthodontic field [15]. Ceramic brackets are very common as an esthetic appliance in contemporary orthodontics. Its introduction is a much-heralded development in the orthodontic treatment of adult patients. The patient's acceptance of ceramic brackets has been unprecedented in the practice of orthodontics and contributed significantly to the expansion and progress of contemporary orthodontic therapeutic modalities [4].

It has been determined that polycrystalline ceramics have a greater coefficient of friction when compared to monocrystalline ceramics. However, it was discovered more than ten years ago that monocrystalline brackets exhibit frictional properties similar to those of metal brackets [16].

Recent research that included metal and ceramic brackets made using various production techniques, such as metal injection molding (MIM) and ceramic injection-molded (CIM), concluded that there isn't a significant difference in the manufacturing processes in terms of friction. Several variables, including the bracket/ligature/archwire combinations, the surface finish of the archwire and bracket slot, the bracket design, and the force the ligature applies to the archwire, have been emphasized as being important in the complicated phenomena of friction [17].

To minimize frictional resistance, ceramic brackets with smoother slot surfaces consisting of metallic (stainless steel and gold), silica lining, or ceramic/plastic slot surfaces have been proposed and are currently being developed [4].

2.1.3 Lithium Disilicate Bracket

There has been growing interest in glass-ceramic systems because of their good esthetics, excellent fracture resistance to occlusal forces, and bonding durability between the prepared tooth surface and ceramic [18].

In the early '90s, IPS Empress 1 (Ivoclar Vivadent, Schaan, Liechtenstein), a leucite-reinforced glass ceramic was launched in the dental market. The scattered leucite crystals in the amorphous glass matrix increased the strength by suppressing crack propagation and enhanced clinical efficacy [18].

Thereafter, IPS Empress2, which is a lithium disilicate glass-ceramic mainly composed of quartz, lithium dioxide, phosphor oxide, alumina oxide, and potassium oxide, was introduced by the same manufacturer.

In 2001, this manufacturer released IPS E-max Press, which is a castable lithium disilicate glass-ceramic with the improvement of mechanical and optical properties so that it combines durability with excellent esthetic [19, 20].

Lithium disilicate ($Li_2Si_2O_5$) typically has a microstructure made up of interconnecting needle-shaped crystals embedded in a glass matrix. In contrast to other commonly used glass ceramics, these have a microstructure that increases strength and toughness; their strength is twice that of the first generation of leucite-reinforced ceramics [21]. This is because the morphology forces crack to spread around each crystal of lithium disilicate [22].

IPS E-max Press ceramics are pressed into a mold by an alumina plunger under pressure using a pneumatic press furnace. The button and sprue portions are usually discarded. However, they are considered useful for re-pressing in some dental laboratories [23].

3. Material and Method

An in-vitro study was conducted at the Research Center of the College of Dentistry at Tishik International University and Department of Mechanics, strengths of the Material lab at College of Engineering, Salahaddin University and Institute of ceramic, glass and construction materials, TU Bergakademie Freiberg, Germany.

In this study 30 brackets were used (10n) from each type;

1. E-max brackets (IPS E-max press, Ivoclar, Germany)
2. Gemini clear brackets (Unitek, 3M, USA)
3. Discovery pearl ceramic brackets (Dentaurum, Germany)

The brackets were of central incisor, slot size of 0.022 inch and all have 4 wings. The E-max bracket manufactured in the laboratory.

3.1 Making New E-max Brackets

3.1.1 Bracket Duplication

For replication, a ceramic bracket from the 3M Company (Gemini clear Brackets) was used. A heavy and light body elastomeric impression material (Harvard PremiumSil, UK) is used for making a copy (Figure 1). When constructing the brackets using E-max, the negative imprint served as a mold.

Before converting acrylic resin brackets into E-max brackets, the pattern acrylic resin (GC U.S.A.) was used as a last step to provide a positive impression of E-max brackets (Figure 2).

Figure 1: The elastomeric impression material (heavy and light body).

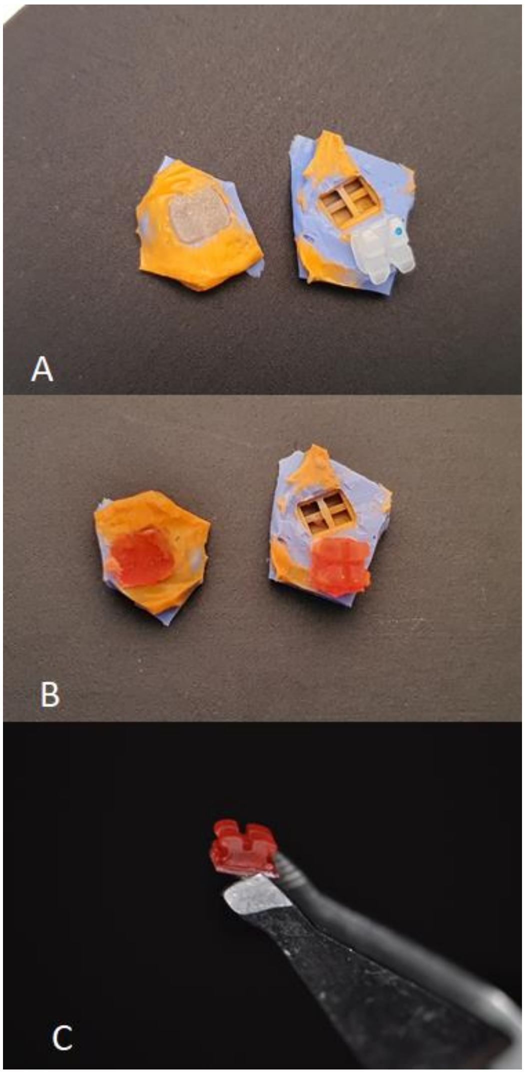

Figure 2: A- Negative impression of 3M bracket, B- Positive impression of 3M ceramic bracket by acrylic, C- Acrylic bracket (side view)

3.1.2 Laboratory Work

In the laboratory, the sprueing process for pressing lithium disilicate ingots was carried out. The acrylic bracket model objects are sprued laterally on the investment ring base by attaching the bracket's base to the wax, as illustrated in (Figure 3), to avoid damaging the bracket's wing and slot.

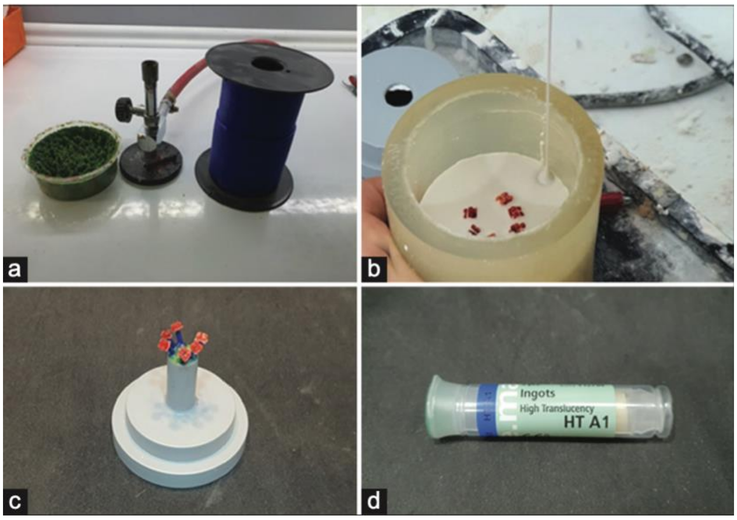

Figure 3: a. Gas torch and wax wire, b. acrylic bracket attached to the ring base by sprue wax wire, c. Investment material, in which ring base and attached acrylic brackets are imbedded in, d. high translucency H1 A1 ingot.

Following that, investing was done using an IPS PressVEST Speed 200 g IPS Silicone Ring and the appropriate ring gauge, with the ring flat with the investment ring base. The investment ring was filled by gradually adding investment material that had been combined at a ratio of (32 ml:22 ml). Cold IPS Alox Plunger for preheating and pressing, together with a cold IPS E-max Press ingot, were placed in the shade (high translucency A1), and the press furnace (such as Programat EP 5010) was turned on just in time for the preheating and self-test phases to be finished. The pressed E-max brackets are reduced to the absolute minimum during the divesting and finishing process using low speed and light pressure, followed by a steam cleaning (according to the Ivoclar Vivadent/E-max Revolution guideline) and glaze firing (Figure 4).

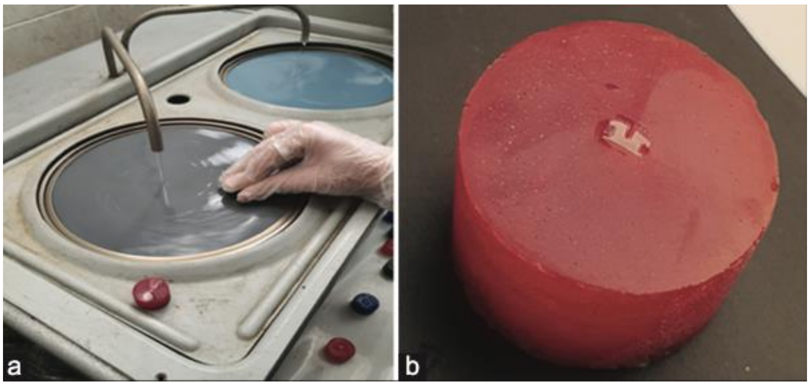

Figure 4: a. metallographic grinding/polishing machine, b. the polished bracket and acrylic mold

3.2 Laboratory Tests for Slot Roughness

Brackets from each brand (n:10) were prepared by cutting the wings down to 1/3 of the slot depth using a fine diamond disk. The slot floor roughness was evaluated by a 3D laser microscope (VK-X1100, Keyence, Germany, (Figure 5) The Function Automatically Adjusts with double scanning to improve the quality of the measurement. The surface roughness parameters Sa (average roughness), Sq (root mean square roughness), and Sz (average peak to valley high depths of five consecutive sampling measurements) were obtained.

Figure 5: 3D laser microscope (VK-X1100, Keyence, Germany)

3.3 Statistical Analysis

Statistical Package for Social Sciences (SPSS) program 17.0 Software (SPSS Inc, Chicago, USA) was used for data entry and analysis.

1. Descriptive statistics was calculated including means, standard deviations, minimum and maximum value, frequency, and percentage, for the 3-dimentional roughness test.
2. Analysis of variance ANOVA was used to compare the 3-dimentional roughness test between the E-max bracket and the other two brackets and to see if there is a significant difference between bracket groups or not (P-value≤0.05).
3. Post hoc test, DUNCANS multiple range test (DMRT), used for assessing multiple comparisons of 3-dimensional roughness test between bracket groups (P-value≤0.05).

4. Result

4.1 Slot Roughness

The 3D profilometer laser scanning pictures are depicted in Figure (6-8) and Table (1).

- The small value of (sa) indicates the less roughness parameter
- The less value of (sz) indicates the flatter surface
- The higher value (Spc) indicates that the point of contact with other objects has a rounded shape.
- The closer the (Sdr) value to zero indicates the more leveled surface, as it becomes a larger value it indicates that the slopes at the surface increase.

Roughness parameters showed significant differences among groups. The Gemini clear brackets showed a uniform surface topography which gave the slot a smoother appearance than other tested slots (Figure 6). The slot of Gemini clear represents compact particles. The Gemini clear bracket slot gave the lowest roughness parameter with flatting of the surfaces (Sz =15.09 µm), with round elevation (Spc=2983.1 µm), compared with other tested brackets. The E-max slot represents a mixture of smooth and porous-like areas (Figure 7). The Sa parameter (3.72 µm) was significantly higher than the Gemini clear one (1.14 µm) and less compared with the Discovery pearl bracket (4.75 µm).

The Discovery pearl gave more roughness parameter (Sa=4.75 µm) with less flat slot (Figure 8). The Discovery slot showed a smooth area with some fissures and pits.

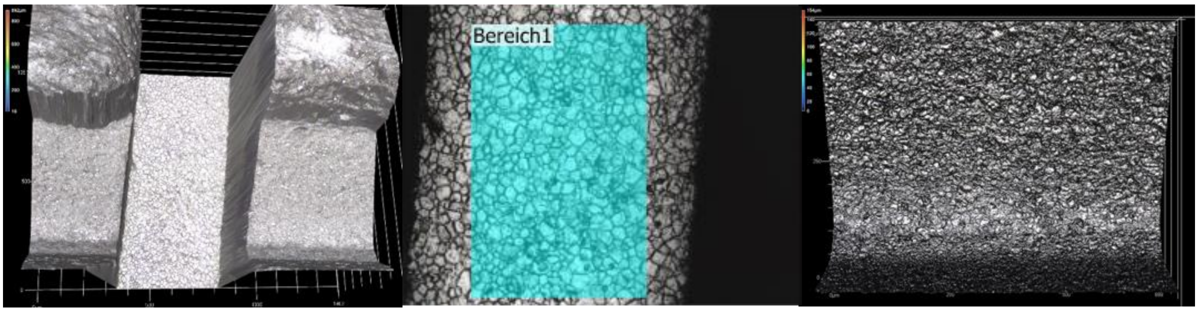

Figure 6: 3D laser profilometer images of Gemini clear bracket.

Figure 7: 3D laser profilometer images of E-max bracket.

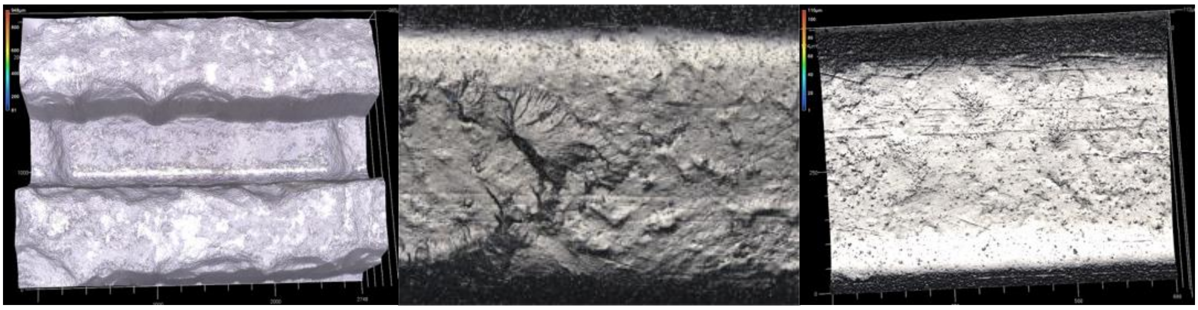

Figure 8: 3D laser profilometer images of Discovery pearl bracket.

Table 1: Results of Slot Surface Roughness (Means and Standard Deviations) *

Product	Sa (µm)	Sz (µm)	Spc (µm)	Sdr (µm)
Gemini clear	1.14 (0.12) [a]	15.09 (0.5) [a]	2983.1 (0.7) [a]	0.56 (0.32) [a]
E-max	3.72(0.23) [b]	20.71(0.7) [b]	2086.96(0.6) [b]	0.3946 (0.4)[b]
Discovery pearl	4.75 (0.44) [c]	49.57 (0.12) [c]	1629.32(0.53) [c]	0.1599(0.4) [c]

*Same superscripts per column imply mean values with no statistically significant difference ($p>0.05$).

5. Discussion

Due to the major role of slots during treatment which is related to friction between the wire and brackets slots, the measuring of roughness parameters of new E-max brackets with other commercially available brackets is important not just theoretically but also clinically to give an idea about the performance of new materials clinically in the future. The Gemini clear brackets gave the lowest (Sa) roughness parameter compared with other tested brackets. This result is related to manufacturer fabrication because the raw materials of Gemini clear brackets are polycrystalline material and it is the same with Discovery brackets but depending on the procedure of girding, polishing, and glazing.

From this cause, the Discovery Brackets gave the higher (Sa) and (Sz) scores which equates to the highest roughness, this result is due to its composition as polycrystalline alumina brackets are less smooth than monocrystalline samples [15], but their frictional characteristics are comparable even though the company used CIM to decrease the roughness, more compact particle and decrease the porous (Manufacturer instruction) but the recent study by Reimann, Bourauel [17] showed no significant differences in friction loss between brackets made by ceramic injection molding and differently manufactured ceramic brackets.

New E-max brackets gave a (Sa) and (Sz) score intermediate between both Gemini clear and Discovery pearl brackets, which reveals the roughness of the E-max is less than Gemini clear and more than discovery, this is despite the composition of E-max from microstructure is constituted by interlocking needle-like crystals embedded in a glass matrix [24].

Nevertheless, the fabrication way and glazing affect the roughness parameters, the more porous the surface is, the higher the roughness. As we saw in the microscope laser scanning of the E-max bracket the porosity was more than the Gemini clear bracket slot surface however it’s a copy of the Gemini clear bracket but maybe the porosity is due to the manufacturing technique, which was press not CAD/CAM, which is more accurate and precise but because of the slot size and inability of CAD/CAM to cut the slot properly, the press technique was the better choice.

Vichi, Fonzar [25] showed that polishing and glazing will lower the roughness of the E-max material block and allow it to yield a higher gloss.

Overall, the results of new creative E-max brackets statistically are acceptable and competitive with other famous commercially available brackets through a limited test in this in vitro study.

6. Conclusion

- Differences were found in slot roughness parameters; Gemini clear gave less Sa compared with the other two brackets while Discovery gave more rounded peaks. (Spc) compared with other brackets.
- New E-max brackets gave acceptable results as a first, newly introduced bracket material compared with the commercially available ones.

7. Author’s Contribution:

We confirm that the manuscript has been read and approved by all named authors. We also confirm that each author has the same contribution to the paper. We further confirm that the order of authors listed in the manuscript has been approved by all authors.

8. Conflict of interest:

There is no conflict of interest in this paper.

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