

3D Slot Roughness of Contemporary Ceramic Brackets

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Abstract

Purpose of Study: To examine the roughness of slots of three ceramic brackets. **Materials and Methods:** Three ceramic bracket types (Encore, Reflections and Inspire ICE). The bottom of each slot of every bracket was selected for evaluation and pictures were taken by optical microscopy at magnification (20x) for a general estimation of the roughness. Then the roughness parameters (S_a , S_q , S_t , S_z) of every slot were examined in a 3D optical profilometer in a higher magnification. **Results:** The picture from Optical microscope gave a differences of textural morphology of brackets slots for tested brackets. Metallic slots gave differences of grooves and striations whereas plastic slots presented peaks and pits. Inspire ICE showed the highest S_a and S_q value, statistically higher than the other brackets tested. Reflections gave the highest S_z and S_t values, which were statistically significant higher than the other brackets, followed by Inspire ICE which presented statistically significant higher values compared to Encore. **Conclusions:** The significant differences were revealed through 3D-images and roughness parameters of slots gives significantly different among the tested bracket. Encore and exhibited low roughness parameters.

Introduction:

The success of tooth movement during orthodontic treatment depends on the ability of orthodontic archwire to slide through brackets and tubes⁽¹⁾. During sliding, friction produced between bracket and archwire leads to reduced force and thus unsatisfactory tooth movement⁽²⁾. The bracket part responsible for friction during sliding of the archwire is its slot. The archwire /slot couple friction has been extensively investigated concerning of wire materials, ⁽²⁻⁹⁾ wire sizes,^{(2-4)(7,8,10)} bracket's slot materials, ^{(3,4,7)(11-16)} bracket'

slot sizes ^(2,5,17) and other test variables, as for example wet and dry conditions ^(4,5,10,15,18,19) and the material and type of ligation^{(6,8,9,12)(20-23)}. When the widely popular esthetic ceramic brackets are used, the influence of friction in mechanics must be of major concern, because these brackets produce higher friction values than metal ones ^{(3,4)(10-13)}. Based on the lower friction values, metallic slots were incorporated within the contemporary esthetic plastic brackets. Surface roughness of orthodontic wires and

brackets is essential for determining the coefficient of friction and the effectiveness of tooth movement⁽²¹⁻²⁴⁾. A specific factor that might influence friction in the archwire /slot couple is the roughness of the slot surfaces. A lately, a research study has analyzed the role of slot roughness in the production of friction⁽²⁵⁾. However, further research is needed on this issue using more sophisticated and detailed methods. The main aim of this study was to examine the roughness characteristics of slots of three different types of ceramic brackets.

Materials and Methods:

Three ceramic brackets commercially available were selected for the present study Table (1). All The brackets were for upper central incisors (Roth 22 slots sizes). Encore ceramic brackets have been reinforced with a metallic slot. Each bracket was examined in an optical microscope (Eclipse ME-600, Nikon Kogaku, and Tokyo Japan) with polarized light in magnification 20x. Pictures were taken at the base of the slot (slot bottom) in a Bright Field (BF) for determining the slot texture. The roughness of each slot was evaluated in a 3D optical profilometer Fig.(1)(Wyko NT 1100, Veeco, Tuscon, AZ, USA), working in VSI mode (Vertical Shift Interference), 10 μ m distance, 50-80 μ m scan length, modulation 2 and at a magnification of 46.1x. The Wyko vision 32 software was running under Microsoft, windows XP. For the experimental purpose the tested brackets were prepared by cutting the wings carefully were removed 2/3 of depth of slot Fig.(2). Brackets were then blown gently with dry air to remove any debris due to cutting procedure. For each bracket, three recordings were made. The roughness parameters used as following:

- (a) Average roughness (S_a), describing the overall surface roughness;
- (b) Root mean square roughness (S_q), representing the height distribution relative to the mean line;
- (c) Maximum roughness depth (S_t), which registers isolated profile features on the surface;
- (d) Average maximum peak-to-valley height depths (S_z), describing five consecutive sampling measurements.

Statistical analysis

One-way (ANOVA) was used to examine the statistically significant differences in roughness parameters. The statistical analysis was performed by SPSS 17.0 Statistic Software (SPSS Inc, Chicago, USA).

Results:

The photographs taken by optical microscopy revealed that the tested brackets had different textural slot surface characteristics. The metallic slot presented a rough surface with grooves and striations. The ceramic slots presented a rough surface with condensed motifs consisting of many peaks and pits (Fig.(1)A,B respectively). Roughness parameters are presented in Table (2). Inspire ICE showed the highest S_a value, which was statistically higher than the other brackets tested. Also Inspire ICE presented the highest S_q value, which was statistically higher than the other tested brackets. Reflections bracket exhibited the second higher S_a value statistically higher compared to the other brackets. Reflection presented the highest S_z and S_t values, statistically significant higher than the rest of brackets, followed by Inspire ICE which presented statistically significant higher values compared to Encore. Representative 3D images of the surface texture of the slots tested are illustrated in Fig.(2). Encore presented nearly parallel grooves some of them appeared smooth and boarder appeared little rough in addition exhibited striations lying at a distance one from another across the base of the bracket. Reflections presented single and liner porosity randomly distributed on the surface, with sharp protrusions of some μ m height in the rest of the surface. Inspire ICE exhibited a smooth surface consisting of lightly elevated sintered like particles,

accompanied by many sharp large protrusion of about 10-15 μm in height, joined randomly in a beehive-like lattice.

Discussion

The action of improvement of dental materials is not too high movement but this action occurs slowly for short (26-28) from this point of view, in this study, the slot roughness of some of ceramic bracket which give some idea about the expected friction that may be occurred during tooth sliding. Grooves and striations on the metallic slot, present in the photographs of optical microscopy, were probably produced during manufacturing. Mechanical manufacturing procedures usually lead to the inclusion of particles and consequently to the formation of rough surfaces with irregularities, a negative evolution for the effective clinical performance of the bracket/archwire system (29). Since the relation between slots and wires contributes to variations in the torque expression of the appliance, this issue acquires further significance (30). The clinical implication of such a condition is the inflexible transfer of the archwire forces to the root of the tooth (30,31). According to the results of roughness parameters, brackets with ceramic slots, especially Inspire ICE, presented statistically higher roughness values in comparison to brackets with metallic slots, this can be interpreted as an increase of friction of the slot/archwire couple (32,33). This result not agreement with other studies, (1,4,3,30) revealed that ceramic brackets with stainless steel slots have higher frictional data compared with those of normal ceramic; for this reason, they are not as competent as metal brackets. This could be because of several factors like different conditions like wet, dry or the type of archwire that used during measured. Nonetheless, the relief of images in 3D optical profilometer might help to explain the roughness values and consequently the clinical behavior of the slot/archwire couple. This increase in roughness parameter due to the composition of mono crystalline brackets which consist of big grain with sharp edge

which improved through 3D optical profilometer. Other studies suggest that high frictional data for monocrystalline brackets may be formed by difference edges like sharp hard edges to formed at the base and walls of the slot with the outer surface of the bracket.¹⁸ Reflections brackets gave nearly uniform 3D pictures, although corresponding to ceramic slot brackets, imply for good clinical performance. This result agreement with other studies shown similar friction between metallic and polycrystalline brackets and less friction in the polycrystalline than that in the monocrystalline^(18,24,25,34,36). Zinelis et al. (2005) (29) showed that the differences in brackets pouring might be due to the significant differences in roughness between raw polycarbonate. Metallic slot brackets presented 3D pictures which may suggest a better clinical performance. The above mentioned may form a basis for future clinical experiments which might constitute a views theoretical basis of the clinical performance of brackets. However, researches (3,11)(32-37) have reported that metal brackets showed lower friction than composite and ceramic ones. Roughness in 3 D mode may be investigated by atomic force microscopy (AFM) and 3-D optical profilometer. Other profilometric procedures, such as Scanning Electron Microscopy (SEM) and 2-D stylus profilometry although extensively used in the past, cannot offer nowadays efficiently characterize roughness (25). Optical profilometer is a 3D, wide and powerful tool useful for performing quantitative measurements of the roughness parameters, evaluating the diverse nature of their surface textures and it is providing information of roughness peaks up to 1 mm in height, whereas AFM provides 3D images for no more than 10 μm in height, although the detection limit of AFM is in the order on nm and that of the 3D Optical profilometer of the order of μm .

Conclusions:

- Optical microscope explained a different of textural morphology of slots of the brackets tested.

- Metallic slots showed grooves and striations comparing with ceramic slots presented peaks and pits.
- Additionally, metallic slots of Encore ceramic brackets tested gave no statistically lower in average of roughness compared to polycrystalline (Reflections) bracket slots.
 - Encore exhibited low roughness parameters and they are accepted to exhibited improved clinical behavior in sliding with archwires.
 - Monocrystalline brackets (Inspire ICE) exhibited high roughness parameter compared to Encore and Reflections ceramic brackets.
 - Optical profilometer provides 3D-images and may be considered a powerful tool for quantities measurement of the roughness parameters of bracket's slot, as well as for the evaluation of the diverse nature of their surface texture.

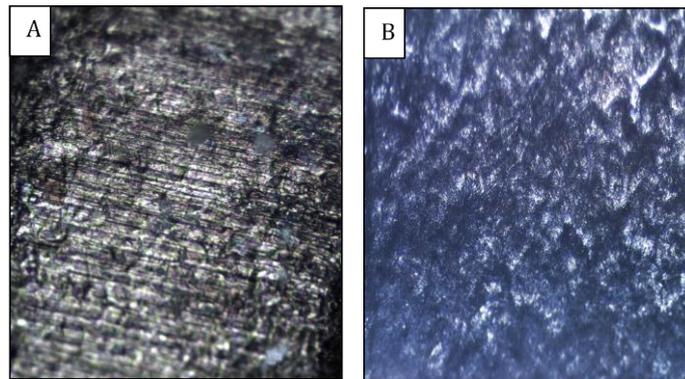


Fig. (1): Reflection light microscopic images: A) Metallic slot for Encore, B) Ceramic slot for Reflection bracket.

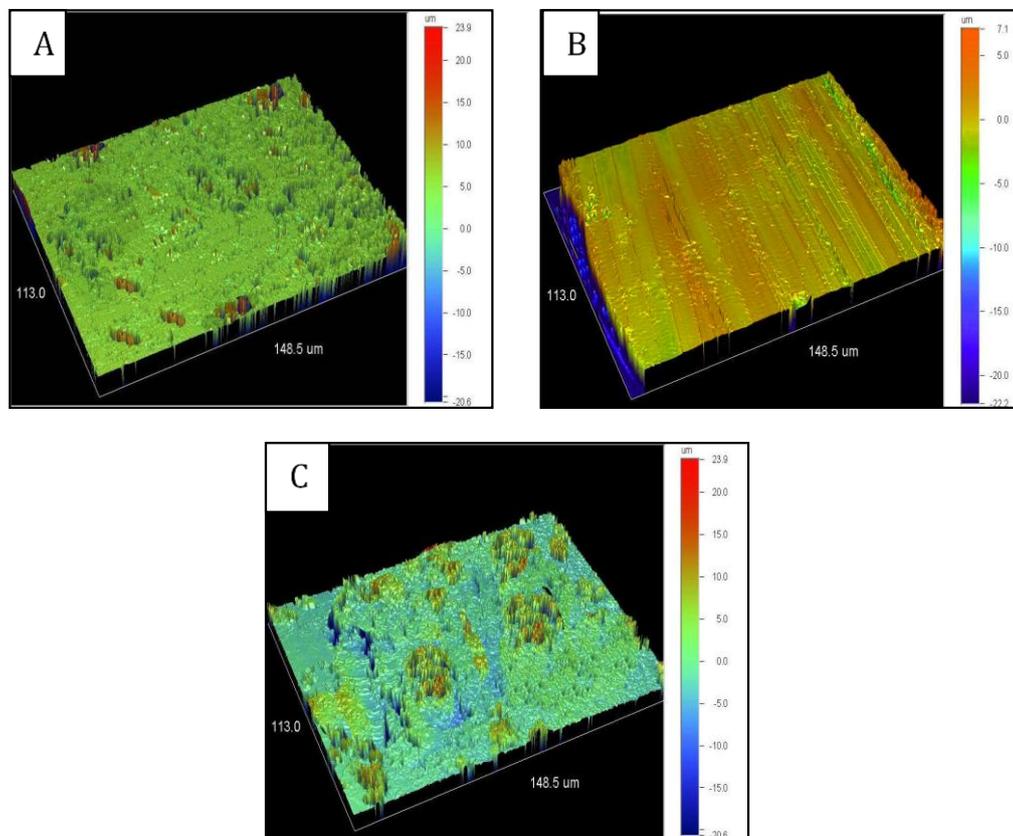


Fig. (2): 3D profilometric images of slots floor of the brackets. A) Reflection, B) Encore and , C) Inspire ICE ceramic brackets.

Table (1):- The commercial tested ceramic brackets.

Commercial Bracket Name	Composition*	Types of Slot	Manufacturer
Inspire ICE	Monocrystalline	Ceramic	Ormco, USA.
Encore	Monocrystalline	Metallic	Ortho Technology- USA.
Reflections	polycrystalline	Ceramic	Ortho Technology, USA.

*Composition according to the manufacturing information

Table (2):- Roughness parameters for tested bracket's slots.

Commercial Names	S_a	S_q	S_z	S_t
	Mean	Mean	Mean	Mean
Inspire ICE	2,000 ^a	2,830 ^a	33,080 ^b	39,190 ^b
Reflections	1,220 ^b	1,690 ^b	40,640 ^a	60,150 ^a
Encore	1,033 ^b	1,680 ^b	24,900 ^c	29,260 ^c

The same letter superscript mean no significant difference between materials ($p > 0.05$)

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