Original Article

In Vivo Evaluation of the Surface Roughness and Morphology of Enamel after Ceramic and Metal Bracket Removal and Polishing using Aluminum Oxide Polishing Burs and Tungsten Carbide Burs

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Abstract

Background: A fixed orthodontic therapy includes bonding of either metal or the ceramic brackets onto the tooth surface. The debonding of these attachments after the conclusion of the treatment to regain the natural surface morphology is proved to be challenging. The aim of this study is to evaluate the surface morphology of enamel after debonding of ceramic and metal brackets after polishing with two different burs, that is, aluminum oxide burs and tungsten carbide burs. **Materials and Methods:** Twenty patients undergoing orthodontic treatment were divided into two groups. Group 1 patients treated with metal brackets and Group 2 patients treated with ceramic brackets. After the completion of the treatment, the brackets are debonded using the conventional orthodontic pliers and impressions were taken, casts were poured, and modified adhesive remnant index scores are measured on central incisors. The right side of the arch is then polished using the aluminum oxide burs and left side of the arch is polished using tungsten carbide bur and impressions were again taken and casts were poured. The surface roughness measurements are done on three sets of dental replicas of maxillary central incisors for each patient using a surface roughness tester. Three replicas from each group are again analyzed by Scanning Electron Microscope for qualitative assessment of the enamel surface. **Results:** The mean surface roughness values with aluminum oxide burs are significantly lesser than tungsten carbide burs in both the groups. **Conclusion:** Aluminum oxide burs produce a smoother enamel surface than the tungsten carbide burs in both ceramic and metal brackets.

Keywords: Aluminum oxide bur, Debonding, Tungsten carbide bur.

Introduction

Obtaining a beautiful smile is always the prime reason a person seeks orthodontic treatment. After all, the difference between an acceptable or pleasing esthetic result for any given treatment is the beauty of the smile. The morphology and the brightness of teeth mainly the maxillary anterior teeth are important to be considered for better dental and facial esthetics. Hence, the teeth should be treated to restore the acceptable harmony of the dentoalveolar structures with their overall facial appearance.

After the introduction of the acid etching by Buonocore[1] in 1955, there was a dramatic change in the bonding of the orthodontic attachments. Newmann,[2] in 1965, introduced the use of epoxy adhesive for bonding attachments directly onto the enamel surface. There is need to provide the patients with more esthetically appealing appliances as the number of adults seeking orthodontic care for esthetics is increased.

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After the treatment with fixed appliances, composite removal should be done to prevent plaque accumulation and restore the esthetic appearance of the enamel surface. Improper removal of the brackets or adhesives may lead to permanent damage to the enamel and the main concern of the orthodontist is to restore the enamel surface as near to its original state as possible. Hence, there should be minimal enamel loss at every stage, that is, bonding, debonding, and enamel clean-up procedures.

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Therefore, many researchers have introduced various techniques for the removal of resins and subsequent polishing of enamel without causing any iatrogenic damage such as scraping of resin remnants with a scaler or band removing plier and removal with a tungsten carbide bur and aluminum oxide disks etc.

Oliver and Griffiths[3] rated the tungsten carbide as the "gold standard" for the removal of the resin remnants against which other methods should be compared. A recent study by Faria-Júnior *et al*.[4] observed that the aluminum oxide polishing burs have resulted in less enamel roughness than that of multi-laminated carbide burs.

Even though the tooth dehydration and absence of ion exchange between saliva and tooth affect the debonding, in most of the studies, evaluation of removal of the adhesive resins and enamel surface roughness was conducted *in vitro*.

Therefore, the aim of this study is to evaluate the efficacy of aluminum oxide polishing burs and tungsten carbide burs on the surface roughness and morphology of enamel in orthodontic patients.

MATERIALS AND METHODS

Twenty subjects who underwent orthodontic treatment in Drs. Sudha and Nageswara Rao Siddhartha Institute of Dental Sciences, Chinnoutpalli were included in this study, irrespective of their gender, and ethnic origin.

Inclusion criteria

The following criteria were included in the study:
1. Subjects with good physical, oral and mental status.
2. No history of previous orthodontic treatment.
3. Patients between the age group of 12 and 30 years.

Exclusion criteria

The following criteria were excluded from the study:
1. History of trauma and dentofacial syndromes.
2. Caries, restorations, or cracks on the maxillary incisors.
3. Localized or generalized enamel defects.
4. Systemic disorders.

The samples were divided into two groups with ten participants in each group.

Group 1: Patients receiving orthodontic treatment using metal brackets (Unitek Gemini MBT 0.022" Brackets, 3M).

Group 2: Patients receiving orthodontic treatment using ceramic brackets (Axim Ceramic Brackets, 0.022" MBT).

As both, the study groups received bonding and debonding procedures in common, the guidelines for the procedures were as follows:

The middle third of the buccal surface of all teeth was etched with 37% phosphoric acid gel (Restorite etching gel, Prime) for 20 s, rinsed with air-and-water spray, and air-dried for 20 s. One layer of primer (3 M Unitek Transbond XT) was applied to the etched area and light-cured for 10 s. Then stainless steel brackets in Group 1 and ceramic brackets in Group 2 were placed and firmly bonded to the teeth with adhesive (3M Unitek, Transbond XT adhesive paste) and light-cured (Ivoclar Vivadent) with a total exposure time of 40 s.

After the completion of the treatment, the brackets were removed with bracket removing pliers (GDC). Then, prophylactic procedures were performed with pumice using a handpiece (ACL-01C, Saeshin) at a low speed of 20,000 rpm. The teeth were washed, dried, and impressions of the maxillary arch were taken using the dual impression technique using polyvinyl siloxane putty and light body impression material (Ad Sil, Acura soft putty, and light cartridge). The casts were made with an epoxy resin material (Type 8000, American Dental Supply). The adhesive remnant index (ARI) on central incisors of the dental replicas (of the debonded teeth with remaining resin) was analyzed with a stereomicroscope (CZM6, LaboMed) at 50 times magnification.

The modified ARI was used to classify the failure mode as follows:

The scale used had a range between 5 and 1.
- Score 5: No composite remained on the enamel;
- Score 4: Less than 10% of composite remained on the tooth surface;
- Score 3: More than 10% but less than 90% of the composite remained on the tooth;
- Score 2: More than 90% of the composite remained;
- Score 1: All of the composites remained on the tooth, along with the impression of the bracket base.

For each patient, the right side of the maxillary arch was selected for finishing and polishing with aluminum oxide discs (Denmark polishing kit). The burs were used at 150,000 rpm under water cooling, in decreasing order of abrasiveness for 20 s each, until we obtain a properly smooth and polished surface. On the left side, the teeth were finished with a multi-laminated tungsten carbide bur (FG-271, SS White), also used at a high speed of 150,000 rpm under water cooling until we obtain a properly smooth and polished surface. After removing the remaining resin, new replicas of polished teeth were obtained with the aforementioned procedures. For the surface roughness measurements, three sets of dental replicas of maxillary central incisors were tested: after debonding and before polishing (initial conditions), after polishing with the aluminum oxide disk system, and after polishing with the tungsten carbide bur system.

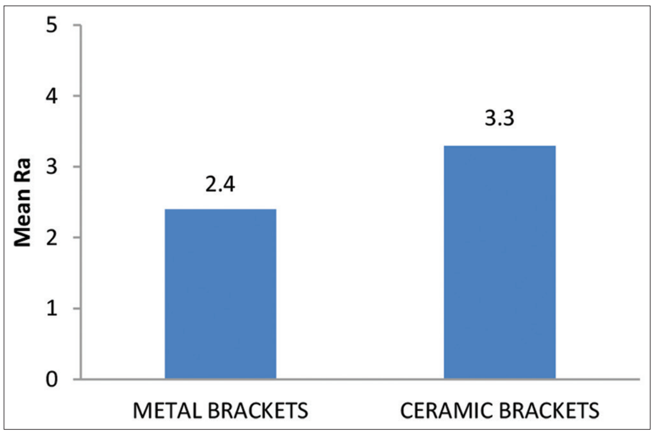
The surface roughness was measured with a surface roughness tester (Surf test SJ-210) at a speed of 0.05 mm per second, with a length of 2.5 mm, and a cutoff of 0.25 mm. Ra values were measured at three different points of the labial surface, where the bracket has been attached and the mean surface roughness was noted. Three replicas from each group were again analyzed by Scanning Electron Microscope (JEOL, JSM-7600 TFE) for qualitative assessment of the enamel surface at a magnification of 500.

Statistical analysis

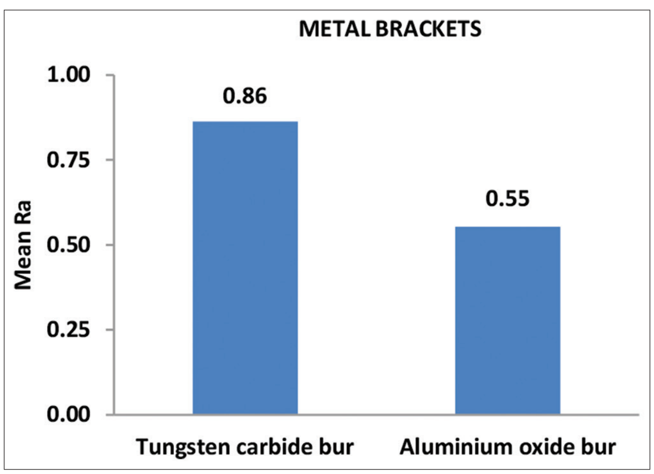
All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 22.0 and are shown in Tables 1-6 and graphically represented in Graphs 1–6. Descriptive statistics were represented with Mean with SD. Paired t-test was applied to find significance. $P < 0.05$ was considered statistically significant.

Results

The modified ARI scores that were measured on the maxillary central incisors in both Group 1 and Group 2 are shown in Table 1. A statically significant difference was observed in both the groups with a mean ARI score of 2.4 in the group with metal brackets and 3.3 in the group with ceramic brackets.

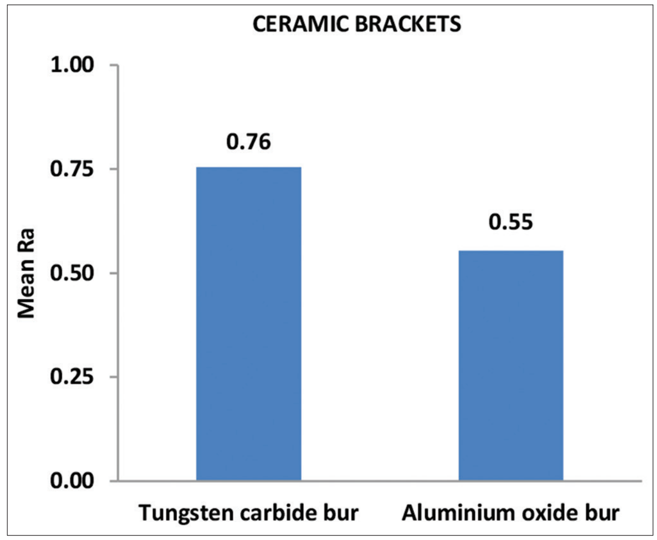


Graph 1: Adhesive remnant index Scores in patients with metal and ceramic brackets

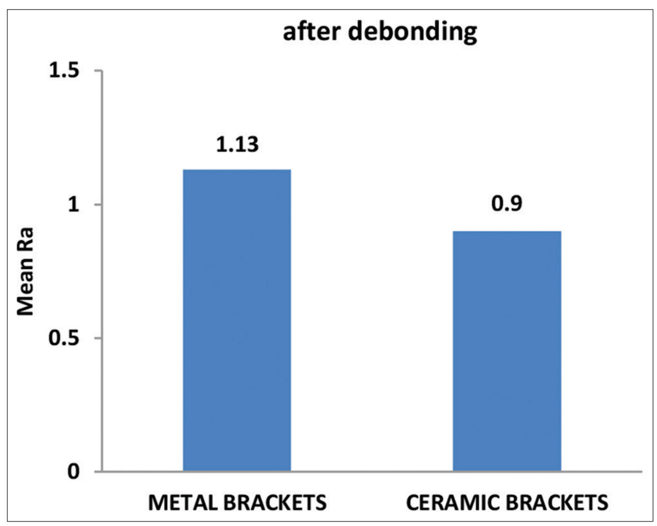


Graph 2: Surface roughness using tungsten carbide bur and aluminum oxide burs in Group 1

The difference in enamel surface roughness between the tungsten carbide bur and the aluminum oxide burs was measured in Group 1, which is shown in Table 2. A significantly lesser surface roughness was observed using the aluminum oxide burs with mean roughness of 0.55 µm than that of the tungsten carbide burs with a mean surface roughness of 0.86 µm. Table 3 shows the difference in enamel surface roughness between the tungsten carbide bur and the aluminum oxide burs in Group 2. Similar to Group 1, significantly lesser surface roughness was observed using



Graph 3: Surface roughness using tungsten carbide bur and aluminum oxide burs in Group 2



Graph 4: Surface roughness immediately after debonding in Groups 1 and 2

Table 1: ARI Scores in patients with metal and ceramic brackets

Variable	Group	*n*	Minimum	Maximum	Mean	SD	Median	IQR	*P*-value
modified ARI Score	Metal brackets (Group 1)	10	1.00	4.00	2.40	0.84	2.0	1.0	0.03
	Ceramic brackets (Group 2)	10	2.00	4.00	3.30	0.67	3.0	1.0	

the aluminum oxide burs with mean roughness of 0.55 µm than that of the tungsten carbide burs with a mean surface roughness of 0.76 µm.

The surface roughness of the enamel immediately after debonding was compared between the two groups which are shown in Table 4. The mean value was 1.13 µm in Group 1 which was significantly lesser in Group 2 with ceramic brackets with a mean value of 0.90 µm. Table 5 shows the difference between the surface roughness of enamel using the tungsten carbide burs in Groups 1 and 2. A significant difference is observed where the roughness values were higher in Group 1 with metal brackets than in Group 2 with ceramic brackets with a mean value of 0.86 µm and 0.76 µm, respectively.

Table 6 shows the difference between the surface roughness of enamel using the aluminum oxide burs in Groups 1 and 2. No significant difference with the mean roughness values of 0.55 µm was observed in both groups.

Table 2: Surface roughness using tungsten carbide bur and aluminum oxide burs in Group 1

Variable	Metal brackets (surface roughness (Ra))					*P*-value
	n	Minimum	Maximum	Mean	SD	
Tungsten carbide bur	10	0.635	1.096	0.863	0.150	0.001
Aluminium oxide bur	10	0.344	0.892	0.553	0.186	

Table 3: Surface roughness using tungsten carbide bur and aluminum oxide burs in Group 2

Variable	Ceramic brackets (surface roughness (Ra))				
	n	Minimum	Maximum	Mean	SD
Tungsten carbide bur	10	0.662	0.856	0.755	0.065
Aluminium oxide bur	10	0.401	0.678	0.554	0.100

The Scanning Electron Microscope is used to check the enamel roughness at the microscopic level at a magnification of 500×.

The surface roughness of enamel immediately after debonding in the Group 1, that is, patients treated with metal brackets is shown in Figure 1.

The surface roughness of enamel after polishing using the tungsten carbide bur in the Group 1, that is, patients treated with metal brackets is shown in Figure 2.

The surface roughness of enamel after polishing with aluminum oxide burs in the Group 1, that is, patients treated with metal brackets is shown in Figure 3.

The surface roughness of enamel immediately after debonding in the Group 2, that is, patients treated with ceramic brackets is shown in Figure 4.

The surface roughness of enamel after polishing using the tungsten carbide bur in the Group 2, that is, patients treated with ceramic brackets is shown in Figure 5.

The surface roughness of enamel after polishing with aluminum oxide burs in the Group 2, that is, patients treated with ceramic brackets is shown in Figure 6.

Discussion

Enamel is composed of submicroscopic crystallites in a sparse organic matrix. It is a heterogeneous tissue. Varied abrasion anomalies are due to its special biophysical and morphological characteristics.[5] Some amount of normal wear of teeth was observed in the adolescent persons. In an extensive study of tooth surface appearance in various age groups, Mannerberg[6] found that morphology varied with tooth brushing habits and age. In long-term studies, some scratches disappeared and new ones appeared on the enamel.[7]

A pleasant esthetic condition of the central incisors is important for a beautiful smile. The surface roughness of enamel is

Table 4: Surface roughness after debonding in Groups 1 and 2

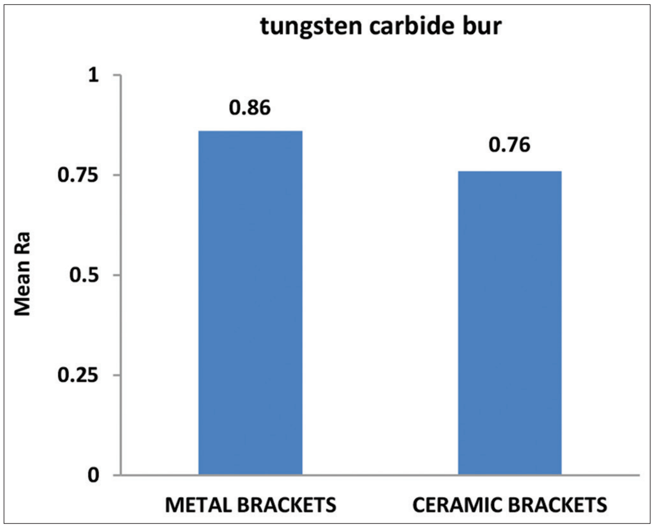
Variable (surface roughness (Ra))	Group	*n*	Minimum	Maximum	Mean	SD	*P*-value
Immediately after debonding	Metal brackets (Group 1)	10	0.89	1.67	1.13	0.29	0.04
	Ceramic brackets (Group 2)	10	0.75	1.14	0.90	0.12	

Table 5: Surface roughness after polishing using tungsten carbide bur in Group 1 and 2

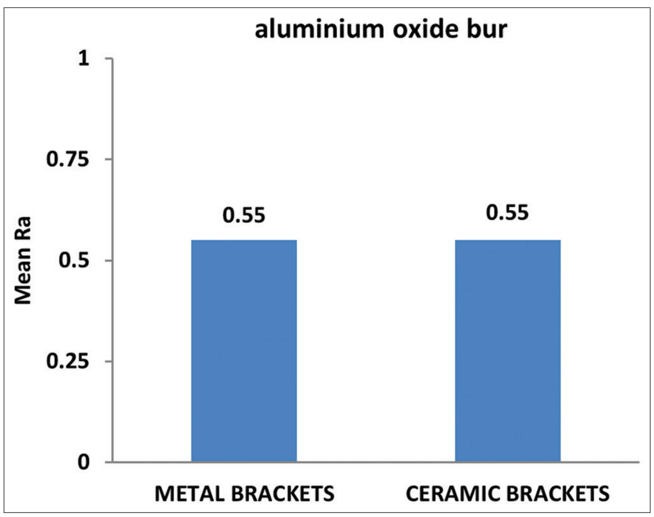
Variable (surface roughness (Ra))	Group	*n*	Minimum	Maximum	Mean	SD	*P*-value
Tungsten carbide bur	Metal brackets (Group 1)	10	0.64	1.10	0.86	0.15	0.05
	Ceramic brackets (Group 2)	10	0.66	0.86	0.76	0.06	

Table 6: Surface roughness after polishing using aluminum oxide bur in Groups 1 and 2

Variable (surface roughness (Ra))	Group	*n*	Minimum	Maximum	Mean	SD	*P*-value
Aluminium oxide bur	Metal brackets (Group 1)	10	0.34	0.89	0.55	0.19	0.98
	Ceramic brackets (Group 2)	10	0.40	0.68	0.55	0.10	



Graph 5: Surface roughness after polishing using tungsten carbide bur in Groups 1 and 2



Graph 6: Surface roughness after polishing using aluminum oxide bur in Groups 1 and 2

connected directly with the brightness and, thus, the esthetics of AQ5 the teeth. Since 1970 bonding of orthodontic brackets on the tooth enamel has become an acceptable clinical technique. After the introduction of the acid etching by Buonocore[1] in 1955, there was a dramatic change in the bonding of the orthodontic attachments. Newmann,[2] in 1965, introduced the use of epoxy adhesive for bonding attachments directly onto the enamel surface. Mitchell, in 1967, was the first author to report the use of the retentive base to directly bond metal brackets on the tooth. The adhesion of metal brackets is obtained with a mechanic interlock between base-adhesive resin-enamel. The metal brackets are being used as the conventional brackets for many years due to their superior strength and even today their frequent usage can be seen in orthodontics.[8]

With the increased demand for esthetics, advancements were made to improve the esthetic appearance of the orthodontic appliance resulting in the development of esthetic orthodontic appliances that include lingual appliances, plastic brackets, and finally ceramic brackets.

Ceramic brackets have shown promise as an esthetic alternative to both plastic and conventional metal brackets and a comparable clinical performance was observed between the ceramic and metal brackets in a few *in vitro* studies. However, the brittle nature of ceramic brackets has resulted in a higher incidence of bracket failure (fracture) during debonding.[9,10]

After completion of the orthodontic treatment, an ideal finish is desired for the tooth surface following debonding of brackets, without removing an excessive amount of tooth structure. Improper debonding results in cracks on the enamel AQ5 surface and enamel prism fractures. Zarinnia *et al*.[10] showed that the bracket removing plier produced the most consistent separation at the bracket-adhesive interface. Therefore in this study, the debonding of all the brackets has been done using the conventional debonding plier.[11]

In this study, ARI scores on teeth showed that the mean score of 2.4 was seen in Group 1. Score 2 was the most frequent (50%), indicating adhesive failure between the bracket base and the adhesive resin with more than 90% remnant on the tooth surface in the case of metal brackets.

Whereas in the second group, the most common failure type was adhesive failure between the enamel and the adhesive resin with an ARI score of 4 being the most frequent (41%), that is, less than 10% of adhesive remained on the tooth surface. The mean score was 3.3 in this group.

The reason for higher ARI scores in ceramic brackets is the adhesion between the resin and the ceramic bracket bases which have increased to a point, where the most common site of bond failure during debonding has shifted to the enamel adhesive interface which is a less desirable site. From the AQ5 bracket base-adhesive interface. This shift has led to an increase in the incidence of bond failures within the enamel surface.[12] Odegaard and Segner[13] found a bond failure to be more prevalent at the enamel-adhesive interface in ceramic brackets in contrast to metal brackets, where the bond failure occurred predominantly at the bracket-adhesive interface. Although the tensile strength of the new ceramics is greater than that of stainless steel, less energy is required to cause fracture of ceramic brackets compared with conventional stainless steel brackets. This phenomenon is related to "fracture toughness," or the ability of a material to resist fracture. During loading, stainless steel will elongate approximately 20% of its original length before failing, while sapphire will elongate less than I% before failing. Thus, ceramics are more likely to fracture than metals under the same conditions during debonding.[9]

There is less chance of enamel loss if failure site at the bracket-adhesive interface macroscopically indicate a safe debonding. However, this, then, requires meticulous removal of the resin remnants from the enamel surface.[14]

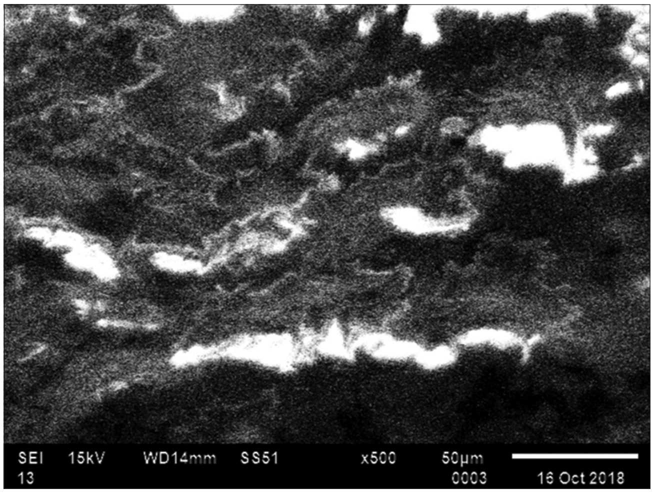


Figure 1: After debonding in patients with metal brackets

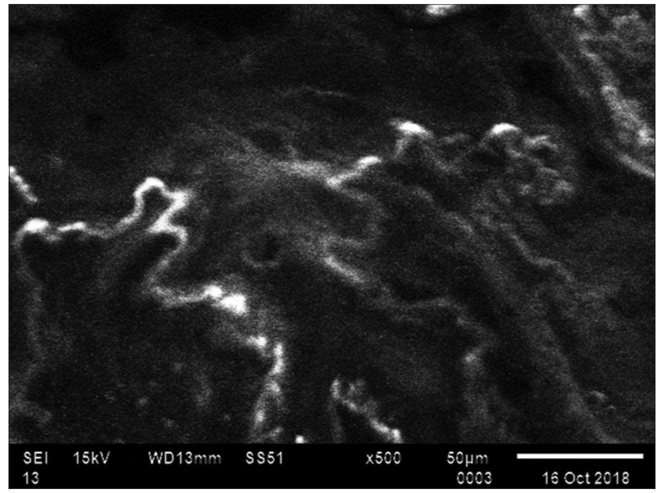


Figure 4: After debonding in patients with ceramic brackets

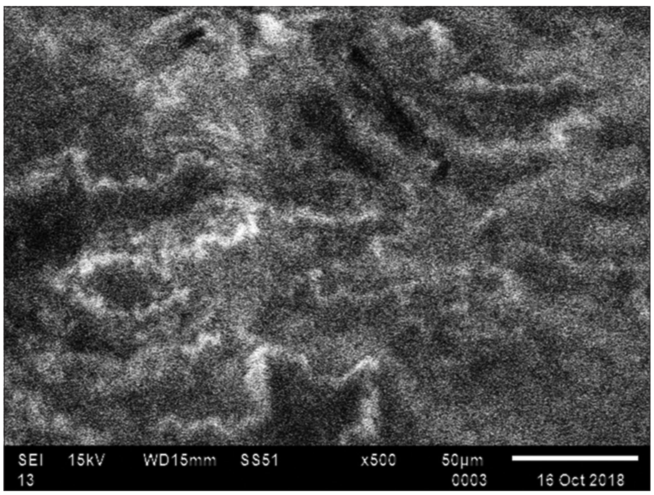


Figure 2: After polishing with tungsten carbide bur in Group 1

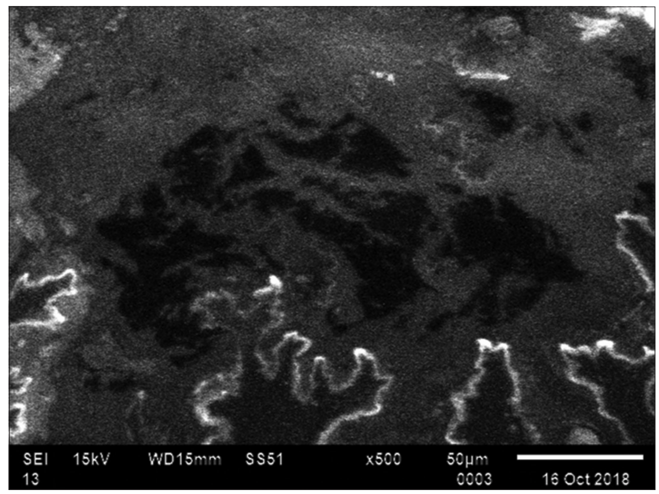


Figure 5: After polishing with tungsten carbide bur in Group 2

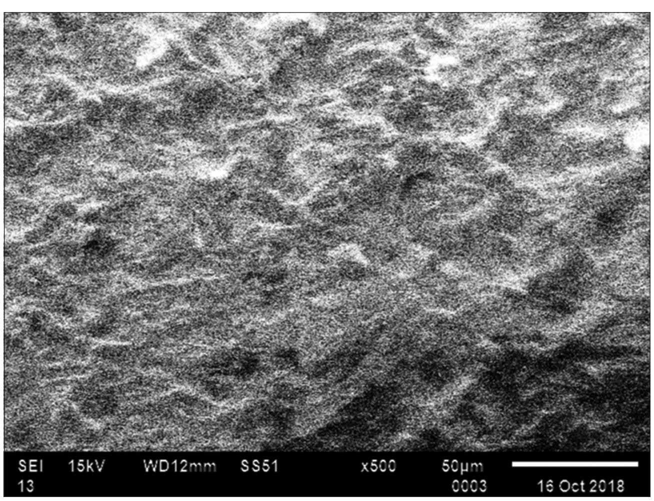


Figure 3: After polishing with aluminum oxide burs in Group 1

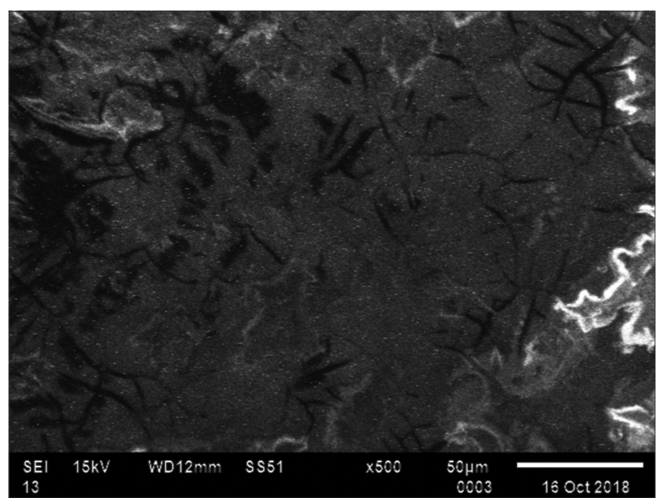


Figure 6: After polishing with aluminum oxide burs in Group 2

For ethical reasons, debonding technique must be aimed to attain the smoothest possible surface through proper finishing and polishing procedures.

In our study, dental replicas, before and after polishing the teeth with different systems, are used to examine the surface roughness of the maxillary central incisors. This choice was justified because extracted teeth do not show an overview of the esthetic and also do not always reproduce the chemical, physical, mechanical, and biological mechanisms that occur in the oral environment.

The debonding outcome (that all resin was left on the tooth) could be clinically advantageous when compared with debonding with the concomitant removal of enamel fragments, which could damage the tooth surfaces. It was observed that a significant correlation between the remnant adhesive left on the tooth and the surface appearance after cleanup. It is an advantage if the bond failure occurs at the enamel-adhesive, because it reduced the amount of residual adhesive, the need for a rotary instrument for cleanup, and, therefore, the incidence of subsequent iatrogenic injury.[4]

Our findings were similar to the study done by Bonetti *et al*.[15] which indicates that rotating instruments that are effectively used for the removal of adhesive resin remnants cause some enamel abrasion proportional to the composition and size of the abrasive particles, its pressure against the enamel surface and the rotaional speed of the instrument. This can be seen in our study in both ceramic and metal bracket groups, the enamel scratching using the rotary burs used in this study was evident in the Scanning Electron Microscope images. Thus, a complete composite removal without affecting the enamel surface cannot be achieved by any instrument can yet.

In this study, Scanning Electron Microscope was used to examine the changes on the enamel surface and to evaluate the surface smoothness using different rotary instruments for residual resin removal after debonding;[16] however, this method cannot provide a quantitative assessment. Therefore, Scanning Electron Microscope analyses may be used only as a supportive tool for quantitative evaluation methods.[17]

The surface roughness tester was used to measure the quantitative values of the irregularities on the enamel surface. Mean roughness (Ra) is measured in this study. The arithemetical mean of absolute values related to the profile deviation (y) matches the mean roughness within the reference length (l). This means surface roughness is measured using the dental replicas immediately after debonding and before polishing, after polishing with tungsten carbide bur, and after polishing with aluminum oxide burs.

Epoxy resin is used for casts fabrication as it replicates a better surface texture in comparison with the gypsum materials.

Zachrisson and Arthun[18] reported that a tungsten carbide bur used at low speed produces a fine scratch pattern and less enamel loss, whereas Ulusoy *et al*.[11] recommended a tungsten carbide bur operated at high speed. Similarly, Zarrinnia *et a*l. found that the carbide burs at high speed are efficient in residual resin removal.[10] According to Hong *et al*.,[7] the method that left the smoothest surface was the Jet high-speed tungsten carbide bur with water coolant. A good surface finish was a result of the fine surface texture and the high speed at which it was used. Therefore, tungsten carbide bur with the speed of 150,000 rpm was used in this study.

Ozer *et al*.[19] recently found that aluminum disks restored the enamel closer to its original smoothness. Starting with the coarse grit and then sequentially progressing to the superfine grit is necessary, but this is time-consuming.[11]

Therefore, in this study, the comparison between the tungsten carbide burs and the aluminum oxide burs has been done.

Tungsten carbide bur with high speed seems to be a very efficient way to clean the surface and the least time-consuming. However, TCB used at high speed can cause damage to enamel, because they are harder than the enamel.[20] In this study, the tungsten carbide burs significantly removed the remaining adhesive in both the groups. Using the tungsten carbide burs, the mean surface roughness produced on enamel on metal brackets was 0.86 µm, whereas in the ceramic brackets, it is 0.76 µm. Hence, a significant difference was observed between the two groups in surface roughness using the tungsten carbide polishing burs. This might be due to the lesser amount of resin remnant present on the enamel surfaces after debonding in the ceramic brackets.

Remnant removal with aluminum oxide finishing burs showed a progressive decrease in surface irregularities but were the most time-consuming method. Similar to the studies done by Eminkahyagil *et al*.[20] though the aluminum oxide burs used from coarse grit to fine grit were time taking, they significantly reduced the amount of adhesive remnant on the tooth surface in both the groups. The amount of reduction of adhesive in both groups was similar with the mean surface roughness of 0.55 µm for both ceramic and metal brackets.

The results have shown that the surface roughness of enamel was significantly lesser with the aluminum oxide burs than that of the tungsten carbide burs. These results were similar to that of the study done by Faria-Júnior *et al*.[4] In Group 1, that is, in patients treated with the metal brackets, the mean surface roughness using the tungsten carbide bur was 0.86µm while the mean value of surface roughness using the aluminum oxide burs was 0.55 µm.

Similarly in Group 2, that is, in patients treated with ceramic brackets, the mean surface roughness using the tungsten carbide bur was 0.76 µm and in patients treated with ceramic brackets, the value was 0.55 µm. In this study, the surface roughness values obtained after finishing with aluminum oxide burs were lower than the values using the tungsten carbide burs. Thus, polishing with aluminum oxide disks gives a smoother finishing of enamel which may improve the light reflection of enamel but is a time-consuming procedure.

Conclusion

The following conclusions can be made from the results obtained.

i. A greater amount of resin remnant is seen with metal brackets than the ceramic brackets after debonding with ARI scores higher in patients treated with ceramic brackets than with metal brackets.

ii. Tungsten carbide burs produced a lesser surface roughness with ceramic brackets than metal brackets.

iii. Aluminum oxide burs have shown no difference in surface roughness between the metal and ceramic brackets.

iv. Aluminum oxide burs produced a significantly smoother surface than the tungsten carbide bur in both ceramic and metal brackets.

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Author Queries???

AQ5: Kindly review the sentence as it seems to be incomplete.