ISSN: 2768-0126
Volume 2 Issue 1
www.escientificlibrary.com
ES Journal of Dental Sciences

Comparative Evaluation of Dentin Surface after Preparation by Diamond Bur and Oscillating Tip, with and without Etching

Research Article

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Received: Feb 11, 2021; **Accepted:** Feb 27, 2021; **Published:** Mar 03, 2021

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Abstract

Objective: Oscillating ultrasonic instruments were basically used to finish marginal preparation, while they produce more rough surfaces, unlike the regular surfaces produced by the rotating diamond instruments. This study aims to investigate the change of dentin roughness after etching using two different preparation tools: diamond bur and diamond ultrasonic tip.

Materials & Methods: Two groups of dentin surfaces related to extracted premolars were considered: the first group consisted from 13 surfaces prepared with a Rotating Diamond Bur (RB-P), the second group consisted of 13 surfaces prepared with oscillating tip (O-P). For all surfaces, the roughness were measured using an optical profilometer microscope once after preparation and thereafter etching with phosphoric acid (35%) for 20 seconds. Two samples were imaged under scanning electronic microscope SEM only after the preparation.

Surface roughness RMS, Developed Interfacial Area Ration (Sdr) and Surface Development were compared using 1-way ANOVA test, Kruskal-Wallis and ANOVA for Ranks test, respectively.

Results & Discussion: Preparation with oscillating tip produced the highest value of roughness (O-P: 3.22 ± 0.73), while there was difference in roughness after the etching procedure (E_O-P: 2.27 ± 0.262) at P_value = 0.046 < 0.05. The etching procedure did not result a valuable change in the roughness in the Rotating Bur Preparation group before (RB-P: 2.72 ± 0.41) and after etching (E_RB-P: 2.39 ± 0.42) at P_value = 0.514 > 0.05. SEM images shows more irregular surface with deeper grooves on the dentinal surface in the O-P group. The highest value of Sdr is associated with the O-P group (0.71± 0.14) resulting the best adhesion.

Conclusion: Etching the dentin surface with phosphoric acid affected the roughness. The effect was more noticeable when the surface is prepared with oscillating ultra-sonic tip. The choice of the preparation tool should depend only which tool is the least traumatic instrument for the marginal periodontal tissues.

Keywords: Roughness; Dentin; Rotating bur; Oscillating ultra-sonic tip; Optic 3d profilometer; Etching; adhesion; Sdr.

Abbreviations:

SEM: Scanning Electronic Microscope

RMS: Root Mean Square

RB-P: Group of the Rotating Bur Preparation

E_RB-P: Group of the Etched surfaces after Rotating Bur Preparation

O-P: Group of the Oscillating tip Preparation

E_O-P: Group of the Etched surfaces after Oscillating tip preparation

Sdr: Surface interfacial development ratio

Introduction

During tooth preparation, sufficient space must be created to allow for the placement of a prosthesis with appropriate esthetics [1-3]. To create a non-visible transition between the prosthesis and the infrastructure tooth, the marginal area of the preparation should be placed inside the gingival sulcus [4]. Usually the final preparation of the marginal areas is generally performed with rotary cutting instruments of fine grain size [5]. Others tend to avoid the rotary instruments because of the difficulty of controlling them near the margins. They tend to use oscillating instruments like sonic or ultrasonic hand-pieces to benefit from its limited rage of movement and the full control of the working-tip during it functions [6]. Yet, the choice is still open and depends more on the clinician's preferences and the ability to control these instruments.

A second disadvantage of rotary instruments is that, despite the use of slow-speed hand-pieces, the gingival tissues could still be injured [7]. Therefore, oscillating instruments were basically used to finish the interproximal areas in tooth preparation, with other advantages such as: less noise and having a longer durability of the bur itself [8], then these instruments were developed for finishing the whole line preparation in full coverage restorations [9, 10].

On the other hand, oscillating instruments produce irregular rough surface appearance, unlike the regular surface that is produced by a rotating diamond instrument [5, 11]. Theoretically, rough surfaces may provide better adhesion by offering a wider surface to cover with the luting agent [12, 13]. Likewise, the study by Mowery et,al., revealed that the rougher dentine surface provided a higher bond strength, which might be attributed to the increased of total surface involved in the bond [14].

It has been investigated the difference in roughness produced by different preparation tools: diamond bur, tungsten carbide burs and diamond ultrasonic tip [10,15,16]. but it has never been mentioned the changes that might happen to the roughness after doing an un-avoidable procedure (etching with phosphoric acid) during the protocol of gluing a prosthesis. To the best of our knowledge, it has never been questioned whether the etching procedure will eliminate the difference of roughness produced by the preparation tool; and, eventually, if there is a benefit to declare the debate of roughening or smoothening the preparation surface.

The null hypothesis of this study is that the difference of preparation tools does not affect the roughness and the develop surface of dentin. Also, it is hypothesized that the etching procedure does not change the roughness and the develop surface of the already prepared dentin-surface.

Materials and Methods

Preparation of the samples

Four intact premolars were considered in this study. The premolars correspond to the following criteria: no caries, no cracks and extracted from young patients for orthodontic indications. The four premolars were preserved in distilled water with 1% chloramine - T solution until the time of experiment.

All the preparations were performed by the same examiner with the same hand-piece that is fixed on a dental chair unit combined with water-cooling.

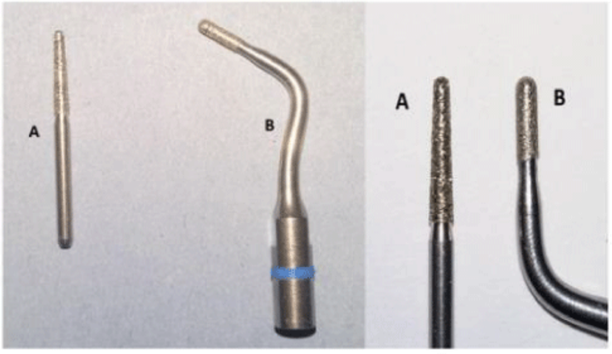

Figure 1: tools of preparation: **A**. rotating bur, **B**. Oscillating tip.

The two preparation tools, (Figure 1), used are:

1- A tapered-body, rounded-tip diamond bur Ref: 856 314 016 (Komet dental, Germany) with grains size 107µm.

2- An ultrasonic tip, F02250 - insert PM1 (ACTEON, France) with grain size 76µm.

The four premolars were initially prepared with the bur. The preparation is performed to eliminate the enamel of the buccal surface until exposing the dentin tissue. The finish line was located 1 mm from the CEJ (Cementum-Enamel Junction) with the shape of medium chamfer (0.5mm). The first group consists of two premolars prepared with the rotating bur (Rotating Bur Preparation Group: RB-P)

Two premolars were chosen to have a secondary preparation (Oscillating Preparation group: O-P). The ultrasonic tip (tapered-body and rounded-tip) was fixed on the hand-piece of an ultrasonic device NEWTRON P5 (ACTEON, France). The power of the device was set on the scale of "15" as recommended by the company instructions for the preparation purpose. A finishing preparation was performed on the surface that was previously prepared with the bur.

Roughness measurement

One premolar of each of the two groups, RP & OP, were half-dried (i.e. drying the surface without losing the humidity inside the dentin tubes) and fixed with a stable matrix on a flat surface in order to prepare them for the profilometric measurements.

They were put under an optical profiler microscope (Photomap 3D, Fogale Nanotec, France) to scan the prepared surfaces, (Figure 2). Thirteen random square

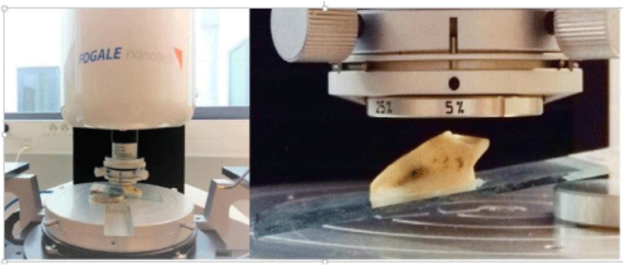

Figure 2: Optical profilometer: Photomap 3D (FOGALE nanotech, France).

surfaces of each group were chosen randomly to be scanned with the microscope. The area of each surface is (160* 160µm). The scanning was performed with the white light laser of the microscope. Data in the form of digital photos were acquired from a collateral software of the microscope. Then, photos were processed with a specific software (Gwydion 2.47, released 18/11/2016, http://gwyddion.net/) to obtain the desired data. The roughness of each surface was measured by the software Gwydion using the images extracted from the optic profiler microscope. Roughness was considered by RMS (Root Mean Square) while the RMS is the root mean square average of the profile height deviations from the mean line.

Imaging with scanning electronic microscope

The other two premolars of each group were dehydrated completely with an alcoholic solution (concentration 90%) for one day and coated with a thin layer of platinum particles in a vacuum. Then they were scanned with scanning electronic microscope (HITACHI S-4800). Multiple images were acquired with multiple scales to illustrate the characteristics of the prepared surfaces. (Figure 5).

Etching the surfaces

After the previous measurements with optic profiler microscope, the same two premolars, one from RB-P group & another from O-P group, were etched with 35% phosphoric acid (UltraDent, USA) for 20 seconds according to the manufacturer's recommendations and then rinsed with a strong current of water and air for 40 seconds. The samples were repositioned under the optical profiler and another thirteen random surfaces were scanned. Each surface square is (160 x 160µm2). Data in the form of digital photos were acquired by the same software of the microscope. The resulted photos were entered in the Gwyddion software and the target data were extracted again (the roughness of the surface RMS, and the development of the surface).

Surface Development Measurement:

The Development of the Surface area (DS) was calculated with the same software (Gwydion) by subtracting the Projected Area from the surface area (DS = SA-PA) while Surface Area (SA) is the square of the whole surface including all the area between the peeks and bottom points (pits), and Projected area (PA) is the square of the scanned surface which was always 160 x 160 = 2510µm2.

Measuring the Developed Interfacial Area Ratio (Sdr):

The developed interfacial area ratio, which is expressed as the percentage of additional surface area contributed by the texture compared to the ideal (basic) plane, was calculated for all groups with the equation:

Sdr = (Surface area - projected surface) / projected surface

Statistical analysis

SigmaPlot (version 12, Germany) software was used for data analysis. One-way ANOVA test, then Holm-Sidak method were performed to compare the roughness between the groups. The level of statistical significance was set at 5%. The development of the surfaces were compared using "ANOVA on Ranks" test within each tool preparation (before and after etching). A Kruskal-Wallis test followed by Tukey Test tests were used to perform the comparison of Sdr values between the groups. The means and standard deviations' of the Sdr measurements, along with the results of the statistical analysis, are summarized in (Table 1).

Results

The statistical analysis shows that the highest value of roughness in the surfaces using the rotating bur before etching (RB-P group) was 3.627µm2, and using the Oscillating tip (O-P group) was 4.876µm2, both cases are before etching. The mean value of RMS roughness for the surface in the RB-P group was 2.271 ± SD (0.4)µm2, and in the O-P group was 3.223 ± SD (0.735) µm2. (Figure 3) and (Table 1) summarize the statistical description of the acquired data.

(Figures 3,4) are images obtained with the optical profilometer microscope. They highlight the roughness differences obtained with bur and oscillating tips. While Figures 5 shows images obtained with SEM.

The development of the surfaces were calculated and compared within each tool preparation (before and after etching) using "ANOVA on Ranks" test because the groups failed in the normality test. The results of the statistical analysis are summarized in (Table I).

Discussion

Producing a rough surface during a preparation in the dental office is a major goal in order to increase the interface surface between the glue and the tooth [12,15,17,18]. Surface roughness is an important factor that influences the bond strength between tooth structure and restorative materials [19, 20]. It can also influence the quality of a preparation as it directly affects the accuracy of cast and prosthesis retention [15, 21-23].

Table 1: Statistical description for the RMS roughness, the Surface area and the Developed Interfacial Area Ratio.

Groups with the same letters indicates that there is no significant difference, while groups of different letters indicate there is a statistically significant difference.
RB-P: Rotating Bur Preparation, **O-P**: Oscillating preparation, **E_RB-P**: Etching Rotating Bur Preparation, **E_O-P**: Etching Oscillating preparation

	Roughness RMS (µm)				**Surface Area (µm2)**				**Developed Interfacial Area Ratio % (Sdr)**			
	RB-P	**O-P**	**E_RB-P**	**E_O-P**	**RB-P**	**E_RB-P**	**O-P**	**E_O-P**	**RB-P**	**O-P**	**E_RB-P**	**E_O-P**
Mean ± SD	2.72 ± 0.41	3.22 ± 0.73	2.39 ± 0.42	2.27 ± 0.262	8.7± 2.2	5.5± 0.5	18.1± 3.5	8.6± 1.8	0.34± 0.08	0.71± 0.14	0.21±0.02	0.33 ± 0.07
	a	b	a,c	c								
Max Value	3.6	4.8	3.2	2.1	10.7	6.4	25.1	12.8	0.42	0.98	0.25	0.5
Min Value	2.1	2.7	1.7	1.8	3.8	4.2	11.45	6.4	0.14	0.44	0.16	0.25
***P* value**	*P* = 0.046		*P* = 0.514		*P < 0.05*		*P < 0.05*		*P* = <0.001			

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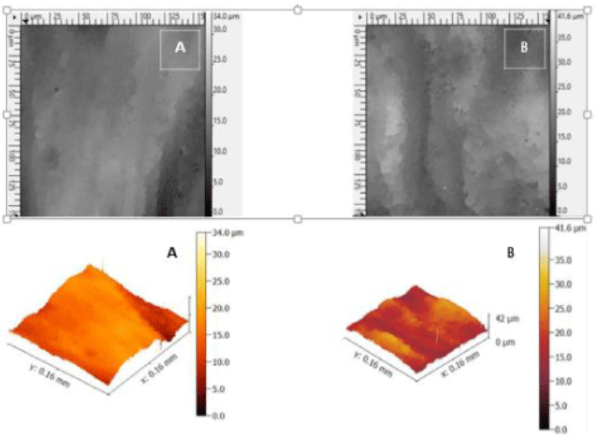

Figure 3: Images acquired with the optical profilometer microscope in 2D (upper photos) and 3D (lower photos) for the surfaces after the preparation: A: Dentin surface prepared with bur (RB-P). B: Dentin surface prepared with oscillating tip (O-P).

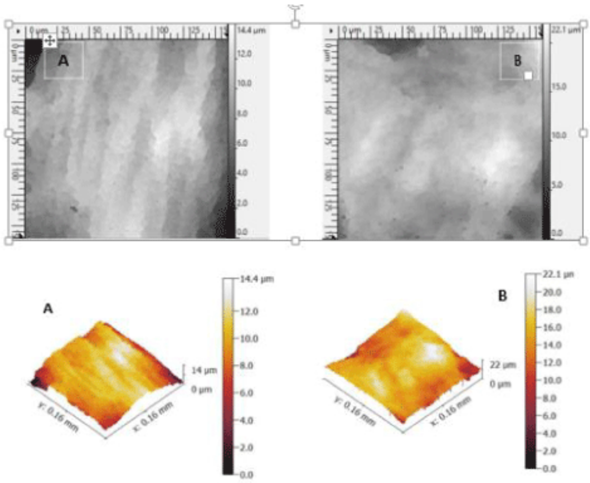

Figure 4: images acquired with the optical profilometer microscope in 2D (upper photos) and 3D (lower photos) view for the surfaces after the etching: A. Dentin surface prepared with rotating bur after etching (E_RB-P). B. dentin surface prepared with oscillating tip after etching (E_O-P).

On the other hand, there is still a debate considering the effect of smoothing the dental surface with a diamond bur or with an ultrasonic tip after the final veneer preparation [18]. Some authors advice to smooth the finish line preparation to gain more consistency and better adaptation of the prosthesis to the dental surface (i.e., a better marginal fit). Also, authors claim that smoothing helps to have a clean surface with a lesser smear layer [17, 24]. While others found that preparing tooth surface by using coarse diamond burs; and, consequently, gaining a rough surface, enhances the bond strength of resin-bonded restorations [12]. and roughened surface can provide some degree of mechanical interlocking with the adhesive [25].

A study shows that when oscillating tips were attached to a fixed apparatus with a constant load, the vibration of the tip was blocked and no results could be obtained [10]. so the preparation were done by the hands of one operator.

Some studies indicate that no differences were detected between enamel and dentine surfaces prepared with the same type of dental bur [16], so the preparation intended to be just in the dentin. However, in most of the clinical cases, the dentin is exposed especially near the cervical line. A total-etch system was used according to the fact that the etch-and-rinse systems are more efficient to dissolve the smear layer. Kenshima.S et,al had observed that the etch-&-rinse adhesive presented the thickest hybrid layer and was the only adhesive system to produce resin tags in high density and uniform distribution along the whole dentin surface, independently of the smear layer thickness [17].

The groups passed the Normality Test, but they failed to pass the Equal Variance Test, so a Holm-Sidak Method Test was performed to make a pairwise comparison between the groups as shown in (Table 1). One-way ANOVA test shows that the difference in the mean values of each two groups is greater than would be expected by chance; and there is a statistically significant difference between the RB-P and O-P groups ($P = 0.046 < 0.05$). Therefore, the first null hypnosis is rejected and there is an effect of the preparation tools on the roughness of the dentin, and the surfaces produced by oscillating tip are rougher than produced by rotating bur. These results agreed with the findings of other similar studies [5, 10, 26].

The images taken by scanning electronic microscope confirms the results and show a semi-regular surface with parallel grooves that characterizes the movement of the rotating bur (Figure 5) while it is noticed that a more irregular surface with deeper discontinuous grooves and pits (more indentations) can be seen on the dentinal surface in the oscillating tip preparation group.

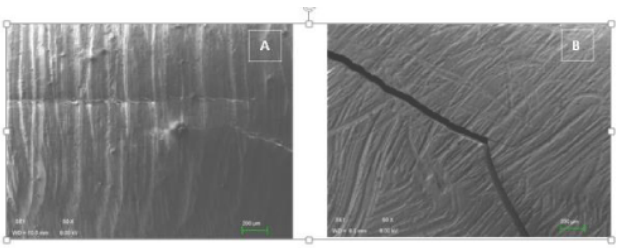

Figure 5: Images of scanning electronic microscope (magnification x50) for the prepared surfaces A: group RB-P, and B: group O-P (a crack can be seen on the dentin surface due to the necessary dehydration procedure before imaging).

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The size of the grains in the diamond bur was 107μm, while it was 76μm for the oscillating tip. Even though, it can still be found that the roughness produced with the rotary diamond bur is much lesser than the roughness produced with the oscillating diamond tip. This smoothness maybe caused by the ordinary rotating movements of the bur, while the movements in the oscillating tip are limited within the same plane. So, it could be concluded that: the manner of movement of the preparation tool is what affects the resulted roughness rather more the size of the grains. This result is also stated by Laufer et al [5] and Wahel et al [13]. It is noticed that the roughness of the preparation tool is not transmitted to the prepared surface. The roughness is dropped in large scale. In the RB-P group, the diamond grains size were (107μm) and the mean resulted roughness was (2.7μm), with a percentage of only 2.5% of the bur roughness. While in the O-P group, the diamond grains size were (76μm) and the mean resulted roughness was (3.2μm), with a percentage of 4.2% of the Ultra-Sonic tip roughness.

The comparison between the two preparation methods after etching reveals that there is no statistical difference between the two groups ($P = 0.514 > 0.05$). It can be concluded that the etching eliminated the difference between the two groups that was found before etching. However there is a significant difference between the roughness of the oscillating groups ($P < 0.001$) before and after etching, which leads to the fact that the etching procedure clearly reduces the roughness. For the rotating bur preparation group RB-P, the roughness is constant with no significant difference before and after etching ($P = 0.187 > 0.05$). This is maybe explained by the fact that the surface is not too rough to be reduced by the etching procedure. This demonstrates that the choice of a preparation tool shouldn't be based on roughness desire, because any difference will be eliminated when the total-etch technique is used.

Studying the surface development revealed that the area of the prepared surfaces changed when they are etched ($P< 0.05$), (Table 1). In other words, the surface is developed to another topographically simpler surface because the square surface decreased to smaller one. Even though the available surface for adhesion is smaller than that before etching, but these results do not necessary mean that the adhesion will be in a lower value. Therefore, another roughness parameter was considered, Surface Interfacial Development Ratio (Sdr). The Sdr is a 3D spatial roughness parameter used as a measure of the surface complexity and the surface enlargement, especially in comparisons between several stages of treatments on a surface, i.e., treating with acid etching in this study. It is a very sensitive parameter for surface changes, and it can provide useful correlations in adhesion applications [27-30] or when considering surfaces used with lubricants and other fluids.

The efficiency of bonding between the resin cement and the dental tissue is related to two important parameters, first is the chemical bond between them which is achieved by adding a coupling agent (silane); and second is the micro-mechanical bond, which is enhanced by increasing the roughness of the dental tissue facing the gluing agent.

It is generally believed that roughening a surface is an effective approach to impede the liquid lubricant migration on it, due to the fact that the contact angle on a rough surface is smaller than that on a smooth surface. Nevertheless, paradoxically, when the surface is rough, lower contact angles yield faster migration velocities [31]. Thus, the higher value of roughness (RMS) leads to a higher value of Sdr, and consequently providing a higher adhesion strength [30]. To facilitate the gluing of a prosthesis, it is recommended to gain a rough surface. Indeed, increasing the surface roughness was previously reported to be more important than chemical conditioning to improve the bonding properties [32].

The ANOVA on Ranks test between the four groups reveals that there is always a significant difference between the groups ($P<0.001$). The highest mean value of Sdr is associated with the group of O-P (0.71 ± 0.14) and, consequently, it is where the best surface for adhesion. The lowest value is associated with the E_RB-P group (0.21 ± 0.02) which lower than E_O-P group (0.33 ± 0.07). It could be recommended to use the oscillating tip in order to enhance the adhesion rather than to gain a rougher surface.

Conclusion

The null hypothesis of this study is refused. Therefore, it could be derived that the difference of preparation tool affected the roughness of the prepared dentin-surface, and the etching procedure with phosphoric acid reduced the roughness of the prepared dentin-surface.

Within the limitation of this study, the followings could be concluded:

1- Preparing with oscillating ultra-sonic tip produced rougher surfaces than with rotating diamond bur.

2- Etching the dentin surface with phosphoric acid affected the roughness of the prepared dentin-surface. The effect was more noticeable when the surface is prepared with oscillating ultrasonic tip.

3- There is no significant difference between the roughnesses of the two prepared surfaces after the total etching procedure.

4- In the case which total etching with phosphoric acid is demanded, and during the preparation of dentin surface: there is no worry about the roughness that will be obtained by the instrument, but only about the least possible traumatic instrument for the vitality of the tooth and the marginal periodontal tissues.

5- It could be suggested to product another investigation to estimate the amount of transferred roughness from the preparation tool to the target surface to be prepared.

Acknowledgement

The author would like to deeply thank Marine Soler (A Graduate from the National Chemistry School in Montpellier) for their mutual help.

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