Comparison of Characteristics of De-bonded Enamel Surface using Atomic Force Microscopy: An In Vitro Study

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Introduction

Removal of the attachments and all the resin fragments from tooth surfaces is the final procedure required for the reappearance of the enamel surface as closely as possible to the original pre-treatment condition. A greater risk of destruction to the tooth surface occurs in cases of adhesive failure between resin and enamel, especially with the use of ceramic brackets, but enamel fracture may also occur with metal brackets. Different materials were tried decades back for the finishing of enamel surface after de-bonding of orthodontic attachments. The generally preferred method is to use a suitable bur in conjunction with a polishing disc and subsequently a polishing paste. Atomic force microscopy (AFM) analysis is a method that uses numerous mechanical scans in high resolution and is particularly recommended for analysis of such surfaces with nanoscale anomalies.

The purpose of this study was to investigate the effects on the enamel surface of two burs: Tungsten carbide finishing bur (G-701, SS White) and composite bur (Shofu GMBH, Germany) and Sof-Lex discs (Shofu GMBH, Germany) on resin removal after de-bonding procedure, evaluated by means of atomic force microscopy (AFM).

Materials and Methods

Sample collection

The sample consisted of 45 human maxillary pre-molars extracted for orthodontic purpose.

Criteria for selection of tooth:

- Teeth without hypoplastic spots and enamel cracks
- Teeth without caries
- Teeth without fracture
- Teeth without fluorosis
- Teeth that were not previously bonded

These teeth were washed in water to eliminate any traces of blood. All teeth were stored in distilled water immediately after extraction, and the distilled water was changed every week.

Conclusion:

From the results obtained, it can be found that Sof-Lex discs used for resin removal created smoother surfaces than tungsten carbide bur and composite finishing bur and hence can be used for better finishing of enamel surface after de-bonding. Finishing of de-bonded surface with any single system will not be adequate to restore the smooth surface of enamel.

Key Words: Bonding, bur, de-bonding, enamel, orthodontic, resin, roughness

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Materials used for conventional bonding:
- Applicator tips
- Three-way syringe
- Kidney tray
- 37% phosphoric acid gel (Eaze etch – Orthofix, Anabond Stedman, India).

Materials used for bracket placement and bonding:
- Stainless steel upper pre-molar brackets (0.022 MBT 3M Gemini brackets)
- Bracket holder
- Boon’s gauge
- Probe
- Sealant (Orthofix - Anabond Stedman, India)
- Adhesive (Orthofix - Anabond Stedman, India)
- Light-curing unit (3M ESPE ELIPARTM)
- Equipment used for de-bonding: De-bonding plier.

Materials used for resin removal and finishing:
- Tungsten carbide bur (G-701, SS Whit) (Figure 1)
- Fiber-reinforced composite bur (Shofu, Germany) (Figure 2)
- Sof-Lex discs (Shofu GMBH, Germany) - Coarse, medium, fine, and superfine (Figure 3)
- Low-speed hand piece.

Equipment used for surface roughness evaluation:
- AFM (Bruker’s Dimension icon with ScanAsyst).

Methodology
Sample preparation
The roots of the teeth were removed using a carborundum disc. Then, tooth was placed on the horizontal table of the trimmer to reduce the thickness of the tooth buccolingually (from palatal surface), thereby maintaining a thickness of 3-5 mm for the crown when measured from the buccal surface. The crowns were embedded in dental stone with the uppermost labial surfaces. The teeth were cleaned and polished with non-fluoridated pumice, rinsed with water, and dried with oil-free compressed air. The surface roughness of the enamel surface before bonding was examined using AFM.

AFM
The surface roughness of the samples was assessed using an AFM.

Bonding procedure
After initial measurements were taken, teeth were etched for 30 s with a 37% phosphoric acid gel (Eaze etch – Orthofix, Anabond Stedman, India) and were thoroughly rinsed with water and air-dried. Teeth were painted with primer (Orthofix - Anabond Stedman, India) and adhesive resin (Orthofix - Anabond Stedman, India) was placed on the bracket bases. The brackets were bonded to the prepared enamel, excess adhesive was removed, and the resin was light-cured for 40 s (10 s each side).

All samples were stored in water at room temperature for 24 h, and the brackets were de-bonded with a de-bonding plier.

The total sample was divided into three groups, consisting 15 teeth in each group and resin removal was done using three different methods.
Group A: Tungsten carbide bur (G 701 SS White).
Group B: Fiber-reinforced composite bur (Shofu, Germany).
Group C: Sof-Lex discs – Coarse, medium, fine, and superfine (Shofu GMBH, Germany).

All bonding, de-bonding, and resin removal processes were applied to the samples by the same hand, and a fresh bur was used for each tooth (Figures 4-6). Complete removal of the resin remnants was verified clinically by visual inspection under a dental operating light.

After clean-up procedures were finished, final roughness parameters were registered with AFM (Figure 7).

Measurements involved three roughness parameters expressed in nanometers:
- Average roughness \( (R_a) \): The arithmetic mean of the height of peaks and depth of valleys from a mean line
- Root mean square roughness \( (R_q) \): The height distribution relative to the mean line
- Maximum roughness depth \( (R_{max}) \): Value that represents isolated profile features.

Statistical analysis
The distribution of the measurements was investigated with the Kolmogorov–Smirnov normality test and Shapiro–Wilk test, and then parametric tests were used. Data for roughness values gathered were statistically evaluated by repeated measurements analysis of variance (ANOVA) for each resin removal method.

Results
The three experimental groups having 15 sample teeth were coded as Group A, Group B, and Group C, and the residual resin was removed using three different methods - Tungsten carbide bur (Group A), fiber-reinforced composite bur (Group B), and Sof-Lex discs (Group C) operating using a low-speed hand piece (10,000 rpm) and water coolant. Scanning of buccal surface of the teeth under AFM before bonding (Figure 8) and after de-bonding (Figures 9-11) was analyzed, and measurements were duly recorded for three roughness parameters, i.e., \( R_a \), \( R_q \), and \( R_{max} \) (Graphs 1-3).

One sample normality test such as Kolmogorov–Smirnov and Shapiro–Wilk test results showed that the samples followed a normal distribution. Therefore to analyze the data, parametric...
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One-way ANOVA and Tukey's honestly significant difference post-hoc test were applied. Paired $t$-test was applied to compare mean values between time points. If $P < 0.05$, then it was considered statistically significant.

The surface roughness was least in Group C followed by Group B and Group A (Graphs 1-3).

Overall comparison among three different groups using paired $t$-test was done, it was found that statistically significant values were obtained in pre-bond and after resin removal among $R_{j}$, $R_q$, and $R_{\max}$ values with $P < 0.001$.

All the roughness parameters were least after de-bonding in Group C.

Discussion

Direct bonding of the orthodontic attachments on etched enamel surfaces with light cure adhesives is commonly considered and accepted to be clinically successful. The removal of attachments and all resin remnants from tooth surface is the final procedure required to be performed for the return of the enamel surface as closely as possible to the original pre-treatment condition without inducing iatrogenic damage. If the remnants are not completely removed, tooth surfaces are likely to become esthetically discolored and entrap plaque with time resulting in caries formation.

The bracket de-bonding procedure should ideally preserve the integrity of the enamel layer. The purposes of de-bonding are to remove the orthodontic attachment and adhesive resin from the tooth surface and restoring the tooth surface to its pre-treatment condition. De-bonding results in an irreversible damage to the enamel ranging from 30 to 60 $\mu$m of surface enamel. An orthodontic adhesive that leaves little or no adhesive remnant is highly preferable as it minimizes irreversible damage to the enamel. The alteration of enamel surface depends on the instruments used for bracket removal, armamentarium for resin removal, and type of adhesive used.
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Removal of brackets and adhesive followed by pumicing restored the tooth surface to its original surface.

AFM was used in this study because it can evaluate the surface roughness quantitatively and allows re-examination of the sample. Finishing of de-bonded surface with any single system will not be adequate to restore the smooth surface of enamel. If there is bulk amount of resin remaining after de-bonding, tungsten carbide bur should be used. Sof-Lex discs can be used to smoothen the enamel surface followed by pumicing. Using multi-step systems seems to be time-consuming and each of these devices leaves the surface of dental enamel with varying degrees of surface roughness. Newer methods including diamond-impregnated rubber cups, points, and silicon carbide brushes were introduced for polishing resin composites to a smooth finishing and glossy appearance. These systems seem to be promising to the clinician for the removal of residual resin and restoring the enamel to its near original state.

Summary and Conclusion
The present study was performed to assess and compare the degree of surface roughness created with three different types of enamel finishing methods - Tungsten carbide bur, fiber-reinforced composite bur, and Sof-Lex discs after de-bonding using AFM.

From the results obtained, it can be concluded that Sof-Lex discs used for resin removal created smoother surfaces than tungsten carbide bur and composite finishing bur and hence can be used for better finishing of enamel surface after debonding.

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