Enamel surface roughness following debonding using two resin grinding methods

Theodore Eliades*, Christiana Gioka*, George Eliades* and Margarita Makou**
*Biomaterials Laboratory, Section of Basic Sciences and Oral Biology and **Department of Orthodontics, School of Dentistry, University of Athens, Greece

SUMMARY The purpose of this study was to assess quantitatively the roughness of the enamel surface following debonding using two resin removal methods. The enamel surface of 30 premolar crowns was covered with black tape with a 3 mm window on the middle buccal third to standardize the area of analysis. The initial enamel surfaces were subjected to profilometry, registering four roughness parameters ($R_a$, $R_q$, $R_t$ and $R_z$). The brackets were bonded to the plaster-embedded enamel surfaces with a chemically cured, no-mix adhesive, and debonded after 1 week. Resin removal in half of the specimens was performed with an eight-bladed carbide bur, and in the other half with an ultra-fine diamond bur, both attached to a high speed hand piece; a second profilometric measurement was made after resin removal. Finishing of all surfaces was achieved with Soflex discs and a third registration of roughness followed. The duration of each resin removal protocol was also recorded. The results were analysed with two-way ANOVA and the Newman–Keuls test with the two resin grinding modes and the three intervals serving as discriminating variables ($n = 15$). For the duration results, a one-way ANOVA was used.

Significant differences ($P < 0.05$) were observed with respect to enamel roughness parameters between the two resin grinding methods used, while there was no consistent roughness-reducing effect of finishing with Soflex discs. Resin removal with a diamond bur was achieved in approximately half the time compared with the eight-bladed bur. The increase in most roughness variables induced by the debonding procedures was not reversed at the end of the finishing stage, regardless of the resin removal protocol used, suggesting an irreversible effect on enamel texture.

Introduction

The search for an efficient and safe method of adhesive resin removal following debonding has attracted the interest of many researchers, resulting in the introduction of a wide array of instruments and procedures (Gwinnett and Gorelick, 1977; Pus and Way, 1980). The lengthy list of proposed protocols involves manual removal with the use of a scaler or band removing plier (Rouleau et al., 1982); various shapes of tungsten carbide burs of eight- to 30-fluted configuration with low or high speed hand pieces (Campbell, 1995; Hong and Lew, 1995); Soflex discs (Howell and Weekes, 1990); and special composite finishing systems with zirconia paste or slurry pumice, as well as ultrasonic applications (Burapavong et al., 1978). Also, novel approaches involving carbon dioxide laser application have been promising (Smith et al., 1999), while the Nd:YAG laser has demonstrated potent structural degradation of the composite, suggesting that it could be used as an adjunct to the removal of residual resin (Thomas et al., 1996).

The use of various burs in conjunction with auxiliaries such as disc polishing and rubber cup paste or pumice finishing seems adequate for resin removal (Zarrinnia et al., 1995). The consensus on this issue is that the sequential use of multiple polishing tools is superior to the application of any one-step procedure (Retief and Denys, 1979; Hong and Lew, 1995), although there is a notable lack of a universally approved protocol for this potentially litigious treatment stage. The alterations of the enamel surface induced by rotary instruments may be irreversible (Piacentini and Sfondrini, 1996) and, occasionally, composite resin residues may be found even after 30 seconds of polishing the debonded surface (Vieira et al., 1993), while the amount of residual resin may be product dependent (David et al., 2002). Along with the introduction of novel methods, the armamentarium of conventional instruments has been fortified by the introduction of specially designed burs which are less aggressive to enamel (Radlanski, 2001).

In spite of the substantial increase in the means available for the removal of adhesive resin post-debonding, the methods utilized to investigate the effects of various resin grinding protocols have not followed the same pace. Thus, assessment of the effectiveness or safety of rotary instruments is limited to inspecting the surface under a scanning electron microscope (SEM) to reveal the topography and morphology of the enamel surface. Nonetheless, standard microscopic techniques lack a quantitative scale and as such cannot be used for the comparative assessment of the roughness of treated surfaces. As a result,
the information provided is subjective and, because the reports presented in the relevant literature have a pivotal role in formulating guidelines for clinicians (Oliver and Griffiths, 1992), the reliability of most protocols is questionable. Alternative techniques involving SEM and X-ray microanalysis (Ruppenthal et al., 1992) have been utilized to assess adhesive remnants following debonding, indicating that the adhesive remnant index is not a reliable means to estimate surface roughness.

The hypothesis tested in this study was that the method of resin grinding may affect enamel roughness. Therefore, the purpose of this investigation was to assess quantitatively the roughness of the enamel surface following debonding using two resin removal methods.

Materials and methods

Thirty premolars extracted for orthodontic reasons within the previous 40 days from testing were used in the study. The teeth were cleaned and the roots removed. On black rectangular pieces of adhesive tape, a round opening of 3 mm in diameter was made and the tape was applied to the middle third of the buccal surface of the tooth to facilitate a means to standardize the enamel surface intended for bonding and analysis. The tape was further secured to the premolar crown surface of the tooth to facilitate a means to standardize the enamel surface intended for bonding and analysis. The tap was used to the premolar crown with cyanoacrylate glue, which was applied to the mesiodistal crown surface to avoid contamination of the prospective bonding buccal surface. The crowns were cut, embedded in plaster cylinders (height 20 mm, diameter 10 mm), coded for identification purposes, and the exposed enamel windows were subjected to profilometric analysis employing a profilometer (Diavite DH-5, Witherfur, Germany) operated under 1.2 mm maximum length and 0.25 mm cut-off. This process involved registration of the following four roughness parameters prior to any treatment (baseline interval):

1. The average roughness ($R_a$), which describes the overall surface roughness, and can be defined as the arithmetic mean of all absolute distances of the roughness profile from the centre line within the measuring length.
2. The root mean square roughness ($R_q$), representing the height distribution relative to the mean line.
3. The maximum roughness depth ($R_z$), which registers isolated profile features on the surface.
4. $R_y$, which describes the average maximum peak-to-valley height of five consecutive sampling depths.

For each specimen two recordings were made with the contact stylus for each registration in a perpendicular direction and the results were averaged. All enamel samples were subjected to acid etching with 37 per cent orthophosphoric acid gel (Etching agent, Reliance, Itasca, Illinois, USA) for 30 seconds, rinsed and dried. Brackets (Dentaurum, Pforzheim, Germany) were bonded to the enamel with a chemically cured, no-mix orthodontic adhesive resin (Unite, 3M/Unitek, Monrovia, California, USA), according to the manufacturer’s instructions. All specimens were then immersed in water for 1 week at 37°C, and the brackets were debonded using a debonding plier. The specimens were divided into two groups. In the first group, removal of adhesive remnants was performed with an eight-bladed tungsten carbide bur (Fressima, F.I.T., Turin, Italy). In the second group, the adhesive was ground with an ultra-fine diamond bur (8 mg of grain per cm²; Fressima, F.I.T.). Both burs were used with a high speed hand piece. A second roughness recording was registered after resin grinding (resin removal interval). Finishing of the treated surfaces of both groups was performed with sequential use of Soflex discs (3M Espe, St Paul, MN, USA) as needed and a third registration of roughness was made. All bonding, debonding and adhesive removal procedures were performed by the same orthodontist and a new bur was used for each session. The time required for the completion of each resin removal protocol was recorded, while the extent of the overall resin removal process was determined by visual inspection of the enamel surface by the same operator. Upon completion of the finishing session the enamel surfaces were examined with a SEM (Leitz, Wetzlar, Germany) to exclude the possibility that adhesive residues were present on the prepared surfaces.

The data for each roughness variable were statistically analysed with a two-way ANOVA with the grinding medium (eight-bladed carbide or diamond bur) and stage (baseline, post-resin grinding and finishing) serving as discriminating variables. The resin removal duration results were analysed with a one-way ANOVA. Group differences for both analyses were further investigated with the Newman–Keuls test at $\alpha = 0.05$ level of significance ($n = 15$).

Results

The two-factor ANOVA indicated significant differences for both the resin grinding medium and the stage (baseline, resin removal, finish) group, whereas the interaction term was not significant, thus allowing the assignment of effects to individual parameters (Sokal and Rohlf, 1995). The ANOVA tables for the roughness variables examined are provided in the Appendix.

Figure 1 demonstrates the variation in $R_y$ throughout the enamel treatment intervals. The results indicated an irreversible enamel surface effect as finishing and baseline levels differed significantly. A difference was also detected with respect to surface roughness between the two techniques, whereas the use of Soflex discs at finishing did not improve the surface profile.
In Figure 2, the results for \( R_q \) are shown. The two resin removal methods showed significantly different effects on enamel roughness, while the finishing procedure restored the enamel texture to its original smoothness, as indicated by the lack of difference between the baseline and finishing intervals.

Figure 3 depicts the findings for \( R_t \), which revealed no difference between the two methods of resin removal, although the enamel showed a significant alteration at the end of the finishing interval relative to its baseline texture.

In Figure 4, the findings for \( R_z \) are illustrated, where the two resin grinding methods yielded significantly different results. At the end of treatment, the use of a diamond bur resulted in the restoration of the surface to its original texture.

Table 1 lists the duration of the resin removal method between the eight-bladed and diamond burs, demonstrating the time efficiency of the diamond bur protocol relative to the carbide bur.

**Discussion**

The concern over debonding-induced enamel surface alterations derives from the importance of the uppermost layer of enamel attributed to its hardness, higher mineral content and more fluoride relative to deeper zones (Øgaard, 2001). The loss of surface enamel and associated exposure of the enamel prism endings to the oral environment may induce a decrease in the resistance of enamel to organic acids produced in plaque and make it more prone to decalcification (Øgaard, 2001).
Therefore, surfaces possessing identical \( R_z \) values may differ significantly in their individual roughness features. To improve the description of the surface profile, additional parameters have been introduced. Nonetheless, some difficulties may be encountered, even with the use of multiple roughness variables. These pertain to the fact that grooves with different depths but with widths comparable with the size of the stylus probe may not be differentiated (Whitehead et al., 1996).

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The results of this study suggest that all roughness variables, with the exception of \( R_s \) for both resin removal methods and \( R_a \) for the diamond bur, presented elevated values at the resin removal interval, which could not be reversed with the use of polishing media at the post-finishing stages. This observation is in accordance with previous research indicating that the use of rotary instruments during debonding induces irreversible structural changes in the enamel (Placentini and Sfondrini, 1996; Eliades et al., 2001).

The difference in the cutting efficiency of the two rotary instruments employed in this study may be determined by a number of parameters, including the bur rotation speed, the pressure applied to the hand piece during cutting, the type of bur and the flow rate of coolant through the hand piece at the bur/tooth cutting interface (Siegel and von Fraunhofer, 1999). Cutting with carbide burs is primarily by plastic flow and flow-dependent fracture processes due to the high shear forces between the blades and the surface. These forces result in plastic ploughing of the surface, followed by brittle fracture adjacent to the furrows. Because material removal by a tungsten carbide blade occurs by flow-driven processes rather than brittle fracture, carbide burs are ideal cutting tools for ductile substrates such as resins.

In contrast, the removal of tooth structure or material with diamond burs results from brittle fracture occurring as the rotated individual diamond chip creates a groove. With this mode, the dislocation motion adjacent to the bur causes an outward flow of material towards the edges of the groove. As a consequence,
plastic strain accumulation is limited and large tensile stresses are generated in the near-surface region, resulting in crack initiation (Siegel and von Fraunhofer, 1999). Consequently, diamond burs are more suitable for brittle materials such as dental enamel and ceramics or hard alloys; it is uncertain whether the incorporation of very fine diamond chips could effectively limit the mode of action of diamond burs and, thus, from this perspective, these should not be used for adhesive resin removal.

Address for correspondence
Theodore Eliades
57 Agnoston Hiroon Street
Nea Ionia
GR-14231 Athens
Greece

References
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Howell S, Weekes T 1990 An electron microscopic evaluation of the enamel surface subsequent to various debonding procedures. Australian Dental Journal 35: 245–252
Appendix

ANOVA tables for roughness data.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>d.f.</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>P*</th>
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<tr>
<td>**Dependent variable: **$R_a$</td>
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<tr>
<td>Stage</td>
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<td>0.254</td>
<td>0.254</td>
<td>0.629</td>
<td>0.431</td>
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<tr>
<td>Bur</td>
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<td>4.859</td>
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<td>0.001</td>
</tr>
<tr>
<td>Stage × bur</td>
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<td>0.180</td>
<td>0.445</td>
<td>0.508</td>
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<tr>
<td>Residual</td>
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<td>22.623</td>
<td>0.404</td>
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<tr>
<td>Total</td>
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<tr>
<td>**Dependent variable: **$R_t$</td>
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<td></td>
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<td>1.646</td>
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<tr>
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<tr>
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<tr>
<td>Total</td>
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<td>6.414</td>
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<td>0.488</td>
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<td>0.839</td>
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*Values represent the possibility that the results obtained are due to random sampling variability.