European Journal of Orthodontics 26 (2004) 333–338
European Journal of Orthodontics vol. 26 no. 3

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 (Ruppental *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 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_t), which registers isolated profile features on the surface.
4. R_z, 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 cm^2; 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_a 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.

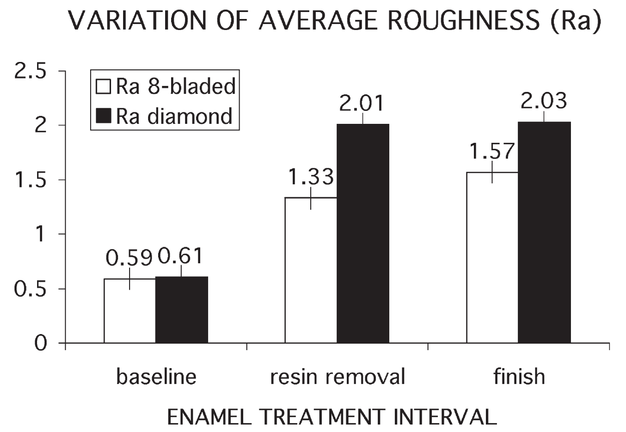

Figure 1 Variation in the average roughness variable (R_a) across the different treatment intervals. The horizontal bars indicate mean values of no statistical difference at α = 0.05 level of significance.

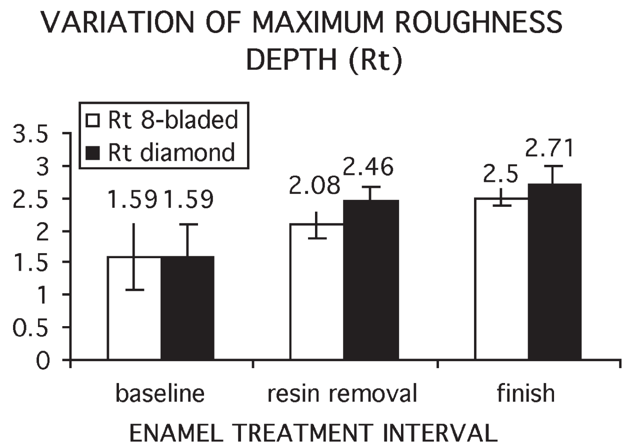

Figure 3 Variation in the maximum roughness depth variable (R_t) across the different treatment intervals. The horizontal bars indicate mean values of no statistical difference at α = 0.05 level of significance.

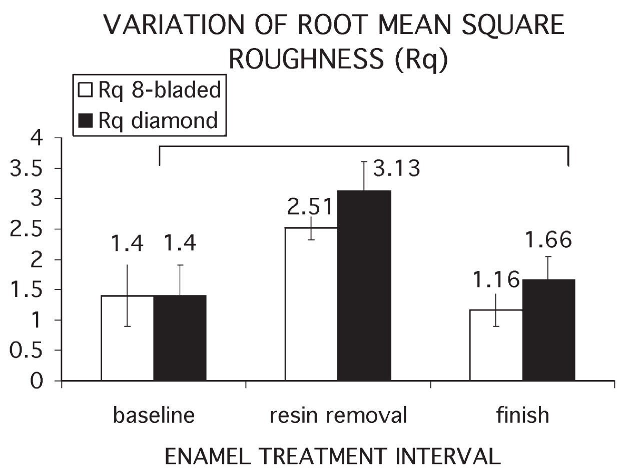

Figure 2 Variation in the root mean square roughness variable (R_q) across the different treatment intervals. The horizontal bars indicate mean values of no statistical difference at α = 0.05 level of significance.

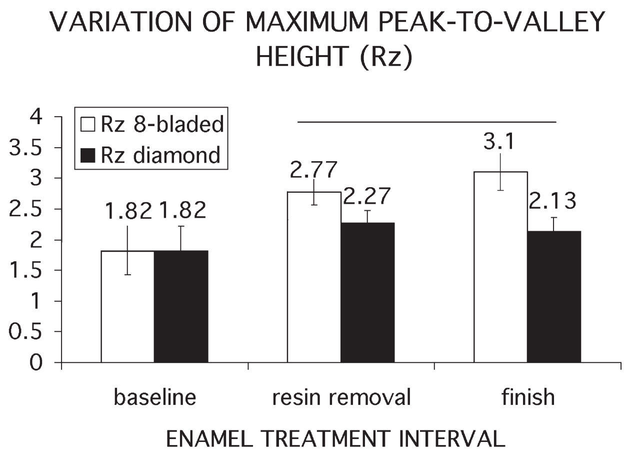

Figure 4 Variation in the R_z variable, which describes the average maximum peak-to-valley height of five consecutive sampling depths, across the different treatment intervals. The horizontal bars indicate mean values of no statistical difference at α = 0.05 level of significance.

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).

Table 1 Duration of the two resin removal methods employed in the study.

Resin removal method	Duration (seconds) [mean (standard deviation)]	Newman–Keuls grouping*
Eight-bladed carbide bur	10.3 (1.2)	A
Ultra-fine diamond bur	5.6 (0.8)	B

*Means with the same letters are not significantly different at $\alpha = 0.05$ level of significance.

Many studies have employed R_a as the sole indicator of surface texture. However, this notion precludes a reliable registration of the surface texture because of two basic fundamental deficiencies of R_a:

1. the inability to indicate the depth of the irregularity, i.e. it cannot differentiate between surfaces with deep or shallow grooves; and
2. the lack of information on the profile of the irregularity, as peaks or valleys, i.e. pores or projections, are registered in an identical manner (Whitehead *et al.*, 1996).

Therefore, surfaces possessing identical R_a 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.*, 1995).

The results of this study suggest that all roughness variables, with the exception of R_q for both resin removal methods and R_z 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 (Piacentini and Sfondrini, 1996; Eliades *et al.*, 2001).

The decreased values of R_a and R_q found for the eight-bladed carbide group are supportive of its use as a superior removal method. R_t showed no alteration between the two resin removal methods, while R_z, which describes the peak-to-valley heights, i.e. the gross irregularities of the surface, was the only one that demonstrated a decreased roughness for the diamond bur-treated group. The clinical implication of this observation must be considered with caution in light of the fact that profilometry does not provide information about the composition of the specimen analysed. The decreased R_z index observed for the enamel specimens treated with the diamond bur, as opposed to a rougher surface associated with the application of the carbide bur, is not indicative of the integrity of the tissue examined. It could be that the diamond-treated enamel presents fewer irregularities than its carbide-treated counterpart, simply because the ability of the former rotary instrument to grind enamel is increased. Far more tissue damage may be induced with this method relative to the superficial grooves that may be caused by the eight-fluted bur.

The time required for resin removal between the two techniques differed by a factor of 2. This may be explained by the more aggressive cutting of the diamond bur; in essence, this mode is actually an indiscriminant type of resin removal along with tooth structure grinding.

It has been suggested that increased enamel roughness following resin removal may effectively be diminished by masticatory loads and the friction developed between the enamel surface and various hard foods. Examination of enamel surfaces subjected to stripping 12 weeks following the procedure, has revealed a decreased roughness relative to the immediate post-stripping stage (Radlanski *et al.*, 1990). However, the pattern of enamel removal in stripping may be different and of limited surface extent.

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

Burapavong V, Marshall G W, Apfel D A, Perry H T 1978 Enamel surface characteristics on removal of bonded orthodontic brackets. American Journal of Orthodontics 74: 176–187

Campbell P M 1995 Enamel surfaces after orthodontic bracket debonding. Angle Orthodontist 65: 103–110

David V A, Staley R N, Bigelow H F, Jakobsen J R 2002 Remnant amount and cleanup for 3 adhesives after debracketing. American Journal of Orthodontics and Dentofacial Orthopedics 121: 291–296

Eliades T, Kakaboura A, Eliades G, Bradley T G 2001 Comparison of enamel colour changes associated with orthodontic bonding using two different adhesives. European Journal of Orthodontics 23: 85–90

Gwinnett A J, Gorelick L 1977 Microscopic evaluation of enamel after debonding: clinical application. American Journal of Orthodontics 71: 651–665

Hong Y H, Lew K K K 1995 Quantitative and qualitative assessment of enamel surface following five composite removal methods after bracket debonding. European Journal of Orthodontics 17: 121–128

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

Øgaard B 2001 Oral microbiological changes, long-term enamel alterations due to decalcification and caries prophylactic aspects. In: Brantley W A, Eliades T (eds) Orthodontic materials: scientific and clinical aspects. Thieme, Stuttgart, pp. 124–139

Oliver R G, Griffiths J 1992 Different techniques of residual composite removal following debonding—time taken and surface enamel appearance. British Journal of Orthodontics 19: 131–137

Piacentini C, Sfondrini G 1996 A scanning electron microscopy comparison of enamel polishing methods after air-rotor stripping. American Journal of Orthodontics and Dentofacial Orthopedics 109: 57–63

Pus M D, Way D C 1980 Enamel loss due to orthodontic bonding with filled and unfilled resins using various clean-up techniques. American Journal of Orthodontics 77: 269–283

Radlanski R J 2001 A new carbide finishing bur for bracket debonding. Journal of Orofacial Orthopedics 62: 296–304

Radlanski R J, Jäger A, Zimmer B, Bertzbach F 1990 Scanning electron microscopic studies on the clinical use of interdental stripping. Fortschritte der Kieferorthopädie 51: 117–122

Retief D H, Denys F R 1979 Finishing of enamel surfaces after debonding of orthodontic attachments. Angle Orthodontist 49: 1–10

Rouleau B D, Marshall Jr G W, Cooley R O 1982 Enamel surface evaluations after clinical treatment and removal of orthodontic brackets. American Journal of Orthodontics 81: 423–426

Ruppenthal T, Stratmann U, Sergl H G, Czech D 1992 Element analytical and quantitative morphometric evaluation of adhesive remnants and enamel loss after debonding of metal brackets. Fortschritte der Kieferorthopädie 53: 99–105

Siegel S C, von Fraunhofer J A 1999 Dental cutting with diamond burs: heavy-handed or light touch? Journal of Prosthodontics 8: 3–9

Smith S C, Walsh L J, Taverne A A 1999 Removal of orthodontic bonding resin residues by CO_2 laser radiation: surface effects. Journal of Clinical Laser Medical Surgery 17: 13–18

Sokal R R, Rohlf F J 1995 Biometry: the principles and practice of statistics in biological research, 3rd edn. Freeman, New York, pp. 330–335

Thomas B W, Hook C R, Draughn R A 1996 Laser-aided degradation of composite resin. Angle Orthodontist 66: 281–286

Vieira A C, Pinto R A, Chevitarese O, Almeida M A 1993 Polishing after debracketing: its influence upon enamel surface. Journal of Clinical Pediatric Dentistry 18: 7–11

Whitehead S A, Shearer A S C, Wilson N H F 1995 Comparison of methods for measuring surface roughness of ceramic. Journal of Oral Rehabilitation 22: 421–426

Whitehead S A, Shearer A C, Watts D C, Wilson N H F 1996 Comparison of two stylus methods for measuring surface texture. Dental Materials 15: 79–86

Zarrinnia K, Eid N M, Kehoe M J 1995 The effect of different debonding techniques on the enamel surface: an *in vitro* qualitative study. American Journal of Orthodontics and Dentofacial Orthopedics 108: 284–293

Appendix

ANOVA tables for roughness data.

Source of variation	d.f.	SS	MS	*F*	*P**
Dependent variable: R_a					
Stage	1	0.254	0.254	0.629	0.431
Bur	1	4.859	4.859	12.028	0.001
Stage × bur	1	0.180	0.180	0.445	0.508
Residual		56	22.623	0.404	
Total		59	27.940	0.474	
Dependent variable: R_t					
Stage	1	1.646	1.646	3.214	0.078
Bur	1	1.257	1.257	2.454	0.123
Stage × bur	1	0.110	0.110	0.214	0.645
Residual		56	28.681	0.512	
Total		59	31.573	0.535	
Dependent variable: R_q					
Stage	1	6.414	6.414	11.859	0.001
Bur	1	9.752	9.752	18.031	<0.001
Stage × bur	1	0.488	0.488	0.902	0.346
Residual		56	30.288	0.541	
Total		59	47.848	0.811	
Dependent variable: R_z					
Stage	1	1.278	1.278	1.806	0.184
Bur	1	12.890	12.890	18.214	<0.001
Stage × bur	1	0.829	0.829	1.171	0.284
Residual		56	39.631	0.708	
Total		59	54.870	0.930	

*Values represent the possibility that the results obtained are due to random sampling variability.