A Pilot Investigation of Enamel Reduction Procedures

• **P. Emile Rossouw,** BSc, BChD, BChD (Hons), MChD (Ortho), PhD, FRCD(C) •
• **Andrew Tortorella,** BSc, DDS •

Abstract

Objective: *To test and describe the use of various combinations of mechanical and chemical techniques for enamel reduction to obtain a smooth surface.*

Methods: *Bovine teeth (2 surfaces on each of 32 teeth) were used. The teeth were mounted in blocks of dental plaster, which were then mounted in a vise. The mesiodistal enamel contact areas were reduced by various combinations of mechanical and chemical aids. The mesiodistal width of each tooth was measured with a digital caliper after initial reduction of the enamel surface and again after polishing. The teeth were subsequently prepared and mounted for scanning electron microscopy.*

Results: *All combinations yielded statistically significant enamel reduction ($p < 0.05$). The use of acid stripping in conjunction with mechanical procedures produced especially smooth enamel surfaces.*

Conclusions: *Steps must be taken to ensure that a smooth enamel surface remains after enamel reduction and polishing. It is recommended that conventional enamel etchants be added to the polishing procedure. Enamel reduction can increase available space, but the quantity of enamel that can be removed without adverse consequences should be carefully evaluated.*

MeSH Key Words: *dental enamel/surgery; malocclusion/surgery; orthodontics, corrective/methods*

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Interproximal enamel reduction is a technique with tremendous flexibility. It can be used as a stand-alone procedure to contour a tooth surface or as an adjunct procedure during other restorative, prosthodontic and orthodontic treatments.

The purpose of this pilot project was to test and describe the use of various combinations of mechanical and chemical techniques for enamel reduction to obtain a smooth enamel surface and to evaluate the residual smoothness of the enamel of bovine teeth after application of these different methods.

Materials and Methods

Bovine teeth were used for this study. They are readily available, and bovine enamel is an acceptable substitute for human enamel in research projects,[1,2] because histochemically all mammalian teeth appear essentially similar.[3] In the present study, the mesial and distal surfaces of 32 bovine teeth were used (total of 64 surfaces). The pulp of each tooth was mechanically removed, and the teeth were mounted in blocks of dental plaster to simulate a dental arch. The blocks were then mounted in a vise for stability, and the mesiodistal enamel contact areas were subjected to reduction by combinations of mechanical and chemical aids (**Table 1**).

The mechanical techniques included removal of the enamel by Midwest high-speed and low-speed handpieces (Midwest Dental Products Corp. Des Plaines, Illinois) equipped with 16-blade tungsten carbide burs (Brasseler, Savannah, Georgia), superfine needle diamond burs (Brasseler), diamond disks (Brasseler) and diamond Lightning strips (Moyco Union Broach, York, Pennsylvania). The stripped enamel surfaces were polished with 3M Sof-Lex extra-thin polishing disks attached to mandrels (3M Dental Products, St. Paul, Minnesota) and 3M Sof-Lex finishing strips (coarse and medium aluminum oxide, as well as fine and superfine) (3M Dental Products) in combination with various enamel acid etching solutions

Table 1 **Results of interproximal enamel reduction (mean ± standard deviation of 9 measurements for each method)**

Method	Enamel loss after initial reduction (mm) (IR)	Enamel loss after polishing (mm) (P)	Enamel reduction by polishing only (mm) (P – IR)
TB + D	0.17 ± 0.02	0.38 ± 0.08	0.21 ± 0.06
TB + S	0.44 ± 0.06	0.54 ± 0.01	0.10 ± 0.06
TB + D + Ph	0.03 ± 0.04	0.07 ± 0.03	0.04 ± 0.02
TB + D + M	0.51 ± 0.04	0.64 ± 0.05	0.13 ± 0.03
TB + D + Pr	0.55 ± 0.05	0.64 ± 0.02	0.09 ± 0.06
TB + S + Ph	0.44 ± 0.09	0.67 ± 0.03	0.23 ± 0.06
TB + S + M	0.29 ± 0.06	0.42 ± 0.03	0.13 ± 0.08
TB + S + Pr	0.17 ± 0.06	0.16 ± 0.09	–0.01 ± 0.06
DS + D	0.19 ± 0.12	0.24 ± 0.06	0.06 ± 0.07
DS + S	0.15 ± 0.04	0.14 ± 0.09	–0.01 ± 0.09
DS + D + Ph	0.22 ± 0.11	0.27 ± 0.07	0.05 ± 0.18
DS + D + M	0.08 ± 0.08	0.19 ± 0.05	0.11 ± 0.07
DS + D + Pr	0.17 ± 0.15	0.33 ± 0.16	0.16 ± 0.03
DS + S + Ph	0.22 ± 0.02	0.26 ± 0.02	0.04 ± 0.02
DS + S + M	0.08 ± 0.01	0.17 ± 0.06	0.09 ± 0.07
DS + S + Pr	0.08 ± 0.03	0.14 ± 0.02	0.06 ± 0.01
DB + D	0.39 ± 0.04	0.53 ± 0.03	0.14 ± 0.03
DB + S	0.24 ± 0.12	0.38 ± 0.12	0.13 ± 0.01
DB + D + Ph	0.28 ± 0.11	0.38 ± 0.08	0.10 ± 0.05
DB + D + M	0.28 ± 0.09	0.49 ± 0.04	0.21 ± 0.12
DB + D + Pr	0.09 ± 0.12	0.02 ± 0.07	–0.07 ± 0.05
DB + S + Ph	0.34 ± 0.11	0.45 ± 0.11	0.11 ± 0.09
DB + S + M	0.37 ± 0.04	0.40 ± 0.05	0.03 ± 0.01
DB + S + Pr	0.39 ± 0.04	0.59 ± 0.06	0.20 ± 0.02
DD + D	0.22 ± 0.06	0.34 ± 0.08	0.12 ± 0.07
DD + S	0.16 ± 0.06	0.22 ± 0.05	0.05 ± 0.05
DD + D + Ph	0.23 ± 0.03	0.39 ± 0.01	0.16 ± 0.03
DD + D + M	0.01 ± 0.12	0.14 ± 0.03	0.13 ± 0.11
DD + D + Pr	0.43 ± 0.07	0.62 ± 0.08	0.19 ± 0.04
DD + S + Ph	0.56 ± 0.09	0.74 ± 0.09	0.18 ± 0.16
DD + S + M	0.36 ± 0.09	0.43 ± 0.03	0.07 ± 0.07
DD + S + Pr	0.28 ± 0.12	0.43 ± 0.01	0.15 ± 0.12

TB = tungsten carbide bur, D = 3M polishing disks, S = 3M polishing strips, Ph = 35% phosphoric acid, M = 10% maleic acid, Pr = Prema enamel microabrasion kit, DS = diamond (Lightning) strip, DB = diamond bur, DD = diamond disk.

in some of the groups. The chemical etching products were the Transbond XT etching gel delivery system containing 35% phosphoric acid (3M Dental Products), Scotchbond Multi-Purpose etchant containing 10% maleic acid (3M Dental Products) and the Prema enamel microabrasion kit containing an abrasive powder in a water-soluble gel combined with a mild concentration of hydrochloric acid (Premier Dental Products, King of Prussia, Pennsylvania). The enamel surfaces were rinsed with distilled water for 60 seconds after the application of the acid compounds.

Three measurements of the mesiodistal width of each tooth were obtained before each method of enamel reduction. A total of 32 methods of enamel reduction were completed, with 9 repetitions of each method, for a total of 288 observations. The measurements were obtained with a digital caliper (Mitutoyo Corporation, Kawasaki, Japan), calibrated to 0.01 mm, after initial reduction of the enamel surface and again after polishing. The caliper tips were specially sharpened to a knife-edged point to make accurate measurement possible (**Fig. 1**).

The average mesiodistal width before enamel reduction and after polishing was determined and used for statistical analysis. The teeth were immersed in 100% ethanol for 1 week after the stripping procedures and then allowed to air dry to remove all moisture. The teeth were then individually mounted on aluminum scanning electron microscopy (SEM) stubs and coated with 3 nm of platinum in a Polaron E 5100 SEM coating unit (Quorum Technologies, East Sussex, England). The samples were then viewed with a scanning electron microscope (Hitachi S-2500, Mito City, Japan) at an operating voltage of 10 kV. Images were photographed at 100× and 500× magnification for descriptive purposes.

Statistical analyses included descriptive statistics and Duncan's multiple range test. The level of significance was set at $p < 0.05$.

Figure 1*: Digital calipers indicating measurement to 0.01 mm.*

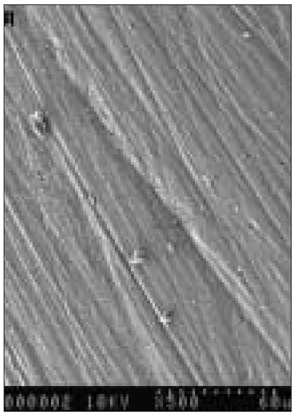

Figure 2a: *Bovine tooth after enamel reduction with a 16-blade tungsten carbide bur plus 3M polishing disks.*

Figure 2b: *Bovine tooth after enamel reduction with a 16-blade tungsten carbide bur plus 3M polishing disks plus 10% maleic acid.*

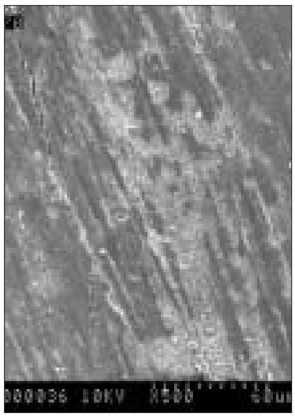

Figure 2c: *Bovine tooth after enamel reduction with a 16-blade tungsten carbide bur plus 3M polishing disks plus Prema enamel microabrasion kit.*

Results

The differences in enamel surface after the initial reduction and after polishing are presented in **Table 1**. There were no significant differences among the groups (Duncan's multiple-range text, $p > 0.05$). However, there was a statistically significant difference between the initial and final enamel measurements ($p < 0.05$) for all procedures, which indicates that all of the techniques removed enamel from these bovine teeth.

Examples of the results of the various procedures, including acid polishing, are shown in **Figs. 2** and **3**. These SEM images revealed that the use of acids in polishing the enamel after initial stripping resulted in a smoother surface. In particular, maleic and phosphoric acids (**Figs. 2b, 3b** and **3c**) yielded equivalent smoothness, whereas the use of the Prema enamel microabrasion kit reduced surface roughness but left visible furrows (**Figs. 2c** and **3d**).

Discussion

Interproximal enamel reduction, also known as interdental stripping or slenderizing, is a well-known technique that is commonly applied during orthodontic treatment. Better alignment and better occlusion of the teeth, as well as simplification of long-term maintenance of tooth alignment, have been reported.[4–8]

In the study reported here, bovine enamel surfaces were subjected to conservative reduction with a variety of orthodontic grinding and finishing techniques and materials, the amount of enamel removed was measured, and the enamel surfaces were evaluated by SEM. Even when the teeth were polished with the finest finishing strips, it was impossible to produce an enamel surface free of the furrows caused during initial abrasion by coarse reduction procedures. This phenomenon has also been recognized by researchers using human enamel.[9–11] The furrows caused by mechanical reduction may enhance the predisposition for plaque retention.[12–14] The use of dental floss apparently cannot prevent plaque accumulation at the bottom of furrows cut into the approximal enamel in this way.[10] A vicious cycle is thus established, with subsequent risk of decalcification, gingivitis, caries or some combination of these problems.[15] The grinding-down of enamel by diamond-coated disks, burs or finishing strips remains the subject of controversy. Although injuries to the enamel surface caused by grinding instruments can predispose the patient to caries and periodontal disease,[12–14] interdental reduction is not yet considered by orthodontists as a problem. Development of a technique that yields a smooth enamel surface after enamel reduction is recommended to prevent iatrogenic lesions.

It is common to reshape the approximal contacts in the anterior region to solve crowding problems[4–8,16,17] and to stabilize the dental arch.[18] This approach to treatment seems to have originated from the finding that aboriginal and prehistoric humans usually exhibited not only occlusal[19,20] but also approximal[19,21] wear of the dentition. The perceived impossibility of artificially producing highly polished surfaces has resulted in a preference to avoid reduction and accept slight crowding as a natural phenomenon.[22] Nonetheless, there is a need for this procedure in clinical practice, as reduction is rapidly becoming a common procedure for the treatment of minor discrepancies in arch length. The reduction procedure is usually limited to the lower anterior dental

Figure 3a: *Bovine tooth after enamel reduction with a diamond disk plus 3M polishing disks.*

Figure 3b: *Bovine tooth after enamel reduction with a diamond disk plus 3M polishing disks plus 35% phosphoric acid.*

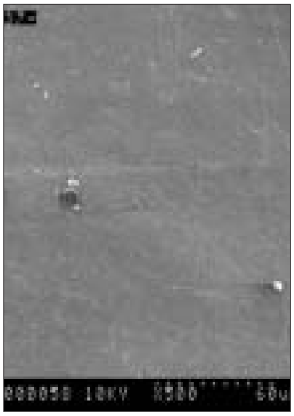

Figure 3c: *Bovine tooth after enamel reduction with a diamond disk plus 3M polishing disks plus 10% maleic acid.*

Figure 3d: *Bovine tooth after enamel reduction with a diamond disk plus 3M polishing disks plus Prema enamel microabrasion kit.*

segment, where caries seldom develop. However, it has recently been proposed that such therapy be extended to the premolar and molar regions[5] to gain space along the dental arch. This method might allow for just as much space as can be achieved by the extraction of premolars. The in vitro study presented here confirms that enamel can be successfully removed by a variety of methods (**Table 1**). Because the results of Radlanski and others[10] indicate that reduction leads to plaque accumulation, careful evaluation is needed to determine whether potential damage to multiple approximal tooth surfaces by enamel reduction is preferable to extraction and other space-gaining procedures. The SEM images obtained in the present study clearly show roughening of the enamel surfaces if left unpolished (**Figs. 2** and **3**).

The etching pattern of enamel appears to play a part in the bond strength of dental resins. However, Denys and Retief[23] stated that it is impossible to define an etched enamel surface as retentive to dental resins only on the basis of distribution of the etching patterns, an observation apparently confirmed by Carstensen.[24] Phosphoric acid concentrations greater than about 27% produce monocalcium phosphate monohydrate, whereas concentrations less than about 27% yield dicalcium phosphate dihydrate.[25] The former is readily soluble and would be completely washed away in the clinical situation, whereas the latter is less soluble. This seems to be a disadvantage in providing a retentive surface for resin bonding following application of low-concentration acids. Conversely, the overall loss of superficial enamel, which is especially rich in fluoride,[26] is probably less after etching with 2% or 5% phosphoric acid than with a 40% solution.[27–30] Also, the depth of acid penetration into the deeper enamel layers seems to be less at low acid concentrations.[31] Therefore, using low-concentration acids could diminish the risk of decalcification in the enamel regions around orthodontic attachments. For this reason acid stripping or polishing in the present study was performed with low-concentration acids.

Light microscopic studies have shown that an enamel surface stripped by abrasive means cannot be highly polished.[22] Hence, acid stripping was tested in the present study, and SEM was used to determine the differences between acid and non-acid polishing (**Fig. 2** and **3**). In addition, it is known that artificially roughened enamel is less resistant to penetration of a lactate buffer[32] and that fluoride treatment must be applied for a lengthy period after stripping.[9,33]

Conclusions

Interproximal enamel reduction is an important auxiliary orthodontic treatment. However, the clinician must take steps to ensure that a smooth enamel surface remains after the polishing procedures described in this article, to ensure that the negative effects of abrasive stripping are eliminated. It is recommended that conventional enamel etchants, as used in orthodontic practice, be added to the polishing procedure during the reduction technique. A rubber dam may be used when any acidic products are included as part of the polishing procedure to prevent further irritation of the gingiva. However, this is a minor consideration, as similar acids are typically used in bonding of brackets.

Given the current emphasis on nonextraction treatment in orthodontics today, enamel reduction is a technique that can increase available space in the dentition, but the quantity of enamel that can be removed without adverse consequences must be carefully evaluated. Reduction should incorporate the best possible finishing of the interproximal enamel surface to meet the biologic requirements of the oral cavity. ◆

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Dr. Rossouw *is professor and clinic director, Baylor College of Dentistry, Dallas, Texas.*

Dr. Tortorella *maintains a private practice in Niagara Falls, Ontario.*

Correspondence to: *Dr. P. Emile Rossouw, Professor and Clinic Director, Baylor College of Dentistry, 3302 Gaston Ave., Dallas, Texas 75246, USA. E-mail: ERossouw@tambcd.edu.*

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