

Quantitative comparison of 3 enamel-stripping devices in vitro: How precisely can we strip teeth?

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Introduction: In this in-vitro study, we aimed to investigate the predictability of the expected amount of stripping using 3 common stripping devices on premolars. **Methods:** One hundred eighty extracted premolars were mounted and aligned in silicone. Tooth mobility was tested with Periotest (Medizintechnik Gulden, Modautal, Germany) (8.3 ± 2.8 units). The selected methods for interproximal enamel reduction were hand-pulled strips (Horico, Hapf Ringleb & Company, Berlin, Germany), oscillating segmental disks (O-drive-OD 30; KaVo Dental, Biberach, Germany), and motor-driven abrasive strips (Orthofile; SDC Switzerland, Lugano-Grancia, Switzerland). With each device, the operator intended to strip 0.1, 0.2, 0.3, or 0.4 mm on the mesial side of 15 teeth. The teeth were scanned before and after stripping with a 3-dimensional laser scanner. Superposition and measurement of stripped enamel on the most mesial point of the tooth were conducted with Viewbox software (dHal Software, Kifissia, Greece). The Wilcoxon signed rank test and the Kruskal-Wallis test were applied; statistical significance was set at $\alpha \leq 0.05$. **Results:** Large variations between the intended and the actual amounts of stripped enamel, and between stripping procedures, were observed. Significant differences were found at 0.1 mm of intended stripping ($P \leq 0.05$) for the hand-pulled method and at 0.4 mm of intended stripping ($P \leq 0.001$ to $P = 0.05$) for all methods. For all scenarios of enamel reduction, the actual amount of stripping was less than the predetermined and expected amount of stripping. The Kruskal-Wallis analysis showed no significant differences between the 3 methods. **Conclusions:** There were variations in the stripped amounts of enamel, and the stripping technique did not appear to be a significant predictor of the actual amount of enamel reduction. In most cases, actual stripping was less than the intended amount of enamel reduction. (Am J Orthod Dentofacial Orthop 2013;143:S168-72)

Grinding interproximal tooth surfaces to reduce tooth size is a common procedure in orthodontics. The indications for interproximal enamel reduction are lack of space, Bolton tooth-size discrepancy,^{1,2} correction of morphologic anomalies, tooth reshaping, and reduction of interdental gingival papilla retraction.^{3,4}

Interproximal enamel reduction is also known as interdental stripping, enamel approximation, or slenderizing.³ Several procedures are used in daily orthodontics to perform precise interdental stripping as part of the treatment plan. Reduction of enamel can be achieved with hand-held or motor-driven abrasive strips but also with disks or burs mounted on a hand piece.

There are different guidelines regarding the optimal amount of enamel reduction. Fillion⁵ recommended reduction maximums of 0.3 mm for maxillary incisors, 0.2 mm for mandibular incisors, and 0.6 mm for premolars and molars. Sheridan and Ledoux⁶ postulated that a gain of 0.4 mm of space by enamel reduction per proximal surface of premolars and molars is possible, and Stroud et al⁷ claimed that up to 0.6 mm of enamel reduction is attainable. As a rule of thumb, various authors consider a reduction of the original enamel by 50% to be acceptable.^{8,9}

Long-term results of interproximal enamel reduction showed no iatrogenic damage—eg, dental caries, gingival problems, or increased alveolar bone loss.¹⁰ Profilometry and scanning electron microscopy were used in studies to prove that a treated enamel surface after reduction and polishing can be similar to or smoother

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than untreated enamel.^{11,12} Zhong et al¹¹ showed that it is possible to reduce interproximal enamel in a reasonable time (2.2 minutes per surface) with a good or very good outcome in 90% of patients, and with enamel surfaces after stripping smoother than untreated enamel.

If the treatment plan calls for stripping, it is important to be able to reduce the enamel by the exact amount required.

Although many studies are focusing on the surface irregularities that could remain after grinding and polishing,^{11,12} only 1 study was identified that presents a quantitative evaluation of stripped enamel.¹² Therefore, the aim of this study was to investigate in vitro on premolars the actual stripping and the intended stripping of 3 commonly used stripping devices. The null hypothesis was that there is no difference between the intended and the actual amounts of enamel reduction. Additionally, the differences between the 3 stripping methods regarding stripping predictability were assessed.

MATERIAL AND METHODS

One hundred eighty teeth were randomly divided into 3 groups according to 3 commonly used stripping methods. In each of the 3 stripping method groups, enamel reductions were set at 0.1, 0.2, 0.3, or 0.4 mm on 1 side; therefore, 15 premolars were allocated for each stripping level subgroup. Ethical approval by the University of Geneva (number 09-129) was obtained to collect extracted premolars from patients who had extraction therapy at the Department of Orthodontics. The patients were given an information sheet describing the study and asked to sign a consent form.

The premolars were stored in 3% thymol solution. They were then aligned and mounted in silicone (Curadent Protesil; Zeta Dental, Riazzino, Switzerland) to simulate the mobility of the natural periodontium.¹² To prevent loosening of the teeth, they were fixed in the silicone base with super glue at the apex of the root. The mobility of the teeth was verified on 30 teeth with Periotest (Medizintechnik Gulden, Modautal, Germany) to make sure that the situation in the mouth was simulated as close as possible. The achieved values (8.3 ± 2.8 units) were within the range of standard values published by Schulte¹³ (−2 to +11 for premolars).

Three methods of interproximal enamel reduction were selected for comparison: group A was treated with traditional hand-pulled strips (45- μ m grits, 0.09-mm thickness; Horico, Hopf Ringleb & Company, Berlin, Germany). Group B had oscillating segmented disks (30- to 40- μ m grits, 0.13-mm thickness, O-drive OD 30; KaVo Dental, Biberach, Germany; OS 1 FH disk Komet; Gebr. Brasseler GmbH & Company KG, Lemgo, Germany). In group C, the enamel was reduced by

motor-driven abrasive strips (40- μ m grits, 0.3-mm thickness, Orthofile; SDC Switzerland, Lugano-Grancia, Switzerland).

Danesh et al¹² analyzed the amount of reduced enamel by polishing after interproximal reduction; it was shown to be between 0 and 0.02 mm. Since this is a relatively small amount, which does not seem clinically significant, we focused only on grinding and left out the polishing.

Before and after stripping, the teeth were scanned by a 3-dimensional (3D) laser scanner (R-250; 3Shape, Copenhagen, Denmark) after they were sprayed with a minimal layer of Pico Scan Spray (Picodent, Wipperfurth, Germany) to prevent reflections in the scan process. The final STL files (Surface Tesselation Language) were imported into Viewbox software (dHAL Software, Kifissia, Greece), where the 3D objects were superimposed. Then a plane was defined at the long axis of the tooth, and the software measured the distance from the sagittal plane to the farthest points mesially and distally on the tooth.

A digital caliper (Schieblehre digital 59112; Fino, Bad Bocklet, Germany) was used to verify the 3D measuring procedure by measuring the mesiodistal premolar widths.

During the stripping process, the amount of enamel reduction was controlled with a gauge, as proposed by several authors.^{14,15}

All measurements and superimpositions were performed by the same operator (A.M.J.). In order to test the 3D measuring procedure, 30 tooth widths were measured by digital caliper (mean, 7.50 ± 0.36 mm) and by the 3D software (mean, 7.49 ± 0.35 mm). No significant difference was found between these 2 measuring procedures. A high correlation was found between these methods ($R = 0.99$, $P \leq 0.001$), in accordance with the study of Alcan and Ceylanoğlu.¹⁶

Three-dimensional superimpositions and measurements were repeated for 30 teeth after 10 days. A high coefficient of reliability was found ($R = 0.99$, $P \leq 0.001$). The random error of the method was calculated with Dahlberg's formula ($Se = 0.0183$ mm).¹⁷

$$Se = \sqrt{\frac{\sum d^2}{2n}}$$

As for the systematic error, the *t* test showed no significant difference between the 3D measurements.

Statistical analysis

The statistical analyses aimed to assess the following: (1) differences between intended and actual stripping for each method separately at 0.1, 0.2, 0.3, and 0.4 mm; and (2) differences in the actual stripping between methods

separately at 0.1, 0.2, 0.3, and 0.4 mm. Plotted histograms indicated that the data were not normally distributed; therefore, no parametric methods for statistical assessment were applied. The first null hypothesis was that actual stripping did not differ from the intended amount of stripping with each method. The Wilcoxon signed rank test was applied for each method and intended amount of stripping. The second null hypothesis was that the actual stripping did not differ significantly between the 3 stripping methods. The Kruskal-Wallis test was applied for each intended amount of stripping. Statistical significance was set at $\alpha = 0.05$, and all analyses were conducted with statistical software (version 12.1; StataCorp, College Station, Tex).

RESULTS

The actual stripping compared with the intended amount of stripping (0.1–0.4 mm) and the stripping method (hand-pulled strip, oscillating segmented disk, or motor-driven strip) showed great variability, with all methods delivering on average less stripping than intended (Fig).

The difference between intended and actual stripping indicated that, at 0.1 and 0.4 mm, the hand-pulled method stripped on average significantly less enamel than intended. The oscillating method ground significantly less at 0.2, 0.3, and 0.4 mm; and the motor-driven strips reduced less enamel at 0.4 mm (Table).

There were no differences in the actual amounts of stripping between the 3 stripping methods for all intended amounts of stripping (0.1–0.4 mm). The *P* values from the Kruskal-Wallis analysis were 0.4 for 0.1 mm, 0.68 for 0.2 mm, 0.94 for 0.3 mm, and 0.75 for 0.4 mm of stripping.

DISCUSSION

In this study, we examined the predictability of 3 stripping methods for delivering the predetermined amount of enamel reduction. Our results indicate that, when testing 3 different stripping methods, the average amount of stripping was in general smaller than the intended amount of enamel reduction. However, big variations were observed regardless of the method used. The amount of enamel reduction was generally overestimated, especially for intended stripping of 0.2, 0.3, and 0.4 mm.

Our findings are in line with those of Danesh et al.¹² In their study, 5 stripping methods were compared in groups of 10 mandibular anterior teeth. Our study differs because we used premolars and aimed to strip 4 predetermined amounts of enamel, whereas Danesh et al only intended to reduce the enamel by at least 0.25 mm.

However, big variations were found by those authors, also ranging from 0.11 to 0.46 mm.

Danesh et al¹² found no significant differences in the amount of ground enamel for 4 of the 5 stripping methods they used. Only the oscillating disk (OD30) ground significantly more enamel (0.32 mm), whereas in our study, the oscillating method did not differ significantly from the others.

The traditional hand-held abrasive strips make reduction of posterior enamel laborious work, according to Sheridan.¹⁸ Additionally, it is postulated that hand-pulled abrasive strips are not all that efficient, because the space obtained after stripping is not as much as expected. The explanation of this is that forcing an abrasive strip into the contact point will move the teeth into the lateral periodontal space, giving a distorted impression of the actual amount of space generated. Furthermore, reduction by hand-pulled strips is not that efficient, since the strip might become twisted between the surfaces, and therefore the enamel reduction session might take longer.¹⁹ This will be less convenient for the patient and the orthodontist. Another disadvantage of hand-pulled stripping was thought to be the rise of temperature in the pulp; this potentially damages the tooth. However, according to Baysal et al,²⁰ this risk is smaller for hand-held strips than for perforated disks or enamel reduction with tungsten carbide burs on premolars.

By using manual strips without a handle, the operator cannot produce the same tension on the strip, which bends and adapts to the shape of the proximal surfaces. On the other hand, motor-driven devices will reduce more enamel at the contact point, so the contact point will be flatter and might even show a little edge around the stripped area. In this case, it will be necessary to smooth the edges and reshape the contact point with further devices such as diamonds burs.

The second enamel reduction method tested in our study was the oscillating segmented disk (O-drive OD 30). With this system, according to Zhong et al,¹¹ it is possible to strip and produce surfaces that are even smoother than natural enamel and in a reasonable time of 2.2 minutes per surface on average.

This method might also be quite acceptable to the patient; only 1 author has mentioned vibrations, which might disturb the patient, when passing tight contact points.¹⁹ Additionally, there is less risk for soft-tissue injuries during the stripping procedure because of the 60° oscillating movement, eliminating the need for lip and cheek protectors.²¹

The last method of enamel reduction evaluated in this study was motor-driven abrasive strips (Orthofile). This method is efficient and less time-consuming for the orthodontist. With similar motor-driven abrasive

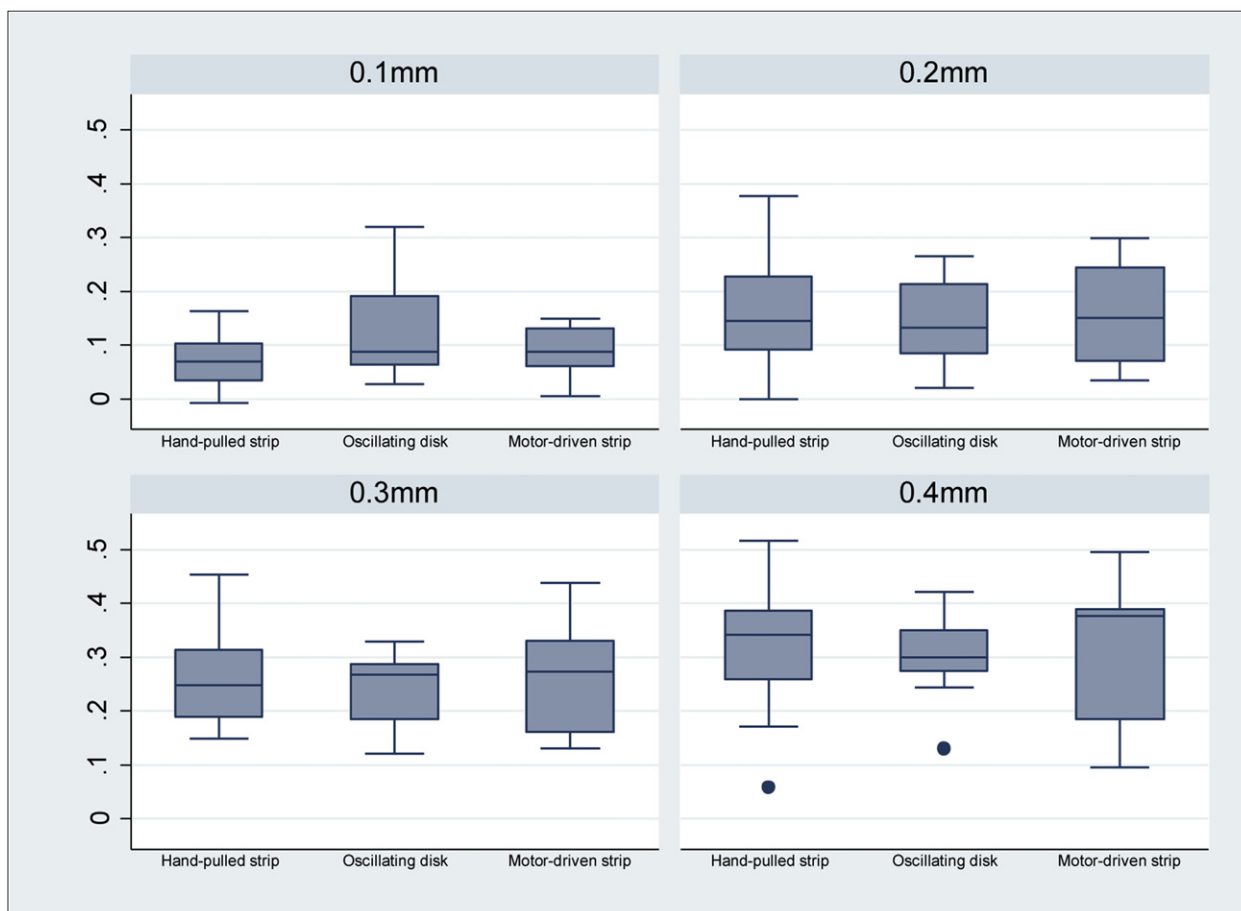


Fig. Box plots of actual vs intended amounts of stripping by intended amount of stripping and method (medians, 25th and 75th percentiles, *whiskers* at minimum and maximum amounts of data, *dots* indicate outliers).

Table. Medians of actual stripping per stripping method and per intended stripping depth

	<i>Intended stripping depth (mm)</i>			
	<i>0.1</i>	<i>0.2</i>	<i>0.3</i>	<i>0.4</i>
Medians and ranges of actual amounts of stripping (mm)				
Hand-pulled strip	0.07* (0.00-0.16)	0.14 (0.00-0.38)	0.25 (0.15-0.45)	0.34 [†] (0.06-0.52)
Oscillating disk	0.09 (0.09-0.32)	0.13 [†] (0.02-0.27)	0.27 [†] (0.12-0.33)	0.30 [‡] (0.13-0.42)
Motor-driven strip	0.09 (0.01-0.15)	0.15 (0.04-0.30)	0.27 (0.13-0.44)	0.38* (0.10-0.50)

**P* < 0.05; [†]*P* < 0.01; [‡]*P* < 0.001.

strips by other companies, it is also possible to reduce smaller amounts of enamel.^{12,14} The motor-driven strips are also quite safe because the moving file cannot hurt the tongue or the lips, whereas the generated vibration is a potential disadvantage.¹⁹

The precision of interdental enamel reduction might be improved by using disks of predetermined thickness, since some manufacturers have recently introduced

them to the market. Further tooth separation with interdental wedges could enhance accuracy by eliminating any interproximal pressure. It also seems reasonable to reduce the enamel progressively, because reduction of smaller amounts of enamel was more predictable.¹⁴

Based on the previous study by Danesh et al,¹² a similar procedure of mounting teeth in silicone was adapted to imitate the physiologic mobility of the teeth; this was

tested by Periotest and found to be within the normal range (-2 to +11).¹³ Carrying out this in-vitro study on embedded teeth brings certain advantages: eg, easier comparison of the stripping devices; good visibility of the teeth with no disturbance from the tongue, cheeks, or head position; and accurate scanning of each tooth.

In this study, some measurements indicated 0 mm of enamel reduction; this might be attributed to either loosening of the teeth in the silicone base or errors during the measuring process (scanning and superimpositions of tooth measurements).

The drawbacks of this study might be associated with the fact that silicone will never react exactly like the periodontal ligament, because it probably will fatigue quicker than a biologic tissue. For an in-vitro study, longer stripping procedures mean more force applications on the tooth and the silicone. This might loosen these teeth in the silicone bases compared with teeth to which no stripping was applied. Loose teeth cannot resist the mechanical movement of the stripping device and are therefore not efficiently ground.

Ideally, the predictability of enamel reduction should be assessed in a clinical setting, along with other outcomes such as operator usability and patient comfort. Unfortunately, proximal scanning and measuring of the teeth will be challenging in a clinical trial setting. Another problem is that stripping cannot be directly performed on crowded teeth, but only after initial alignment; thus, teeth might move during or after interproximal stripping from stretching of the periodontal fibers, resulting in an imprecise assessment of the stripping result.

CONCLUSIONS

Overall, this study showed large variations in the stripped amounts of enamel. In most cases, actual stripping was on average less than the intended amount of enamel reduction.

The stripping technique does not appear to be a significant predictor of the actual amount of enamel reduction.

Further studies are needed to compare stripping devices in vivo.

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