



ORIGINAL ARTICLE

A comparison of traditional orthodontic polishing systems with composite polishing systems following orthodontic debonding

Elizabeth A. Melvin^a, Qingzhao Yu^b, Xiaoming Xu^c, Camille G. Laird^d,
Paul C. Armbruster^d, Richard W. Ballard^{d,*}

^a Private Practice of Orthodontics, 1540 Rock Springs Road, Smyrna, TN 37167, USA

^b LSU Health Sciences Center School of Public Health, 2020 Gravier Street, Department of Statistics, New Orleans, LA 70112, USA

^c LSU Health Sciences Center School of Dentistry, 1100 Florida Ave, Department of Prosthodontics, New Orleans, LA 70119, USA

^d LSU Health Sciences Center School of Dentistry, 1100 Florida Ave, Department of Orthodontics, New Orleans, LA 70119, USA

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KEYWORDS

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Abstract *Introduction:* At the completion of treatment, the orthodontic practitioner's goal is to effectively remove all traces of adhesive and return enamel to its initial state. With the advent of new polishing systems being released each year, there may be one product that is superior to others.

Aim: The purpose of this study is to determine the efficacy of new polishing systems (in the last 5–10 years) used in general dentistry on enamel surface roughness following debond utilizing profilometry and scanning electron microscopy and compare them to established orthodontic polishing systems results.

Methods: Fifty-two mandibular incisors were randomly assigned to one of five test groups (N = 10) and two incisors (untreated enamel) were used for profilometer and scanning electron microscopy analysis at the end of testing. After bracket removal, the teeth were polished using traditional polishing products (Komet H48L bur, Reliance 'Renew' point) and newer polishing products (Coltene Spiral Composite Plus Polisher, Ultradent Jiffy Composite Polishing Spiral or 3M Sof-Lex™ Diamond Polishing System). The results were evaluated using a profilometer and scanning electron microscopy images.

Results: The results of a one-way analysis of variance (ANOVA) determined that the mean change in enamel surface roughness was not statistically different both in the traditional and novel

* Corresponding author.

E-mail address: rball1@lsuhsc.edu (R.W. Ballard).

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groups. Tukey's Honestly Significant Difference (HSD) test found that there was no statistically significant difference in the change in enamel surface roughness between instrument groups.

Conclusions: There was no statistically significant difference in enamel surface roughness after polishing between traditional orthodontic polishing systems and the selected novel polishing systems. SEM analysis revealed similar findings. This supports previous research suggesting that a wide variety of polishing systems or none at all, may be used to restore enamel smoothness after removal of orthodontic appliances.

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1. Introduction

With the days of banding all individual teeth for orthodontic treatment in the past, direct bonded orthodontic attachments have significantly changed the practice of orthodontics (Bishara et al., 1999). Not only is direct bonding to teeth a more time efficient practice, but it also provides a more comfortable patient experience and an improvement in gingival health (Kim et al., 2010). Direct bonding of orthodontic brackets is typically accomplished by an acid-etch technique that bonds the bracket to the enamel of a tooth with either a chemical or light-cured adhesive material (Sharma et al., 2014). The ideal orthodontic adhesive is the one that withstands masticatory and orthodontic forces, facilitates easy removal for the practitioner, and is removed with minimal to no enamel damage upon adhesive debonding.

At the completion of orthodontic treatment, the practitioner's goal is to effectively remove all traces of adhesive and return enamel to the pre-treatment state. Studies have shown that methods of adhesive removal such as the use of scalers and burs, may produce visible rough surface with grooves up to 20 μm deep, and a loss of up to 100 μm of enamel (Dumore and Fried, 2000). Bollen et al. (1997) stated that the surface roughness critical threshold value is 0.2 μm . Without complete removal of adhesive, the tooth surfaces may allow for easier plaque formation and even become discolored (Hong and Lew, 1995). Ideally, the removal of adhesive should result in limited to no enamel abrasion, leaving a visually smooth surface (Zarrinnia et al., 1995). However, Campbell (1995) conducted a survey in which 80% of surveyed orthodontists noted some enamel scarring after debonding of orthodontic appliances.

Bracket and adhesive removal protocols vary among orthodontic practitioners. Webb et al. (2016) conducted a survey of orthodontists in which participants were asked to identify the bur they most commonly used to remove adhesive after appliance removal. The results revealed that the majority of respondents used a high-speed handpiece with a 12 fluted carbide bur. The survey also asked what polishing systems were used following adhesive removal. The most common polishing device after adhesive removal was a Renew point (Reliance Orthodontics, Inc; Itasca, IL, USA) (Webb et al., 2016). However, most respondents indicated that they do not perform any extra steps to polish the enamel.

Several studies have aimed to address the most effective way to remove adhesive resin following debonding without damaging the enamel surface, but a universal protocol has not been established (Andrews et al. 2016; Fan et al., 2017;

Webb et al., 2016; Zarrinnia et al., 1995). Furthermore, there is no evidence on how many flutes a carbide bur should have to remove adhesive without damaging enamel, whether pumice is necessary to polish, what bur to polish with, and if the polishing should occur in a wet or dry field (Andrews et al. 2016; Webb et al., 2016).

Alessandri Bonetti et al. (2011) stated that removal of residual adhesive with rotary instruments does cause enamel removal which was dependent on the characteristics of the abrasive particles, the speed and pressure exerted by the operator. It was reported that removing residual adhesive with Arkansas stones, green stones, diamond burs, steel burs, and lasers should be avoided (Janiszewska-Olszowska et al., 2014). Janiszewska-Olszowska et al. (2014) felt that research should explore methods for complete removal of adhesive while producing minimal loss of enamel and a smooth surface. According to these results, a variety of products may be suitable for adhesive removal and polishing.

Previous studies have sought to determine if there was a significant difference in enamel surface roughness after debonding using non-orthodontic polishing systems but did not find any significant difference (Andrews et al. 2016; Shah et al., 2019). With the advent of new composite polishing systems being released each year, one must ask if any would be suited for orthodontics. Bansal et al (2019) found that some composite polishing systems produced a very smooth enamel surface. Evaluation and discovery of polishing systems that could be used to produce a well-polished enamel surface would be of significant benefit to the patient regardless as to whether it was designed and/or marketed for orthodontic patients. By comparing different systems to each other, practitioners have the flexibility to choose multiple products that produce satisfactory results and are best suited for their practice.

This study sought to compare the efficacy of the most commonly used carbide bur and polishing point used by orthodontists, as determined by Webb et al, (2016) to three composite polishing systems released in last 5–10 years and marketed for use in general dentistry to polish enamel after debonding of orthodontic brackets. This study evaluated the enamel smoothness following debonding and enamel polishing with these systems utilizing profilometry and scanning electron microscopy and compared them to established orthodontic polishing systems results.

2. Materials & methods

Prior to initiation of this study, approval was obtained from the Institutional Biosafety Committee of LSU Health New

Orleans, Health Sciences Center, IBC# 18037. One operator performed all operations on the samples of this study except the statistical analysis.

2.1. Teeth selection/preparation

Fifty-two previously extracted, human, mandibular incisor teeth were obtained and stored in distilled water at room temperature. The inclusion criteria for the sample teeth included the facial surface being free of caries, restorations or visible cracks. The lingual surface of each tooth was bonded with composite to a straight wire and embedded in a plastic container filled with plaster rock. This block served to secure and align the facial surface of each incisor. Each tooth's facial surface was then cleaned with pumice, rinsed with water and dried with air.

2.2. Bonding protocol

A standard bonding protocol was performed for 50 of the samples after a preliminary scan with the profilometer established a baseline roughness for each tooth. Each tooth was air-dried before applying Transbond™ Plus Self-Etching Primer (3 M Unitek, Monrovia, CA, USA) for six seconds and air dispersed. Transbond™ XT (3 M Unitek, Monrovia, CA, USA) light cure adhesive was applied onto the mesh of a mandibular incisor twin orthodontic bracket (Mini Master Series, American Orthodontics; WI, USA). Bracket placement was centered on the facial surface of each tooth in alignment with its long axis in the area that was scanned prior to bonding. Any excess adhesive was removed and the bracket was light cured for a total of 12 s, with 6 secs from the mesial and 6 s from the distal of the bracket (Elipar 3 M ESPE; Irvine, CA, USA).

2.3. Debonding and adhesive removal protocol

After 24 h, the brackets were debonded using an Orthopli bracket removing plier (Orthopli; Philadelphia, PA, USA). Any remaining resin was removed with a handpiece. A 12-fluted carbide bur (Komet H48L bur; Komet; Rock Hill, SC, USA) in a high-speed handpiece was used without water to remove the remaining resin under the light of an operative lamp and 3x loupe magnification. Once the facial surface appeared visually clean of residual adhesive under 3x loupe magnification, the removal was considered complete and ready for polishing.

2.4. Polishing protocol

After adhesive removal, the fifty samples were randomly assigned to one of the five test polishing groups (N = 10) as outlined below. Two incisors received no treatment and were used for profilometer and scanning electron microscopy analysis at the end of testing to allow for comparison to virgin enamel.

Group 1: Komet H48L bur (10 teeth) (Komet; Rock Hill, SC, USA)

Group 2: Reliance 'Renew' point (10 teeth) (Reliance Orthodontics Products; Itasca, IL, USA)

Group 3: Coltene Spiral Composite Plus Polisher (10 teeth) (Coltene; Cuyahoga Falls, OH, USA)

Group 4: Ultradent Jiffy Composite Polishing Spiral (10 teeth) (Ultradent Products Inc; South Jordan, UT, USA)

Group 5: 3 M Sof-Lex™ Diamond Polishing System (10 teeth) (3 M Unitek; Monrovia, CA, USA)

The Komet H48L bur served as the control group because no additional polishing was performed after its use. The traditional orthodontic polishing systems were the Komet H48L bur (Group 1) and the Reliance 'Renew' point (Group 2). The composite polishing systems were the Coltene Spiral Composite Plus Polisher (Group 3), Ultradent Jiffy Composite Polishing Spiral (Group 4) and 3 M Sof-Lex™ Diamond Polishing System (Group 5) polishing systems. Each polishing product was applied for 10 s using a friction grip or latch-style attachment on a slow speed handpiece, according to manufacturer guidelines, to standardize polishing protocols for time and polishing speed.

2.5. Profilometry protocol

A TalyScan 150 3D Surface Profilometer (Taylor Hobson, IL, USA) was used to scan and analyze each facial surface of the extracted teeth before and after the treatment. The FTSS gauge with a stylus scan tip was used. The profilometer measured to an accuracy of 5 µm following a standardized protocol. Large scale (2.65 mm) and resolution of 42 nm were selected. The scan conditions were: scan area: 2.0 mm × 2.0 mm, X (bi-direction) speed: 1000 µm/s, Y: 5 µm/step (the "space" (resolution) of both X and Y directions were 5 µm). The profilometer scanned area was determined visually by marking the area on which the bracket would be placed, centered on the facial surface and according to the long axis of the tooth. Three measurements per tooth were obtained and averaged to provide a mean measurement. The surface roughness over the scanned area (S_a) was calculated and 3D images were generated using the TalyMap Universal software (Version 3.2.0) on the instrument. The 3D images are included alongside of the SEM images of each sample (Figs. 1–6).

2.6. SEM protocol

The facial surfaces of one randomly selected tooth from each of the polishing groups and the two non-instrumented teeth were analyzed by SEM. The samples were sputter-coated with carbon and observed under an S-2700 Scanning Electron Microscope (Hitachi, Japan) at 20 kV accelerated voltage. The images from the SEM were acquired at 250×, 500×, and 1000× magnifications through a Thermo Noran digital acquisition system while only images with 1000× magnification are shown in Figs. 1–6. Because most of the quantitative analysis of the surface roughness and 3D images were provided by the profilometry, only a few samples were analyzed by SEM to provide high resolution images, which supplement the profilometry data.

2.7. Statistical analysis

A one-way analysis of variance (ANOVA) and Tukey's Honestly Significant Difference were used to test for significant dif-

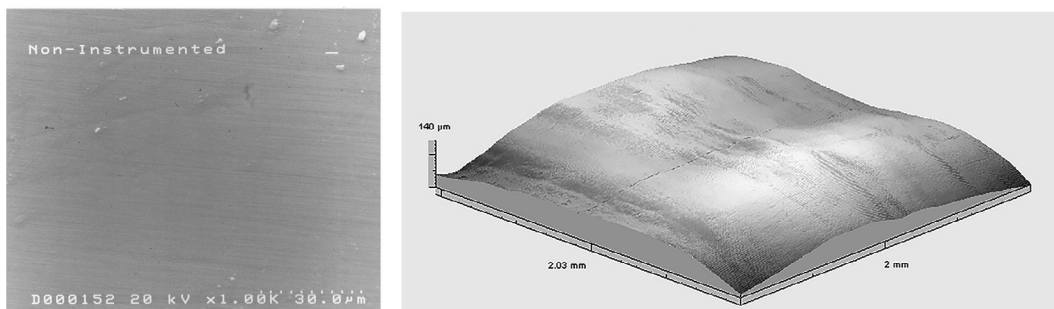


Fig. 1 SEM and 3D image showing enamel surface of virgin enamel (no-treatment sample).

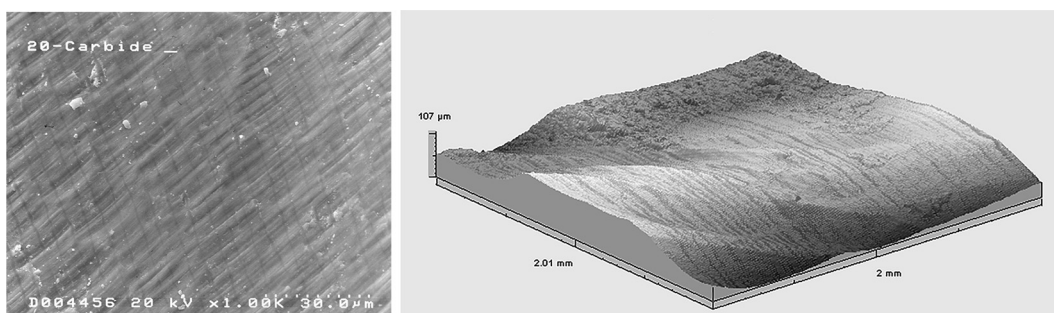


Fig. 2 SEM and 3D image showing enamel surface after using Komet H48L Bur.

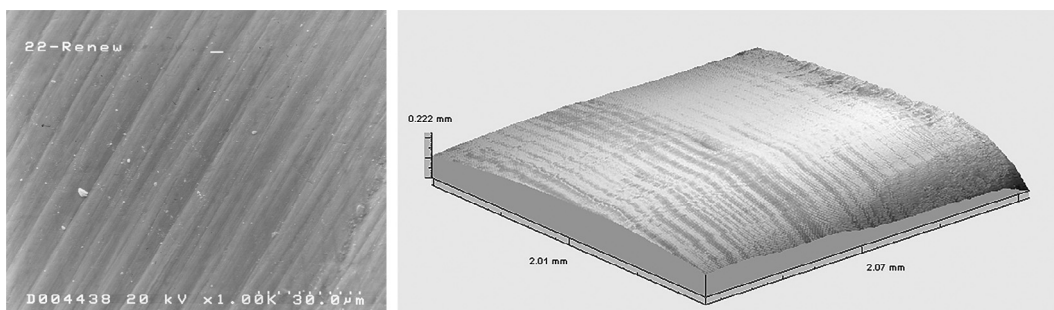


Fig. 3 SEM and 3D image showing enamel surface after using Reliance Renew point.

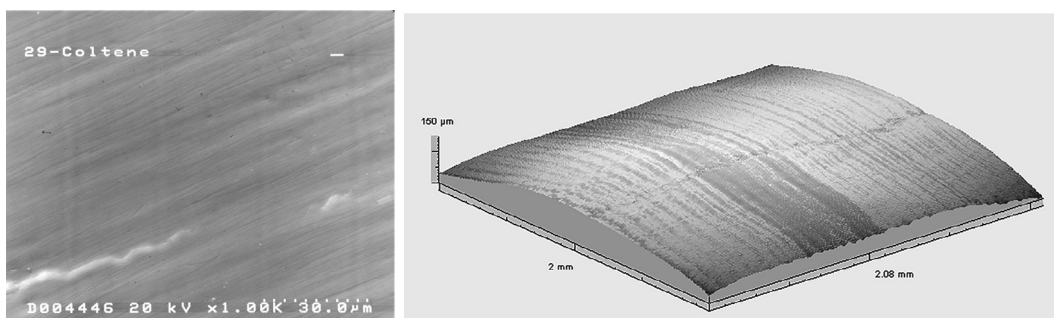


Fig. 4 SEM and 3D image showing enamel surface after Coltene Spiral Composite Plus Polisher.

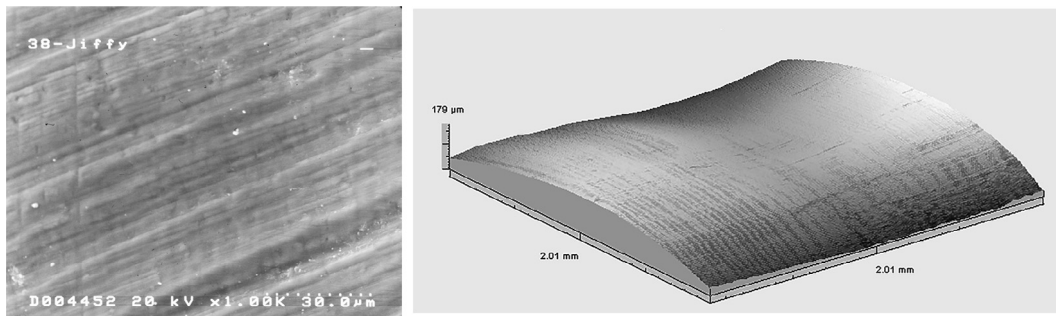


Fig. 5 SEM and 3D image showing enamel surface after Ultradent Jiffy Composite Polishing Spiral.

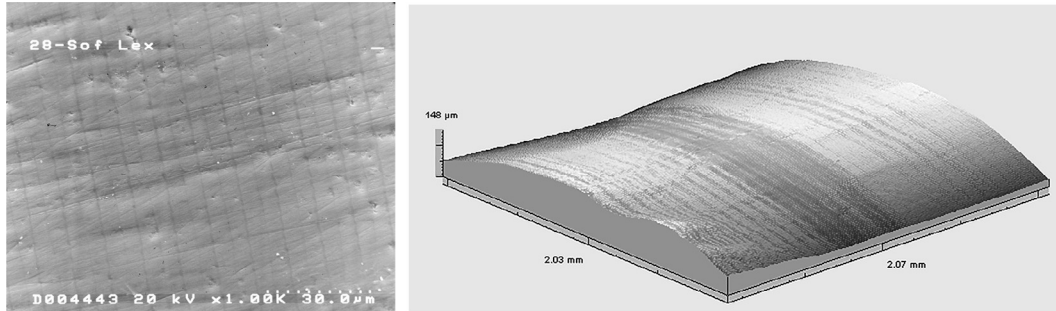


Fig. 6 SEM and 3D image showing enamel surface after using 3 M Sof-Lex Diamond Polishing System.

ferences between polishing groups. The significance level for all statistical tests is set at 0.05. All analysis was performed using SAS 9.4 (Cary, NC, USA).

3. Results

The profilometer measurements (mm) of surface roughness (S_a) pre and post-treatment were used to calculate the mean change in enamel surface roughness between each group (Table 1). A one-way analysis of variance (ANOVA) was used to test for any difference between the mean enamel change after polishing in the traditional and novel groups. The test concluded that there was not a statistically significant difference ($p = 0.98$). Although the SEM images and 3D profilometry images revealed visual differences among bur types, (for example, Komet Carbide (Fig. 2), Reliance ‘Renew’ point (Fig. 3), and Ultradent Jiffy Composite Polishing Spiral (Fig. 5) produced rougher surfaces than Coltene Spiral Com-

posite Plus Polisher (Fig. 4) and 3 M Sof-Lex™ Diamond Polishing System (Fig. 6) the post-hoc multiple comparison by Tukey’s Honestly Significant Difference (HSD) test found no statistically significant difference in the change in enamel surface roughness between bur groups. There was also no statistically significant difference between instrument types in the traditional polishing group ($p = 0.33$) and among the novel polishing groups ($p = 0.47$). Table 2 shows the differences in

Table 1 Mean change in enamel surface roughness (R_a) as measured by profilometer (N = 10).

Group	Mean change (R_a)
Komet H48L Bur	0.00968
Reliance ‘Renew’ Point	-0.01133
Coltene Spiral Composite Plus Polisher	0.00066
Ultradent Jiffy Composite Polishing Spiral	0.00565
3 M Sof-Lex Diamond Polishing System	-0.00798

A positive mean change indicated the enamel had a greater surface roughness than the tooth prior to testing, and a negative mean change indicated the enamel had a lower surface roughness than prior to testing.

Table 2 Comparisons between each pair of groups.

Bur Type Comparison	Difference Between Means	Simultaneous 95% Confidence Limits
Carbide H48L Sample - Jiffy Spiral Sample	0.00403	-0.04111 0.04917
Carbide H48L Sample - Coltene Spiral Sample	0.00902	-0.03612 0.05416
Carbide H48L Sample - Sof-lex Spiral Sample	0.01766	-0.02748 0.06280
Carbide H48L Sample - Renew Sample	0.02101	-0.02413 0.06615
Jiffy Spiral Sample - Coltene Spiral Sample	0.00499	-0.04015 0.05013
Jiffy Spiral Sample - Sof-lex Spiral Sample	0.01363	-0.03151 0.05877
Jiffy Spiral Sample - Renew Sample	0.01698	-0.02816 0.06212
Coltene Spiral Sample - Sof-lex Spiral Sample	0.00864	-0.03650 0.05378
Coltene Spiral Sample - Renew Sample	0.01199	-0.03315 0.05713
Sof-lex Spiral Sample - Renew Sample	0.00335	-0.04179 0.04849

the mean changes in enamel surface roughness between any pair of groups with the 95% confidence intervals. The null hypothesis is that there are no significant differences in the mean changes for each pair of groups. A 95% confidence interval including 0 indicates that the p-value of testing the null hypothesis is larger than 0.05. The Tukey's HSD test ensures the control of the overall type-I error in the multiple pairwise comparisons. In the results, all 95% confidence intervals include 0, indicating no significant differences between any pair of groups. All groups produced smooth appearing enamel surfaces, so no superior polishing efficiency was determined since the use of each bur was standardized at 10 s of polishing per tooth.

4. Discussion

This study sought to evaluate the enamel smoothness following debonding and enamel polishing with three composite polishing or novel systems compared to established orthodontic polishing systems. The traditional orthodontic burs and novel polishing systems used in this study all yielded similar results. In fact, the carbide bur without an additional polishing product did not demonstrate a significant difference in enamel surface roughness when compared to other products. This is in contrast to previous studies that concluded there was a significant difference in enamel surface roughness change pretreatment and post-treatment when using a tungsten carbide bur to remove residual adhesive (Garg et al. 2018; Goel et al., 2017; Vidor et al., 2015). An additional study found that after debonding, Sof-Lex disks most successfully returned enamel to its original surface roughness (Özer et al., 2010). Osorio et al. (1998) found that Sof-Lex disks produced an enamel surface that was second to the Enhance system with the gloss polishing paste or superior to the Enhance system without the polishing paste. Yet, the current study discovered that the mean change in enamel surface roughness was not statistically different than the polished groups, both in the traditional and novel group. As a result, this suggests that additional polishing may not be necessary when using a 12-fluted carbide bur to remove residual adhesive. This finding was in agreement with Cardoso et al. (2014) which stated that polishing with pumice paste was insignificant in restoring enamel to its original condition and as such, it should be considered optional.

Even within each group, each system provided a statistically similar amount of change in enamel surface roughness that did not significantly differ from the enamel surface roughness prior to bonding of the bracket. This coincides with the 3D and SEM images, which reveal similar appearing surfaces. The carbide bur may be determined to be slightly less smooth than the polishing burs. When this is compared to the non-instrumented sample, you can see there is a slightly more apparent difference in the striations visually. Overall, there is no large ditching or notching apparent on the enamel surface of any polishing group. While 3D and SEM images are not a quantitative assessment of the change, the images support the results of our profilometric findings that there is no significant difference between polishing groups.

The profilometer and the SEM analyze the enamel surface roughness in a very limited field of view. Although a 2 mm × 2 mm area was scanned, the profilometer has the capability to detect and measure micrometers into the surface

(Eliades et al., 2004; Mohebi et al., 2017). In this study, the resolution of the profilometer was set at 5 µm in both X and Y directions and each scanned 2.0 mm × 2.0 mm area contained 401 traces with 401 point/trace (total 160,801 data points). At high magnifications, minute differences in the surface topography of the enamel are appreciated pretreatment and post polishing. However, it was not necessarily clinically relevant to pick out the same area at a micrometer level with the software. Finally, if any of these polishing points can produce a satisfactory result, determining the longevity of each product and the number of teeth each one could be used on would be clinically useful.

Future studies could use a larger sample size or look into another method of analyzing the enamel surface smoothness, such as atomic force microscopy or even scoring of enamel photos prior to and after treatment with different polishing points (Mohebi et al., 2017). Images of teeth immediately post debonding and post polishing can be compared to pretreatment photos to evaluate the luster. This may allow some insight into how the patient or other practitioners notice enamel scarring that may occur during or after debonding. Additionally, if the profilometer detected a smoother area after polishing, some enamel must have been removed. This study, however, did not investigate exactly how much enamel may have been removed after polishing.

5. Conclusion

There was no statistically significant difference in enamel surface roughness after polishing between traditional orthodontic polishing systems and the selected novel polishing systems. SEM and 3D analysis revealed similar findings. The results show that there is no necessity for specific orthodontic polishing systems, as the enamel surface roughness is similar while comparing the polishing methods used by general practitioners and orthodontists.

6. Ethics statement

The manuscript contains the following statement that the work has been approved by the appropriate ethical committees related to the institution in which it was performed.

Prior to initiation of this study, approval was obtained from the Institutional Biosafety Committee of LSU Health New Orleans, Health Sciences Center, IBC# 18037.

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CRedit authorship contribution statement

Elizabeth A. Melvin: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Qingzhao Yu:** Data curation, Formal analysis, Writing – review & editing. **Xiaoming Xu:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Camille G. Laird:** Data curation, Investigation, Writing – review & editing. **Paul**

C. Ambruster: Conceptualization, Methodology, Supervision, Writing – review & editing. **Richard W. Ballard:** Conceptualization, Methodology, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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