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Scanning Electron Microscopic Analysis of Enamel Morphology Post Interproximal Reduction, Finishing and Sealant Application: An *in Vitro* Study

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Abstract

Background: The objective of present study was to qualitatively and quantitatively evaluate the surface irregularities produced by three different methods of IPR followed by polishing and sealant application, using Scanning Electron Microscope (SEM) and Profilometer.
Methods: The study sample comprised of 100 extracted permanent maxillary 1st premolar teeth divided into 10 groups with 1 control group and 9 experimental groups according to the stripping method employed (hand-pulled abrasive strips, air rotor stripping and IPR file system) and subsequent finishing procedures (sealant application and polishing strips). The statistically significant intergroup comparison for the difference of mean scores between independent groups and difference among groups was determined by t test, one-way analyses of variance (Anova) and Tukey HSD Post Hoc test at level of significance set at 5%. or $p < 0.05$.
Results: Surface roughness value (Ra) obtained using Profilometer and SEM images at 500x and 1500x magnification of IPR using diamond burs followed by sealant application (Group 7) had reasonably smooth surface. IPR File System when used with non-possibility of carrying out any adjunct finishing procedures (Group 4), disturbed the enamel surface to the least.
Conclusion: Finishing procedures used post IPR gave smoother enamel surfaces making it necessary for reduction of number and depth of grooves created by IPR. Best combination which produced minimal enamel surface roughness post IPR in present study was diamond burs followed by sealant application.

Keywords: IPR, mechanical stripping, sealants, polishing strips, Profilometer

1. Introduction

Stripping is a method that has been described in the literature for decades[1]. Interproximal reduction (IPR), also known as enamel stripping, reproximation, or slenderization, involves intentionally removing a portion of enamel from the interproximal contact area, thereby reducing the mesio-distal width of a tooth.

There has been an increasing trend in the use of the IPR technique (66%) as it has far-reaching implications for the correction of crowding/regression of crowding, esthetics, cosmetic recontouring, increased post-treatment stability, Bolton tooth size discrepancy, elimination of black gingival triangles, and bilateral tooth asymmetries (2, 3).

IPR can be performed using a variety of techniques. These include manual stripping with a thin metal strip, rotary instruments such as diamond disks on a contra-angle handpiece, special drills (tungsten carbide and diamond) with deactivated tips (4), and special kits for IPR with segmented oscillating diamond disks and strips attached to a contra-angle handpiece (5) Reports of increased incidence of periodontal disease and caries as the remaining grooves predispose a tooth to debris and bacterial attachment after IPR (6). Polishing after IPR to reduce the depth of the furrows using coarse abrasives and the application of sealants has been suggested by various authors to obtain a smooth enamel surface (7, 8).

The aim of the present study was to qualitatively evaluate, using scanning electron micrographs (SEM) at 500x and 1500x magnification, the changes in the enamel surface that occur when hand-drawn strips, diamond drills, and IPR file systems are used according to the interproximal reduction procedure standardized by Sheridan (IPR). In addition, the effectiveness of polishing strips or the use of sealers in altering the surface morphology that occurs after IPR was also evaluated.

Furthermore, the results of SEM were quantitatively supported using profilometers (surface roughness testers) to evaluate the change in enamel topography in the different experimental groups and to reach a conclusion on the optimal method for interproximal reduction and reworking of the reduced enamel surface.

2. Methods

The sample size for the study was estimated using Epi Info software (TM) considering the standard deviation between the control and experimental groups from the previous study.

Statistical Package for Social Sciences (SPSS) version 22.0 (IBM SPSS Statistics for Mac, Armonk, NY: IBM Corp, USA) was used for the analysis. The significance of the test was 0.80 or 80%. Considering the error and dropouts, the sample size was 10 per group.

100 extracted permanent maxillary 1st premolars were selected from the total 150 procured specimens using the following inclusion and exclusion criteria.

Inclusion criteria

Intact proximal enamel surface of extracted premolars without caries, restorations and cracks.

Exclusion criteria for sample

Teeth with insufficient enamel thickness, hypoplastic enamel or developmental defects, loss of proximal surface due to wear.

Sample preparation

The extracted teeth were washed with distilled water and disinfected with 70% ethanol. They were randomly divided into 10 groups (n=10). Each tooth was mounted with a self-curing polymerization resin and color-coded for easy identification. The prepared specimens were stored in distilled water.

Prior to IPR, periapical radiographs of each mounted tooth were taken to assess the thickness of the proximal enamel, followed by finishing and application of the sealant in each group.

- **Group 1 (White):** control group; no. IPR
- **Group 2 (Yellow):** IPR with hand-held abrasive strips.
- **Group 3 (Green):** IPR using diamond grinders.
- **Group 4 (Pink):** IPR using the IPR file system
- **Group 5 (Blue):** IPR using hand-guided sanding strips and subsequent sealing
- **Group 6 (Orange):** IPR using hand-guided sanding strips followed by finishing with Soflex polishing strips
- **Group 7 (Olive):** IPR using diamond cutters, followed by sealing.
- **Group 8 (Black):** IPR using diamond burs followed by finishing with Soflex polishing strips
- **Group 9 (Red):** IPR using the IPR file system followed by application of the sealer.
- **Group 10 (Copper):** IPR using the IPR file system followed by finishing with Soflex polishing strips

Before peeling, a contact breaker of 50 and 100 µm was used to make room for the application of the method IPR.

Group 1 served as the control group and groups 2, 5 and 6 were abraded with safe, medium-coarse Horico strips in a back- and-forth motion. Abrading was done under wet conditions. The strip was held in the hand and guided interdentally with light force. A new abrasive strip was used for each specimen to avoid abrading with a blunt abrasive strip and to maintain uniformity.

Groups 3, 7, and 8 were machined with safely tipped diamond burs of size 0.040 mm, medium grit, tapered shape with pointed end, and 8 mm length on a high-speed water-cooled handpiece. The drill was set below the contact point and guided with light strokes in the occlusal direction and alternately from buccal to lingual to produce proper interproximal morphology and parallel enamel walls. A new diamond bur was used for each specimen.

Groups 4, 9, and 10 were stripped using the IPR file system. The system consisted of mini-stripping strips mounted on a special contra-angle handpiece with a tip that oscillated from buccal to lingual. Single-sided strips of medium grit (blue color) attached to the handpiece were used for stripping. The strips oscillated back and forth interdentally and gradually exfoliated the enamel. A new strip was used for each sample to avoid ablating with a blunt strip, as the grains of the strip are lost during the procedure.

The IPR gage with a range of 0.10 mm to 0.50 mm was used to measure the amount of reduced enamel after IPR to ensure that no more than 0.25 mm of enamel thickness was removed.

All 10 groups of premolars were reduced by the same dentist using a standard technique to avoid minimal errors. Teeth were removed randomly to avoid operator bias.

Helioseal® -F (Ivoclar Vivadent, Bendererstrasse) was applied to the proximal surfaces of groups 5, 7 and 9. The tooth surfaces were first rinsed and then dried. The sealant was cured for 30 seconds with a light curing unit.

Polishing strips - Soflex medium grit (3M EPSE, United States) were used to polish the abraded enamel on the surfaces of groups 6, 8, and 10. The strips were pulled by hand under constant pressure and inserted interdentally. Forty passes of the strips were used on each surface. The strip was changed after each specimen as it wore off quickly.

The prepared specimens were removed from their holders and cut along the long axis to separate both proximal surfaces.

A scanning electron microscope was used to qualitatively assess the surface of the enamel after the various methods of IPR and finishing. The specimens were dehydrated in an incubator for 40 minutes. After they were thoroughly dried, they were mounted on aluminum stubs with adhesive tape and labeled. The samples were then coated with colloidal gold in a gold sputtering machine (JEOL, JFC 1100) for 20 minutes and then viewed under a scanning electron microscope (JEOL, JSM - 6100 Japan) at 10 kV accelerating voltage and low vacuum chamber pressure with a working distance of 15 mm. Photomicrographs were taken at the center of each test surface under 500x and 1500x magnification to maintain homogeneity. Images were captured using a camera attached to the scanning electron microscope and displayed on the computer screen.

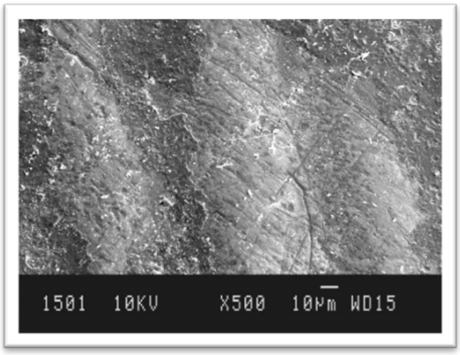
The dried samples were stabilized on clay and evaluated using a profilometer (Mitutoyo SJ-400). The diamond stylus (2µm tip radius) was used under constant measurement along the center of the abraded interdental enamel for standardization. The stylus physically moving along the surface recorded the height, flatness, step and curvature of the surface. The device was calibrated using a standard reference point and then set to move at a rate of 0.5 mm/second over a length of 1 mm during the test. For each sample, 3 images were taken with the contact pin placed perpendicular to the enamel surface, and the results were averaged.

3. Results

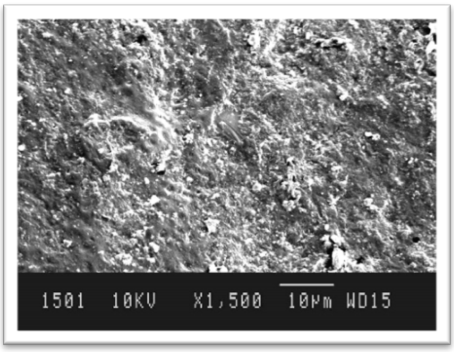
Intergroup comparison of scanning electron micrographs of proximal enamel surfaces of extracted teeth of control group (group 1) with three ipr methods (group 2, 3 and 4)

GROUP 1. Control Group

The surface of the enamel in the control group (Group 1) was not completely smooth. Some slight grooves and irregularities were seen, which could be due to wear caused by tooth brushing (Figs. 1 and 2).



a-GROUP 1
(500X MAGNIFICATION)



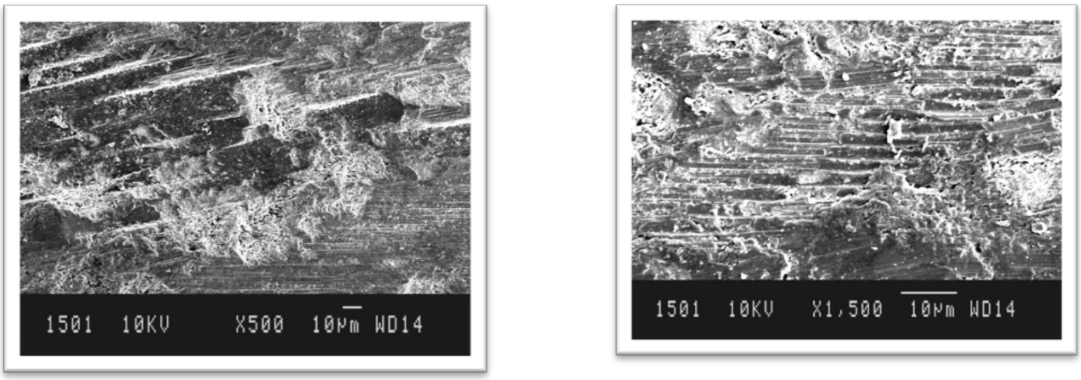
b- GROUP 1
(1500X MAGNIFICATION)

c- GROUP 2 (500X MAGNIFICATION) | d-GROUP 2 (1500X MAGNIFICATION)

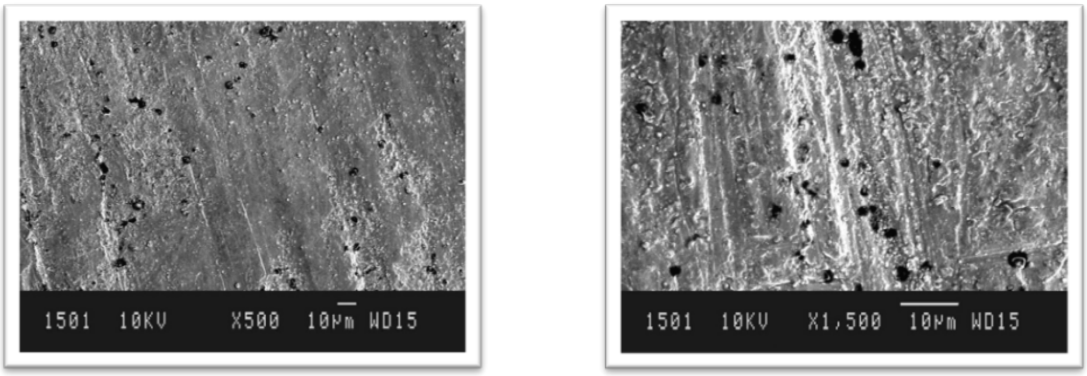
Figure 1.

GROUP 2. Stripping by hand pulled abrasive strips

The surface of the enamel differed markedly from that of the control group. The surface appeared to be criss-crossed by deep and irregular furrows forming hills and valleys, and no rod-like structure was evident in the enamel. The deep furrows were irregularly distributed and became clearly visible under both magnifications, 500x and 1500x. (Figs. 3 and 4)



e- GROUP 3 (500X MAGNIFICATION) | f- GROUP 3 (1500X MAGNIFICATION)

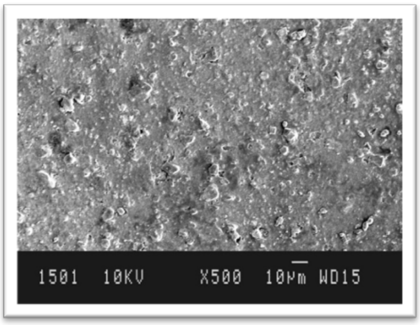


g- GROUP 4 (500X MAGNIFICATION) | h-GROUP 4 (1500X MAGNIFICATION)

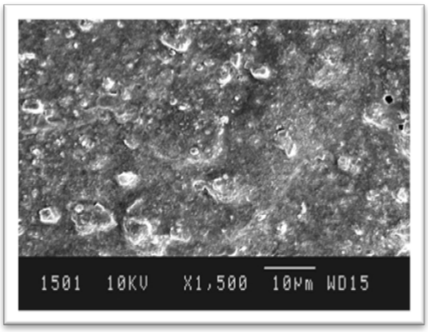
Figure 2.

GROUP 3. Stripping by diamond burs

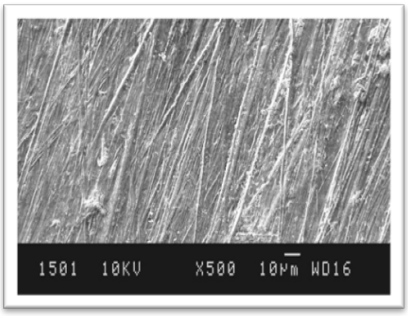
The topography of the enamel was significantly altered by the use of diamond cutters for interproximal reduction, as these grooves appeared to be of greater depth and size. Step-like depressions and deep craters were seen at both 500x and 1500x magnification. (Figs. 5 and 6)



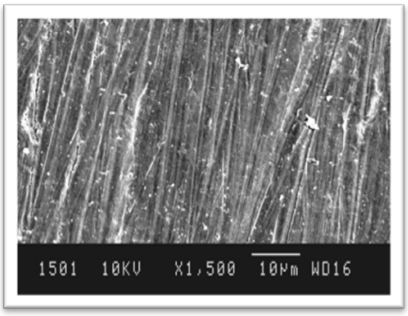
i- GROUP 5
(500X MAGNIFICATION)



j- GROUP 5
(1500X MAGNIFICATION)



k- GROUP 6
(500X MAGNIFICATION)

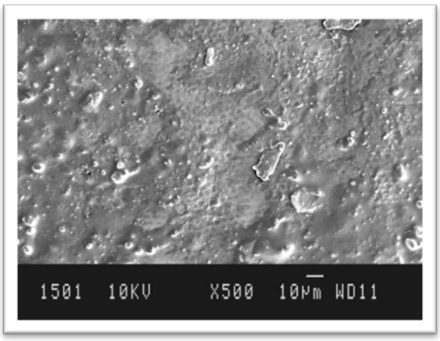


l-GROUP 6
(1500X MAGNIFICATION)

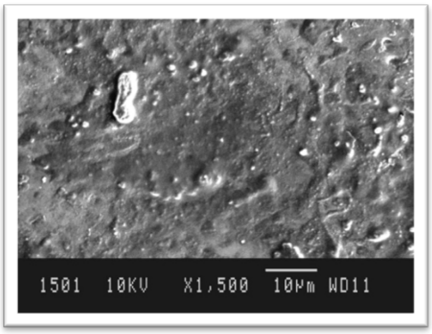
Figure 3.

GROUP 4. Stripping by IPR file system

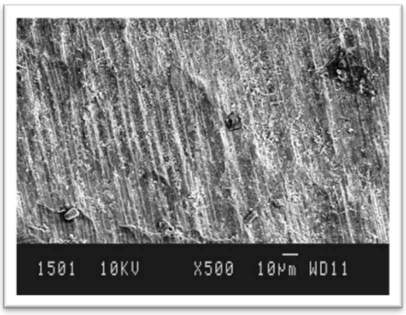
The enamel surface after stripping with the IPR file system appeared smooth compared to hand-drawn strips and diamond burs, as the depth of the grooves and valleys was significantly shallower and shallower at both 500x and 1500x magnification. (Fig. 7 and 8)



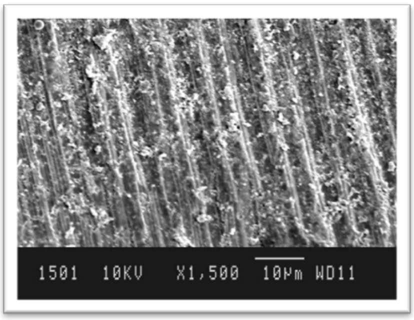
m- GROUP 7
(500X MAGNIFICATION)



n- GROUP 7
(1500X MAGNIFICATION)



o- GROUP 8
(500X MAGNIFICATION)



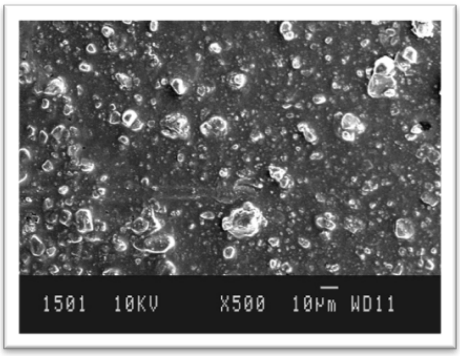
p- GROUP 8
(1500X MAGNIFICATION)

Figure 4.

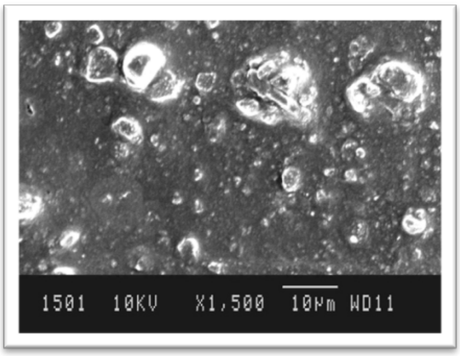
Intergroup comparison of scanning electron micrographs of proximal enamel surfaces of extracted teeth post stripping using hand pulled abrasive strips (group 2) with adjunct finishing procedures (group 5 and 6)

Group 2 (Surfaces subjected to interproximal reduction using abrasive strips) vs Group 5 (Surfaces subjected to sealant application post reduction using abrasive strips)

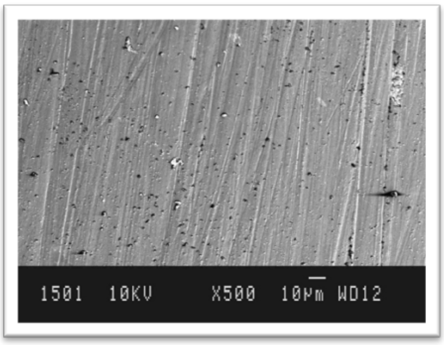
Application of the sealer after reduction with hand-drawn strips showed that the effect of the sealer was limited to filling in some areas of the reduced surface. The surface obtained appeared porous. The stripped surface appeared grainy due to sealing clusters, but was smoother under both 500x and 1500x magnification compared to the surface obtained without sealing after reduction with hand-drawn strips (Group 2). (Figs. 9 and 10)



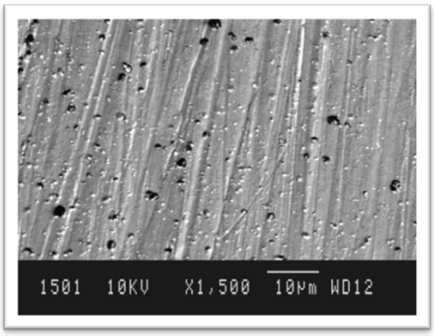
q- GROUP 9
(500X MAGNIFICATION)



r- GROUP 9
(1500X MAGNIFICATION)



s- GROUP 10
(500X MAGNIFICATION)



t- GROUP 10
(1500X MAGNIFICATION)

Figure 5.

Group 2 (Surfaces subjected to interproximal reduction using abrasive strips) vs Group 6 (Surfaces subjected to polishing strips post reduction using abrasive strips)

The application of finishing strips reduced the number of grooves caused by Horico strips and their depth. The grooves caused by stripping remained, but were shallower and rounder compared to unpolished surfaces. The surface obtained was prone to demineralization, but this risk was limited compared to an unpolished surface obtained only by hand-drawn strips (Group 2). (Fig. 11 and 12)

Intergroup comparison of scanning electron micrographs of proximal enamel surfaces of extracted teethpost stripping using diamond bur (group 3) with adjunct finishing procedures (group 7 and 8)

Group 3 (Surfaces subjected to interproximal reduction using diamond burs) vs Group 7 (Surfaces subjected to sealant application post reduction using diamond burs)

The application of a sealant after reduction with diamond burs proved beneficial in masking the deep grooves and stepladder appearance of the enamel surface that occurred during interproximal reduction of the enamel with diamond burs alone. A smooth enamel surface topography was obtained, with sealing clusters visible at both 500x and 1500x magnification. (Fig. 13 and 14)

Group 3 (Surfaces subjected to interproximal reduction using diamond burs) vs Group 8 (Surfaces subjected to polishing strips post reduction using diamond burs)

Finishing with polishing strips after removal with the air rotor was useful in reducing the grooves and furrows caused by the highly abrasive action of the drills. However, polishing with strips was not sufficient to ensure an adequate enamel surface. The enamel surface continued to appear rough with grooves and craters irregularly distributed over the entire reduced surface, although they were flatter and smoother and were visible under both 500x and 1500x magnification. (Figs. 15 and 16)

Intergroup comparison of scanning electron micrographs of proximal enamel surfaces of extracted teeth post stripping using ipr file system (group 4) with adjunct finishing procedures (group 9 and 10)

Group 4 (Surfaces subjected to interproximal reduction using IPR File system) vs Group 9 (Surfaces subjected to sealant application post reduction using IPR file system)

Application of the sealer after reduction with the IPR file system gave the reduced enamel a porous appearance. Sealer clusters were visible at both 500x and 1500x magnification. The surface obtained was smoother compared to the surface obtained after reduction with the IPR file system alone and also after finishing with polishing strips. (Fig. 17 and 18)

Group 4 (Surfaces subjected to interproximal reduction using IPR File system) vs Group 10 (Surfaces subjected to polishing strips post reduction using IPR file system)

Finishing the reduced surface with polishing strips after application of the IPR file system did not significantly improve the reduced enamel topography compared to IPR file system used alone or in conjunction with sealing. The finished enamel surface continued to exhibit an irregular surface with grooves and streaks visible under both 500x and 1500x magnification. (Figs. 19 and 20)

The Stylus Profilometer was used to obtain quantitative data on the roughness of the enamel surface. For each sample, 3 images were taken with the stylus placed perpendicular to the enamel surface, and the results were averaged. Statistical tests were used to compare and analyze statistically significant differences between the previously enumerated groups. The results are presented in Tables 1-6.

Table 1 shows the distribution of surface roughness values of ten groups (n=10) calculated by Stylus Profilometer (surface roughness metre). This shows that the extracted premolars in the control group (Group 1) had the smoothest surface with an Ra value of 0.46 ± 0.024µm. The Ra value was calculated using the formula total length of peaks + total length of valleys / total number of peaks and valleys.

Table 1. Surface Roughness (Ra) Value

GROUPS	MEAN ± SD Surface roughness (Ra)	Ra (min)	Ra (Max)
Group1 (Control group)	0.46 ± 0.024µm	0.43	0.49
Group 2 (IPR by Horico strips)	0.99 ± 0.023 µm	0.96	1.03
Group 3 (IPR by Diamond burs)	0.89 ± 0.021 µm	0.86	0.93
Group 4 (IPR by IPR file system)	0.69 ± 0.034 µm	0.61	0.72
Group 5 (IPR by Strips & sealant)	0.87 ± 0.023 µm	0.84	0.92
Group 6 (IPR by abrasive strips & soflex strips)	0.88 ± 0.011 µm	0.86	0.89
Group 7 (IPR by burs & sealants)	0.54 ± 0.015 µm	0.51	0.55
Group 8 (IPR by burs & soflex strips)	0.80 ± 0.009 µm	0.79	0.82
Group 9 (IPR by IPR file system & sealants)	0.55 ± 0.013 µm	0.53	0.56
Group 10 (IPR by IPR file system & soflex strips)	0.82 ± 0.005 µm	0.81	0.82

Table 2 shows that the value of surface roughness of control group (group 1) was compared with all experimental groups using unpaired t-test. There was a statistically significant difference in the surface roughness values of the groups subjected to the three IPR methods (abrasive strips, diamond drill and IPR file system) compared to the control group (Group 1).

Table 2. Intergroup comparison of surface roughness (ra) of control group with experimental groups

		Group	Mean Ra (µm)	SD	t test	p value
Group 1 (0.46±0.024)	VS	Group 2	0.99	0.023	49.961	<0.01*
		Group 3	0.89	0.021	46.500	<0.01*

	Group 4	0.69	0.034	18.050	<0.01*
	Group 5	0.87	0.023	39.968	<0.01*
	Group 6	0.88	0.011	49.806	<0.01*
	Group 7	0.54	0.015	8.651	<0.01*
	Group 8	0.80	0.009	37.301	<0.01*
	Group 9	0.55	0.013	9.119	<0.01*
	Group 10	0.82	0.005	47.737	<0.01*

*: statistically significant (p value <0.05)

A statistically significant difference was also found when the control group was compared to the finishing methods applied after IPR using Soflex strips and sealer.

Table 3, 4, 5 and 6 shows the comparison between the 10 groups using Tukey HSD post hoc test.

Table 3. Intergroup comparison of mean surface roughness value (ra) of three stripping methods without adjunct finishing procedures (group 2, 3 and 4) using tukey hsd post-hoc test

Groups Compared	Mean Difference	p-value
GROUP 2 vs GROUP 3	-0.1000	<0.01*
GROUP 2 vs GROUP 4	-0.3000	<0.01*
GROUP 3 vs GROUP 4	-0.2000	<0.01*

*: statistically significant difference (p value <0.05)

A statistically significant difference ($p < 0.05$) was observed in the comparison between group 2 i.e., hand drawn abrasive strip (mean Ra value 0.99 ± 0.023μm) and group 3 (diamond drill, mean Ra value 0.89 ± 0.021μm), group 3 with group 4 (IPR file system, mean Ra value 0.69 ± 0.034μm) and group 2 with group 4. The smoothest surface was obtained with group 4 i.e., IPR using IPR file system with mean Ra value 0.69 ± 0.034μm. (Table 3)

When comparing between groups, a statistically significant difference was found between group 2, i.e., hand drawn sanding strips (mean Ra value 0.99 ± 0.023 μm), and groups 5 and 6, i.e., hand drawn sanding strips followed by sealing and finishing (mean Ra value 0.87 ± 0.023 μm and 0.88 ± 0.011 μm, respectively).

When comparing groups 5 and 6, a statistically insignificant difference was found with a p-value of 0.427. The comparison between the groups revealed that the smoothest surface was obtained in group 5, i.e., by interproximal reduction with abrasive strips followed by sealing with a mean Ra value of 0.87 ± 0.023 μm. (Table 4)

Table 4. Intergroup comparison of mean surface roughness value (ra) using hand pulled abrasive strips (group 2) and adjunct finishing procedures (group 5 and 6) using tukey hsd post-hoc test

Groups Compared	Mean Difference	p- value
GROUP 2 VS GROUP 5	-0.1200	<0.01*
GROUP 2 VS GROUP 6	-0.1100	<0.01*
GROUP 5 VS GROUP 6	0.0100	0.427

*: statistically significant difference (p value <0.05)

Table 5. Intergroup comparison of mean surface roughness value (ra) using diamond burs (group 3) and adjunct finishing procedures (group 7 and 8) using tukey hsd post-hoc test

Groups Compared	Mean Difference	P Value
Group 3 vs Group 7	-0.3500	<0.01*
Group 3 vs Group 8	-0.0900	<0.01*
Group 7 vs Group 8	0.2600	<0.01*

*: statistically significant difference (p value <0.05)

A statistically significant difference ($p < 0.05$) was observed when comparing groups between group 3 (stripping with diamond burr, mean Ra value (0.89 ± 0.021 μm) and group 7 (stripping with diamond burr followed by sealing application, mean Ra value of 0.54 ± 0.015 μm), group 3 and group 8 (stripping with diamond drill followed by finishing with polishing strip, mean Ra value of 0.80 ± 0.009 μm) and group 7 with group 8. The smoothest surface was obtained in group 7, *i.e.* stripping with diamond drill followed by sealer application, with mean Ra value of 0.54 ± 0.015 μm. (Table 5)

A statistically significant difference ($p < 0.05$) was found when comparing group 4, *i.e.* removal with the IPR file system (mean Ra value 0.69 ± 0.034 µm), with group 9, i.e. The smoothest surface was found in group 4, *i.e.* removal with the IPR file system and subsequent application of the sealant (mean Ra value 0.55 ± 0.013), in group 4 with group 10, i.e. removal with the IPR file system and subsequent finishing with polishing strips (mean Ra value 0.82 ± 0.005 µm), and also in groups 9 and 10 in comparison with each other. The smoothest surface was obtained in group 9, *i.e.* removal with the IPR file system and subsequent application of the sealer, with a mean Ra value of 0.55 ± 0.013 µm. (Table 6)

Table 6. Intergroup comparison of mean surface roughness value (ra) using ipr file system (group 4) and adjunct finishing procedures (group 9 and 10) using tukey hsd post-hoc test

Groups Compared	Mean Difference	P Value
Group 4 vs Group 9	-0.1400	<0.01*
Group 4 vs Group 10	0.1300	<0.01*
Group 9 vs Group 10	0.2700	<0.01*

*: statistically significant difference (p value <0.05)

4. Discussion

Surface roughness analysis by SEM revealed that the untreated enamel surfaces had some rough, uneven surfaces that were due to slight interproximal wear of the enamel by brushing and flossing. These results were in agreement with the findings of Grippaudo C et al. (1). All experimental groups were significantly rougher compared to the control group.

Comparison of the SEM photomicrographs of the enamel surface after flossing in groups 2, 3 and 4 showed that the enamel surfaces of the teeth in group 2 had deep and irregular grooves that formed hills and valleys and were significantly rougher than those of groups 3 and 4. The enamel surface of group 3 had grooves that appeared to be deeper and larger. Ladder-like depressions and deep craters were visible. The SEM photomicrographs of the melt surfaces of group 4 appeared to be smooth, as the depth of the grooves and valleys were much shallower and shallower than those of groups 2 and 3 at both 500x and 1500x magnification.

When comparing hand-drawn strips and their associated finishing procedures (Group 2 with 5 and 6), the finishing procedures with Soflex polishing strips reduced the depth and number of furrows created by rounding them, and the sealant after peeling covered the furrows and furrows, and the surface appeared smooth compared to the images of the enamel surface without additional finishing procedure, but rough compared to Group 1.

The SEM photomicrographs of group 3 and the associated finishing procedures (groups 7 and 8) were compared. The application of a sealant after reduction with diamond burs was found to be beneficial in masking the deep grooves and step ladder appearance of the enamel surface. The smooth surface topography of the enamel was achieved with clusters of the sealant visible under both 500x and 1500x magnification. The polishing strips and subsequent removal with the air rotor were useful in reducing the grooves and furrows formed by the drills, but were not sufficient for an adequate enamel surface.SEM For Group 4 and its associated finishing procedures, Groups 9 and 10, the enamel surface appeared smooth after the initial removal with the IPR file system and subsequent finishing by applying the sealer, as the sealer penetrated the irregularities and gave the enamel a smooth appearance. After application of the polishing strips, the enamel surface continued to exhibit an irregular surface with grooves and streaks visible under both 500x and 1500x magnification.

The values of SEM were further supported by a quantitative assessment of the enamel surface after IPR using a profilometer. The surface roughness value (Ra value) showed that the untreated enamel surfaces (group 1) had some roughness, which was due to slight interproximal wear of the enamel by brushing. All experimental groups were significantly rougher compared to the control group. (Table 1 and 2)

Comparison of the mean surface roughness (Ra) of three stripping methods without additional finishing processes (groups 2, 3 and 4) showed that the smoothest enamel surface was obtained after IPR in group 4, IPR by the IPR file system.

The surface roughness (Ra) value of group 2 compared to the additional finishing procedures in groups 5 and 6 showed that the Ra value decreased after the finishing procedures, indicating a smoother enamel surface. These results were consistent with the results of SEM analysis.

Comparison of the mean surface roughness (Ra) of diamond cutters, group 3, and the associated finishing processes, groups 7 and 8, showed that the smoothest surface was obtained when removing with diamond cutters followed by sealing with a mean Ra value of 0.54± 0.015 µm, which was closest to the value of the control group (0.46 ± 0.024µm). Both finishing groups 7 and 8 were smoother than group 3. SEM Photomicrographs confirmed similar results.

Comparison of the mean surface roughness (Ra) of group 4 (0.69 ± 0.034µm) and the associated finishing processes, groups 9 and 10, showed that the smoothest surface was obtained in group 9 (0.55 ± 0.013µm).

According to the surface roughness (Ra) values, IPR using diamond cutters in conjunction with the sealer and IPR using the file system in conjunction with the sealer gave the smoothest surfaces. IPR using only hand drawn sanding strips resulted in the roughest surfaces (Table 1).

The present study found that the IPR file system is reasonably effective for reduction without additional finishing procedure and is better than hand-drawn abrasive strips and diamond burs as it disturbs the enamel surface the least.

The best results were obtained by applying a sealant after interproximal reduction, as it covered the irregularities caused by stripping. Chirla A et al (7) had similar results after the application of sealant. The effectiveness of sealants in preventing caries is well documented, and properly applied sealants ensure long-term retention (7,8,11-15).

The advantage of sealing abraded enamel surfaces for the dentist is that it saves chairside time spent finishing the abraded surfaces with a series of fine abrasives.[16] On the other hand, sealant failures are usually due to a flawed procedure evidenced by moisture contamination prior to sealant application (9,17-18), technical difficulties in maintaining a dry working field, delay of the intraoral remineralization process, and cytotoxic effects of the sealant against sealing of proximal enamel surfaces (10,19). Difficult access to the reduced interproximal surfaces of posterior teeth may also hinder the clinical application of sealant, and physiological wear is an obstacle to its effective duration (20). Applying a thick layer instead of a thin layer may lead to plaque accumulation and the formation of pockets in the undercut (21). The sealant may discolor or peel over time, requiring frequent reapplication (22).

The use of polishing strips to rework the reduced enamel surface helps to reduce the surface retention ability of interproximally reduced surfaces. SEM Photomicrographs of the present study show that post-treatment of enamel surfaces with Soflex polishing strips reduced furrows and grooves on the entire surface after pickling. The Soflex strips resulted in significant smoothing of the furrows, but complete elimination of irregularities was not achieved.

By using intra-oral simulated conditions in this study, an attempt was made to take advantage of the in vitro system and still achieve clinical relevance of the results. The study could be further improved if the procedure was evaluated in vivo, as the in vitro evaluation lacked intraoral conditions and their effects on enamel surface roughness after reduction and finishing.

Since none of the experimental groups achieved the Ra value comparable to the unmodified enamel surface, it is important to provide hygiene instructions to patients undergoing interproximal reduction, including plaque control and prophylactic measures such as topical application of fluoride, to prevent adverse consequences of the procedure.

CONCLUSIONS

IPR represents a valid therapeutic modality in the hands of an orthodontist which, when performed efficiently in selected cases, helps to achieve treatment goals without compromising the integrity of the dental and periodontal tissues.

The present study included modern IPR techniques that can be related to daily orthodontic clinical practice, with the aim of finding a method that disturbs enamel topography as little as possible.

The following conclusions were drawn from the results of the present study:

1. The hand-held mechanical comminution process resulted in the greatest surface roughness.
2. The IPR filing system, when used without the ability to perform additional finishing procedures, disturbed the enamel surface the least.
3. The application of a sealer according to IPR resulted in smoother enamel surfaces.
4. Soflex polishing strips reduced surface roughness, but the enamel surface appeared rougher compared to the unmodified enamel surface.
5. Finishing procedures according to IPR resulted in smoother enamel surfaces, so it

was necessary to reduce the number and depth of grooves.

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