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# Comparison of Enamel Roughness and Calcium Release between Manual and Mechanical Stripping with and without Polishing after Demineralization

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**ABSTRACT**

**Objectives:** Proximal enamel stripping is one way to create space in orthodontic treatments that leaves grooves on the enamel surface and predispose teeth to caries. The aim of this study was to compare the two common stripping systems and the effect of polishing after the stripping process on the level of surface roughness.

**Materials and Methods:** Twenty-five extracted teeth were randomly divided into five groups:untreated control (C), mechanical stripping (Sn), mechanical stripping and polishing (Sp), manual stripping (Dn), manual stripping and polishing (Dp). Mechanical stripping used a SWISS denta care Quality oscillating system, manual stripping used Dentaurum hand tapes, and polishing used Soflex disks. Teeth underwent pH-cycling and the amount of released calcium was measured by spectrometry. Samples were examined under atomic force microscopy (AFM) before and after demineralization. Baseline and post-demineralization surface roughness values (Ra, Rq, Rz) were calculated. Finally, scanning electron microscopy (SEM) images were obtained from two samples of each group. data analysis was done by One-way ANOVA. P-value<0.05 was considered statistically significant.

**Results:** There was no significant difference between the stripping methods in terms of surface roughness parameters, but there was a significant difference between the polished and unpolished groups ($P<0.05$). Calcium release was significantly lower in the Sp group compared to the other groups ($P<0.05$). In SEM images, the least amount enamel damage was related to the Sp group.

**Conclusion:** Unlike stripping systems, polishing is considerably useful in decreasing enamel roughness. Totally, mechanical stripping and polishing has shown the best consequences on enamel structure.

**Keywords:** Dental Polishing; Microscopy, Atomic Force; Microscopy, Electron, Scanning; Orthodontic Appliances; Spectrophotometry

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## INTRODUCTION

Dental crowding and space insufficiency are among the most frequently encountered orthodontic abnormalities. If left untreated, approximately 50% of the 15–50-year-old population have mild to moderate mandibular crowding and irregularities in incisor teeth [1]. Orthodontic therapies entail a variety of techniques for space gaining, including tooth extraction, maxillary expansion, molar

distalization and incisor proclination. The appropriate technique is selected according to the patient's clinical condition. Non-extraction orthodontic therapy has gained increasing interest over the recent years. In this commentary, interproximal reduction (IPR) has become a widely accepted clinical procedure to promote space gaining in the dental arch [2, 3].
Incorporating IPR reduces the length of orthodontic treatment and results in stability in anterior inclination and transverse dimensions of the jaw. Although this method is increasingly used today, there are concerns about IPR performance as the enamel structure that provides chemical, thermal, and abrasive protection is removed. The surface roughness caused by IPR may increase the adhesion of cariogenic bacteria and increase the risk of caries. However, long-term clinical studies do not show iatrogenic degeneration such as dental caries, gingival disease, and increased bone loss following IPR [4-6]. Proximal reduction can be achieved by Air-rotor stripping (ARS) with tungsten carbide burs or diamond burs and diamond-coated strips, handpiece or contra-angle mounted diamond-coated stripping disks or handheld or motor-driven abrasive strips [6-9].
Each of the above-mentioned techniques have their own advantages and disadvantages. Air-rotor stripping can create substantially more space than other methods but produces more enamel roughness [10]. Although using hand-held strips is time consuming and may not be easy to handle in all posterior areas [11]; this technique has been recognized as the safest method in terms of heat generation [12].
Compared to manual abrasive strips, abrasive stripping systems based on oscillating motion with the help of motor-driven instrument have become a popular treatment option [11]. Studies have shown that these systems yielded better results than other techniques. Studies also have shown that grinding and polishing with these oscillating systems, such as the ortho-strip, creates a smoothness equivalent to that of unstripped enamel surfaces. It has also been reported that acid penetration of ortho-strip strips (Intensiv Dental SA, Montagnola, Switzerland) results in smoother surfaces than safe tipped bur kit OS discs (STARS burs, Raintree Essix, Inc. Metairie, LA, United States) and less acid penetration occurs in these systems [13-15].
Various studies have investigated the efficiency of ortho-strips in performing IPR and have shown the superiority of this system over others [13-16]. In these studies, only the extent of degradation and the properties of the stripped surfaces have been investigated. However, it is necessary for clinicians to understand the reaction of the stripped surfaces to decay and pH-cycling processes, which has not been investigated in previous studies.
Therefore, the aim of this study was to compare the effect of manual and mechanical stripping with or without polishing on the enamel roughness and calcium release after pH-cycling; which ultimately leads to finding the best stripping method with the least effect on caries susceptibility and the least amount of destruction of the enamel structure.

## MATERIALS AND METHODS

The study protocol was approved by the ethics committee of the university (IR.TUMS.MEDICINE.REC.1400.033).

***Sample size***

Sample size was calculated to be a minimum of 10 proximal surfaces from maxillary premolars in each group according to a previous study [17] assuming alpha=0.05 and beta=0.2, using one-way ANOVA power analysis feature of PASS15.

***Specimen preparation***

A total of twenty-five intact human maxillary premolars which were extracted due to orthodontic indications were collected. Teeth with carious lesions, defects, stains, fluorosis, any signs of demineralization, cracks or restorations, were discarded. Immediately after collection, the teeth were immersed in 0.9% saline. The attached tissues were removed and the teeth were rinsed under running water and cleaned using a sickle scaler. They were then immersed in 0.5% chloramine T solution at 4°C for a maximum of 7 days and embedded to the specimen carrier using self-cure acrylic resin for easy handling.
The twenty-five teeth (fifty available proximal

surfaces) were randomly divided in to five equal groups (n=5 teeth and obviously 10 proximal surfaces per group) according to the applied stripping protocol. The experimental groups were as follows:

***Group I:*** Control group with no stripping (C)

***Group II:*** Stripped with a quality oscillating system (Sn)

***Group III:*** Stripped with a quality oscillating system followed by polishing (Sp)

***Group IV:*** Stripped with two-sided manual abrasive strips (Dn)

***Group V:*** Stripped with two-sided manual abrasive strips followed by polishing (Dp)

Mechanical stripping was performed using SWISS denta care Quality oscillating system (groups Sn and Sp). Dentaurum hand tapes were used for manual stripping (groups Dn and Dp). Soflex disks were used for polishing (groups Sp and Dp).

***Study procedure***

All stripping procedures were carried out according to the manufacturer`s instruction and performed by a single operator. In order to equalize the amount of removed enamel, a digital gauge was used in the following order: first mesiodistal dimension of teeth was measured and then stripping was initiated until the digital gauge showed 0.25mm reduction in the mesiodistal dimension. Therefore, all samples were stripped 0.25mm. After stripping and polishing, samples were kept in 100ml of distilled water and were placed in an ultrasonic device for 2 minutes. Then teeth were removed from the acrylic bed and sectioned in a labiolingual direction so that each proximal surface could be evaluated under an atomic force microscope (AFM). The samples were examined under atomic force microscope (SOLVER NEXT) in semi contact mode. The Ra, Rq and Rz parameters were evaluated. Ra shows the overall surface roughness and is the arithmetic average of the absolute values of the profile heights over the evaluation length. Rq is defined as the mean root square average of the profile heights over the evaluation length and Rz is the average maximum peak-to valley height of 5 consecutive sampling depths.

Teeth were examined under a stereomicroscope (M80, Leica, Wetzlar, Germany) at ×10 magnification for observing the exact stripped surfaces and the control group in which teeth were not stripped were covered by a layer of nail polish. All teeth were subjected to the artificial demineralization process. Each sample was individually immersed in 80mL of demineralizing solution (pH 4.3) containing 0.075 molar of acetic acid (SIGMA CAS: 64-19-7), 2.0mM of calcium hydrogen phosphate (SIGMA CAS: 7757-93-9) at 37°C for 6 hours for a total of 15 days, then rinsed with double-deionized water [18]. After 6 hours of demineralization each sample was kept in 10mm of distilled water. Surface roughness was assessed by measuring the amount of released calcium in demineralization solution using atomic absorption spectroscopy (Spectr AA 220, Varian, Australia). After 15 days of demineralization, samples were again examined by AFM to measure surface roughness after demineralization. At the end two random samples from each group were prepared for Field emission scanning electron microscopy (FESEM) under ×300 magnification for qualitative evaluation and were scored by a blind operator according to enamel defects index (EDI) scoring system (Table 1).

**Table 1.** Enamel demineralization index scoring system

| Score | Surface characteristics |
|---|---|
| **0** | smooth surface without scratches, visible perikymata* |
| **1** | acceptable surface with fine scratches spread |
| **2** | rough surface with several rough scratches or visible minor grooves |
| **3** | surface with rough scratches, large grooves and enamel damage visible to the naked eye |

*Perikymata are transverse wavy ridges that correspond to the incremental lines of Retzius.

***Statistical analysis***

Data analysis was done by One-way ANOVA and Tukey's test in PASS15 software. P-value<0.05 was considered statistically significant.

## RESULTS

***Surface roughness***

The mean and standard deviation of Ra, Rq, and Rz parameters were measured before and after immersion in demineralization solution.

By subtracting the Ra, Rq, and Rz parameters after immersion in the demineralization solution from the corresponding baseline values, the magnitude of change in these parameters was determined and reported as ΔRa, ΔRq and ΔRz (Ra, Rq, and Rz parameters before and after exposure to demineralization solution are shown in figures 1-3).

One-way ANOVA showed a statistically significant increase regarding Ra ($p<0.0001$), Rq ($p<0.0001$) and Rz ($p<0.0001$) values after demineralization in all groups. Regarding Ra and Rq, the smallest changes were noted in Sp group, followed by Dp, C, Sn and Dn. There was a significant difference between polished groups (Sp and Dp) and unpolished groups (Sn and Dn). Regarding Rz, the smallest changes was noted in Dp group, followed by Sp, C, Dn and Sn.

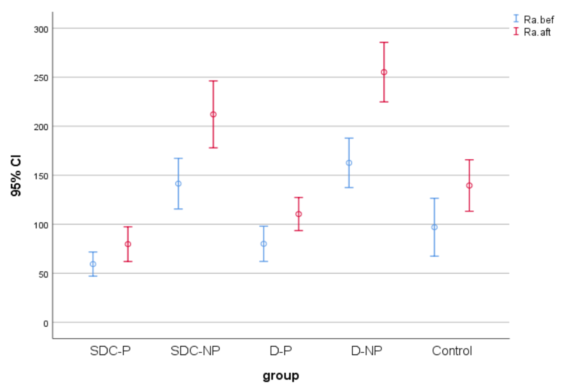


**Fig 1.** Amount of Ra parameter before and after exposure to demineralization solution. SDC: SWISS denta care; D: Dentaurum; P: Polished; NP: Not-polished.

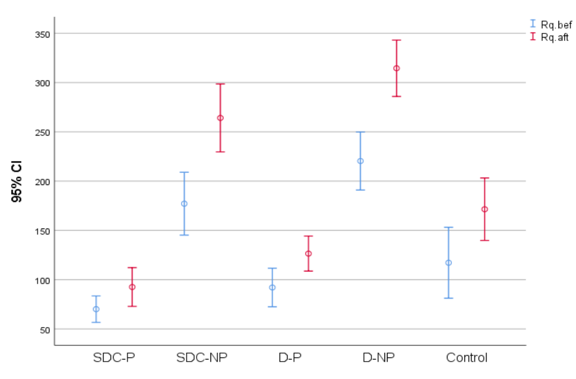


**Fig 2.** Amount of Rq parameter before and after exposure to demineralization solution. SDC: SWISS denta care; D: Dentaurum; P: Polished; NP: Not-polished.

There was a significant difference between polished groups (Dp and Sp) with Sn. Table 2 presents these findings in greater detail.

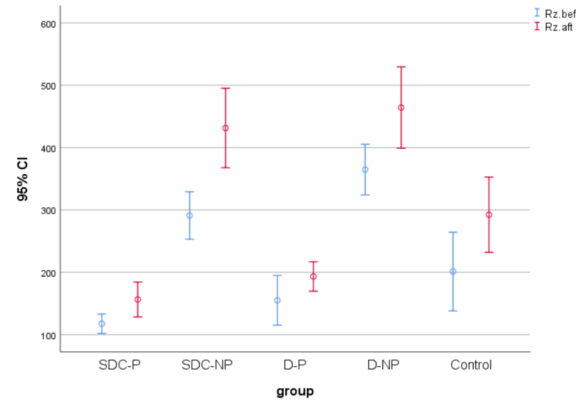


**Fig 3.** Amount of Rz parameter before and after exposure to demineralization solution. SDC: SWISS denta care; D: Dentaurum; P: Polished; NP: Not-polished.

**Table 2.** Pairwise comparison of different groups regarding the change of Ra (ΔRa), Rq (ΔRq) and Rz (ΔRz) after immersion in demineralization solution using Tukey's test.

| Groups | | Mean difference± SD error | | |
|---|---|---|---|---|
| | | ΔRa | ΔRq | ΔRz |
| Sp | Sn | -50.31± 13.12* | -64.54± 13.78* | -101.44± 26.18* |
| | Dp | -10.02± 13.12 | -11.89± 13.78 | 0.78±26.18 |
| | Dn | -72.17± 13.12* | -71.61± 13.78* | -60.56± 26.18 |
| | C | -22.19± 13.12 | -31.81± 13.78 | -52.30± 26.18 |
| Sn | Dp | 40.29± 13.12* | 52.64± 13.78* | 102.22± 26.18* |
| | Dn | -21.85± 13.12 | -7.06± 13.78 | 40.87± 26.18 |
| | C | 28.12± 13.12 | 32.72± 13.78 | 49.13± 26.18 |
| Dp | Dn | -62.15± 13.12* | -59.71± 13.78* | -61.35± 26.18 |
| | C | -12.17± 13.12 | -19.92± 13.78 | -53.09± 26.18 |
| Dn | C | 49.97± 13.12* | 39.79± 13.78* | 8.26± 26.18 |

*Indicates a statistically significant difference. C: Control group with no stripping; Sn: Stripped with a quality oscillating system; Sp: Stripped with a quality oscillating system followed by polishing; Dn: Stripped with two-sided manual abrasive strips; Dp: Stripped with two-sided manual abrasive strips followed by polishing; SD: standard

### Amount of released Calcium

The mean amount of calcium released in the demineralization solution was measured. One-way ANOVA showed significant differences between all groups. The lowest amount of released calcium was observed in the Sp group followed by Dp, Sn, C and Dn group, respectively (figure 4).

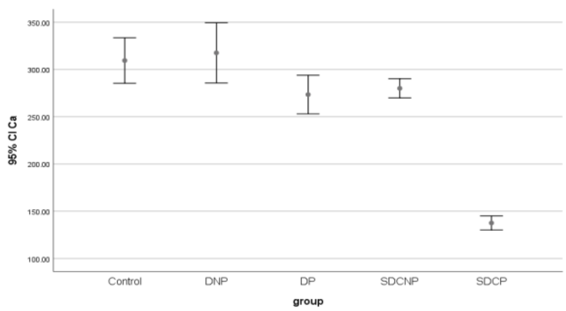


**Fig 4.** Calcium released (mg/liter) in different groups before and after demineralization. SDC: SWISS denta care; D: Dentaurum; P: Polished; NP: Not-polished.

Released calcium in the Sp group was significantly lower in comparison to other groups. The amount of calcium in Dp and Sn was significantly lower in comparison to Dn. The greatest amount of released calcium was observed in Dn (Table 2).

### Scanning electron microscopy

Figure 5 shows the SEM evaluation of enamel in proximal surfaces after stripping with different methods and is scored by EDI scoring system. The magnification in images was 300 and 100µ scale bar was used. Surfaces stripped by oscillating system showed relatively smoother surfaces in comparison to mechanical strips. Surfaces which were stripped by oscillating system and polished by sof-lex disks showed even smoother surfaces than the control samples.

## DISCUSSION

According to our literature review, multiple studies have compared the surface roughness by different methods secondary to stripping with oscillating tools and other methods and have presented conflicting results [12, 13, 19, 20]. Evaluation of surface roughness can be conducted using different quantitative methods such as profilometry and qualitative methods such as SEM and atomic force microscope (AFM). SEM is one of the most common methods that is used when the surface is scratched and distorted, although SEM has limitations in defining the surface topography and only provides a two-dimensional image [21]. Another method to evaluate the surface roughness is mechanical and optical profilometry [22]. AFM is a technique that has recently gained popularity in dentistry; in which the surface of the sample is scanned with a probe or lever. AFM records the interaction between the probe and the sample's surface [23].

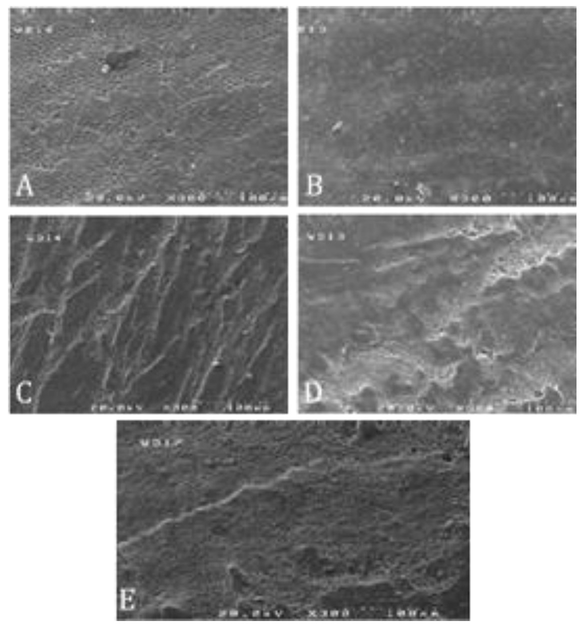


**Fig 5.** SEM evaluation; A: sample from C group with EDI score=1; B: sample from Sp group with EDI score=0; C: sample from Sn group with EDI score=2; D: sample from Dp group with EDI score=3; E: sample from Dn group with EDI score=3.

In this study, we used AFM and SEM to investigate surface roughness. AFM has been proven to be useful for investigating small irregularities on hard surfaces. The advantage of AFM is that it provides both three- and two-dimensional images while requiring minimal sample preparation. Traditionally, SEM, which is a qualitative method, has been used to investigate surface roughness. As a result, because it does not give us quantitative data, it does not have the ability to compare the surface

roughness of different samples [21, 24-29].
Among the previously conducted studies, a study by Danesh et al. was the only experimental study to subject specimens to demineralization and demineralization solution after stripping, and then measure the surface roughness through profilometry, SEM, and polarization microscopy [30]. No other study has to date evaluated the effect of pH-cycling after stripping. We`ve also used demineralization and demineralization solution.
In current research, according to the obtained results, there was no statistically significant difference in surface roughness parameters between Sp and Dp groups. In Danesh et al. study [30], the control group showed a non-significant decrease in the surface roughness parameter (Ra) after demineralization, which is in contrast to our study in which the control group showed a significant increase in surface roughness. This difference can be due to the difference in the study procedures regarding the formulation of the demineralization solution and the duration of the demineralization period. The cited authors used a demineralization solution which consisted of 1.6g (1.6%) hydroxyethyl cellulose (HEC), 33mL distilled water, 15mL KCl (1mol/L), 33mL sodium acetate (0.2mol/L), 15mL liter of acetic acid (0.2mol/L), 1 mL of $KH_2PO_4$ (90mmol/L), and 1mL of $CaCl_2$ (150mmol/L), while we used 40mL of demineralizing solution containing 0.075 M acetic acid and 2mM calcium hydrogen phosphate. In the mentioned study, specimens were kept in the demineralization solution for 24 hours, while in the present study specimens were kept in the demineralization solution for a much longer period, i.e., 6 hours a day for 15 days.
There was statistically significant difference between the polished and unpolished groups. The reason for the surface roughness parameters being lower in the polished groups in comparison to the control group can be attributed to the fact that the smear layer resulting from stripping and polishing fills the surface irregularities and creates a more uniform surface than the control group that did not receive any stripping or polishing [31]. Also, considering that the control group had been in the oral environment for a long time and has been exposed to various factors, it covers a wider range of surface roughness, while the other groups have been subjected to stripping and polishing and are more uniform. Evaluating the results of the surface roughness parameters showed that regardless of the type of stripping method, performing the final surface polishing yields surface roughness equal to the control group [32].
In our study, all parameters of surface roughness increased after exposure to demineralization solution. ΔRa and ΔRq parameters did not show any significant differences between the two polished groups and between the polished groups and control group. However, these parameters were proven to be significantly lower in polished groups in comparison to unpolished groups.
The ΔRz parameter in the polished groups (Dp and Sp) was significantly lower than the unpolished oscillatory group (Sn). Although the reported ΔRz values were less in the polished groups compared to the Dn group, however this difference was statistically insignificant [33].
It has been stated that changes in the Ra parameter greater than 0.3μm can be detected by patients [34]. Therefore, considering that the mean ΔRa values were less than this number in all experimental groups, none of the Ra changes would be detectable by patients. On the other hand, the critical Ra value for bacteria adhesion and colonization is reported to be 0.2μm [35], which according to the results of our study, can be an issue in Sn and Dn groups, which did not receive any sort of polishing.
Several methods have been used to evaluate the effectiveness of interventions on tooth structure to provide resistance to demineralization such as micro-hardness measurements [36], electron microscopic evaluations, measurements of calcium and phosphorus ions released in the dissolved demineralizing agent by atomic absorption spectroscopy [37] and measuring the depth of lesions under a polarized electron microscope [38]. In the present study, released calcium ions were used.
The amount of calcium release from the

demineralization solution in the Sp group was significantly lower than all other groups. The greatest amount of released calcium was observed in the Dn, C, Sn, Dp and Sp groups, in descending order. The amount of calcium release in the Sp group was significantly lower than all groups. The amount of released calcium in the Dp and Sn groups were significantly lower than the Dn group. There was no statistically significant difference between the amount of released calcium in group C and Dp, Sn and Dn groups.

The significant difference in the release of calcium from the Sp group can be explained by the fact that oscillating systems are less operator-dependent compared to manual systems and the possibility of errors and excessive enamel removal is less in these systems. Along with polishing, they create a surface that releases less calcium even compared to the unstriped enamel surface. Danesh et al. also showed that interproximal enamel surfaces treated by oscillating system and polishing had a smoothness comparable to the initial surface roughness before stripping and also exhibited significantly lower acid penetration depths compare to other groups [30].

Surface erosion and calcium ion release are phenomena of acid erosion [39]. The difference of surface smoothness between control and not polished groups is not enough to affect the resistance to demineralization and calcium release. Moreover, this in vitro study was not able to simulate the actual demineralization and remineralization cycle that takes place in the oral environment [40].

The SEM images prepared from the samples were in line with the other results and showed that according to the EDI scoring, the samples stripped with the oscillating system received a score equal to or even better than the control group.

It is worth mentioning that the results of this in vitro study cannot be fully extrapolated to the oral environment because the oral dynamic conditions including dental biofilm, pH changes due to dietary habits and oral hygiene practices. It is recommended that future studies further simulate the oral environment, for example incorporating microbial biofilm instead of pH-cycling and demineralization solution. In addition, effects of caries control substances such as fluoride and other prophylactic substances can be investigated after performing proximal stripping.

## CONCLUSION

Unlike stripping systems, polishing is considerably useful in decreasing enamel roughness. Totally, mechanical stripping and polishing has shown the best consequences on enamel structure.

## ACKNOWLEDGEMENT

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## CONFLICT OF INTEREST STATEMENT

None declared.

## GENERATIVE AI IN SCIENTIFIC WRITING

None declared.

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