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http://dx.doi.org/10.1590/1678-7757201302117

Minimal alterations on the enamel surface by micro-abrasion: *in vitro* roughness and wear assessments

Marcela Charantola RODRIGUES[1], Rafael Francisco Lia MONDELLI[2], Gabriela Ulian OLIVEIRA[3], Eduardo Batista FRANCO[4], Wagner BASEGGIO[5], Linda WANG[2]

1- MSc, PhD student, Department of Operative Dentistry, Dental Materials and Endodontics, Bauru School of Dentistry, University of São Paulo, Bauru, SP, Brazil.
2- DDS, MSc, PhD, Associate Professor, Department of Operative Dentistry, Dental Materials and Endodontics, Bauru School of Dentistry, University of São Paulo, Bauru, SP, Brazil.
3- MSc, Department of Operative Dentistry, Dental Materials and Endodontics, Bauru School of Dentistry, University of São Paulo, Bauru, SP, Brazil.
4- DDS, MSc, PhD, Full Professor, Department of Operative Dentistry, Dental Materials and Endodontics, Bauru School of Dentistry, University of São Paulo, Bauru, SP, Brazil.
5- DDS, MSc, PhD, Department of Operative Dentistry, Dental Materials and Endodontics, Bauru School of Dentistry, University of São Paulo, Bauru, SP, Brazil.

Corresponding address: Prof. Dr. Rafael Francisco Lia Mondelli - Departmento de Dentistica, Endodontia e Materiais Odontológicos, Faculdade de Odontologia de Bauru, Universidade de São Paulo - Alameda Dr. Octávio Pinheiro Brisolla, 9-75 - Cx Postal 73 - 17012-901 - Bauru - SP - Brazil - Phone: 55 14 32358265 - Fax: 55 14 32261495 - e-mail: rafamond@fob.usp.br

Received: February 7, 2012 - Modification: January 3, 2013 - Accepted: January 30, 2013

ABSTRACT

Objective: To evaluate the *in vitro* changes on the enamel surface after a micro-abrasion treatment promoted by different products. Material and Methods: Fifty (50) fragments of bovine enamel (15 mm x 5 mm) were randomly assigned to five groups (n=10) according to the product utilized: G1 (control)= silicone polisher (TDV), G2= 37% phosphoric acid (3M/ESPE) + pumice stone (SS White), G3= Micropol (DMC Equipment), G4= Opalustre (Ultradent) and G5= Whiteness RM (FGM Dental Products). Roughness and wear were the responsible variables used to analyze these surfaces in four stages: baseline, 60 s and 120 s after the micro-abrasion and after polishing, using a Hommel Tester T1000 device. After the tests, a normal distribution of data was verified, with repeated ANOVA analyses ($p\leq 0.05$) which were used to compare each product in different stages. One-way ANOVA and Tukey tests were applied for individual comparisons between the products in each stage ($p\leq 0.05$). Results: Means and standard deviations of roughness and wear (μm) after all the promoted stages were: G1=7.26(1.81)/13.16(2.67), G2=2.02(0.62)/37.44(3.33), G3=1.81(0.91)/34.93(6.92), G4=1.92(0.29)/38.42(0.65) and G5=1.98(0.53)/33.45(2.66). At 60 seconds, all products tended to produce less surface roughness with a variable gradual decrease over time. After polishing, there were no statistically significant differences between the groups, except for G1. Independent of the product utilized, the enamel wear occurred after the micro-abrasion. Conclusions: In this *in vitro* study, enamel micro-abrasion presented itself as a conservative approach, regardless of the type of the paste compound utilized. These products promoted minor roughness alterations and minimal wear. The use of phosphoric acid and pumice stone showed similar results to commercial products for the micro-abrasion with regard to the surface roughness and wear.

Key words: Micro-abrasion. Enamel. Roughness. Wear.

INTRODUCTION

Many patients consider enamel staining unpleasant, leading them to seek treatment in order to remove it[2,5,9].

A correct diagnosis is the first step to reach a successful approach, as different levels of compromised dental structures require distinct decisions to avoid sub or over-treatments. It is extremely relevant that these white spots are not related to caries activity, such as for patients who have undergone orthodontic treatment[8,10,19].

White spots provoked by fluorosis are the most common etiologic factors that cause color alterations[3,9]. These characteristics correspond to the clinical manifestation of a defective process during the enamel maturation and mineralization phases, resulting from an excess of fluoride[3,9]. However, other clinical situations may also cause enamel staining, such as hypo-calcification (imperfect formation of enamel) with an irregular texture[8,10,19].

For this purpose, slurries made of the mixture of different acid and abrasive systems were combined in a technique called enamel micro-abrasion[2,5]. This technique was first based on Croll's[4] (1998) description: superficial layers of enamel with color or structural modifications are eliminated by selective removal utilizing an association of an erosive agent (mainly hydrochloric or phosphoric acids) with an abrasive agent (pumice paste or silicone carbide). A sub layer is exposed with normal characteristics.

The effectiveness of a removal technique depends on the level of the compromised substrate. It is indicated only for more superficial alterations, and is an easier and more conservative procedure, which results in a more appealing appearance. Also, this selection seems to be acidic-type dependent[1].

Clinical reports have been attesting the efficacy of superficial enamel removal[9]. Despite the advantages and available resources for this procedure, there is still a lack of knowledge about the consequences of this approach.

The purpose of this study was to clarify the influence of products based on different associations of acid (hydrochloric or phosphoric) with different abrasives (pumice or silicone carbide) on the enamel by means of roughness and wear assessments.

MATERIAL AND METHODS

This *in vitro* experimental design involved two factors under analysis: products (in five levels) and stages of treatment (in four levels).

Figure 1 presents the main information about the products used in this study, highlighting the acid and abrasive components.

Preparation of specimens was conducted according to Mondelli[12] (2009). Fifty (50) bovine incisors were selected, excluding teeth with severe wear, fracture or other visible alterations. The roots were discarded and the crowns were cut with a diamond disc, using a low speed cutting machine (Isomet 1000/Buehler, Lake Bluff, IL, USA) to obtain blocks of 15 mm x 5 mm. To obtain parallel surfaces, one metallic matrix was used and the opposite dentin surfaces were cleaned, acid-etched for 15 s and restored with a dentin bonding system (Adper Single Bond 2, 3M ESPE, St. Paul, MN, USA) and the Filtek Z250 (3M ESPE, St. Paul, MN, USA) composite resin. Next, all the enamel surfaces were individually fixed in acrylic bases and polished using a mechanical polishing machine (APL 4, Arotec, Cotia, SP, Brazil). A water-cooled sequence of #320, #600, #800 and #1200 abrasive silicone carbide discs (Extec Corp., Enfeld, CT, USA) were used under a constant load of 172 g for 30 s each. A diamond suspension of 1 µm (Buehler, Lake Bluff, IL, USA) was applied with a felt disc and a 10 min-ultrasonic bath in deionized water was employed to remove all residues on the surface.

The roughness and wear were assessed using a basic Hommel Tester T100 (Hommelwerke GmbH ref. #240851, Schwenningen, Germany). The roughness assessments were standardized with parameters of Tminimum=0.01 µm, Tmaximum=8.00 µm, Lt=5 mm, Lm=4.5 mm and Lc=0.25 mm (cut-off), with T= tolerance, Lt= real extension of reading, Lm= extension considered, and Lc= cut-off. Five random readings were taken for each surface.

When the wear was assessed, all readings were performed from the control side of the surface to the micro-abraded side. Thus, wear reading was performed from the reference area (control side-not challenged for none groups) to treated area. The difference determines the provoked wear. The parameters were adjusted to Tminimum=8 µm, Tmaximum=40 µm, Lt=10 mm, Lm=9 mm and

Figure 1- Information regarding tested materials

Groups	Comercial brand	Erosive agent	Abrasive agent
G1	Silicone Polisher (Optimize System – TDV, Pomerode, SC, Brazil)		aluminium oxide
G2	-	phosphoric acid 37%	pumice stone (SSWhite, Rio de Janeiro, RJ, Brazil)
G3	Micropol (DMC Equipments LTDA, São Carlos, SP, Brazil)	hydrochloridric acid 6.6%	silicon carbide
G4	Opalustre (Ultradent, South Jordan, UT, USA)	hydrochloridric acid 6.6%	silicon carbide
G5	Whiteness RM (FGM Dental Products, Joinville, SC, Brazil)	hydrochloridric acid 12%	silicon carbide

Table 1- Mean and standard deviation (SD) of Ra (µm) of initial surface roughness and roughness after 60 seconds, 120 seconds, and polishing

	Initial Roughness	Roughness after 60 s	Roughness after 120 s	Roughness after polishing
Groups	Mean±SD	Mean±SD	Mean±SD	Mean±SD
G1	7.29±1.57^{Aa}	7.16±1.26^{Aab}	7.06±1.39^{Aa}	7.26±1.81^{Aa}
G2	6.69±1.60^{Aa}	4.63±1.05^{Ab}	3.60±1.54^{Bb}	2.02±0.62^{Bc}
G3	6.96±2.12^{Aa}	8.57±3.74^{Ba}	5.51±3.42^{ACa}	1.81±0.91^{Bb}
G4	6.63±2.61^{Aa}	4.62±0.77^{Ab}	3.32±0.57^{BCbc}	1.92±0.29^{Bc}
G5	6.61±1.83^{Aa}	7.40±2.75^{Aab}	2.18±0.47^{Bb}	1.98±0.53^{Bb}

Different lower case letters indicate differences between columns and different capital letters indicate differences between rows

Table 2- Mean and standard deviation (SD) of wear (µm) after 60 seconds, 120 seconds, and polishing

	Wear after 60 s	Wear after 120 s	Wear after polishing
Groups	Mean±SD	Mean±SD	Mean ± SD
G1	11.51±2.10^{Aa}	15.29±2.75^{Ab}	13.16±2.67^{Aab}
G2	27.65±6.57^{Ba}	35.58±1.60^{Bb}	37.44±3.33^{Bb}
G3	14.28±5.06^{Aa}	35.28±5.78^{Bb}	34.93±6.92^{Bb}
G4	26.96±5.70^{Ba}	34.71±1.27^{Bb}	38.42±0.65^{Bc}
G5	11.91±2.59^{Aa}	32.98±4.13^{Bb}	33.45±2.66^{Cb}

Different lower case letters indicate differences between columns and different capital letters indicate differences between rows

Lc=0.00 mm (cut-off).

The specimens were randomly assigned into 5 groups (n=10), as shown in Figure 1. Half of each specimen surface was protected with adhesive tape (3M do Brasil Ltda., Sumaré, SP, Brazil), and acted as the reference control side. Only the other half was than treated with one of the techniques under evaluation. The recommendations of each manufacturer were followed. In Group 2, 37% phosphoric acid was mixed with the same volume of pumice, resulting in homogeneous slurry. During the micro-abrasion, each specimen was fixed in the same way to a metallic base to be abraded under constant pressure of 217 g. This procedure was performed using a low speed and a torpedo-shaped siliconee rubber cup for 30 s. Another 30 s-application was performed, for a total of 60 s.

Next, the slurry was washed out with an air-water spray for 30 s. A new series of roughness and wear assessments was performed. The same steps were repeated to obtain 120 s-registrations. In the end, the surfaces were polished with felt discs and polishing paste (Diamond Excel/ FGM Produtos Odontológicos, Joinville, SC, Brazil) for 30 s at low speed.

After testing, the normal distribution of data was verified. Repeated measures of ANOVA analysis were used to compare each product in different stages ($p \leq 0.05$). One-way ANOVA and Tukey tests were applied for individual comparisons between the products in each stage ($p \leq 0.05$).

RESULTS

Tables 1 and 2 summarize the means and standard deviations of roughness and wear, respectively.

Regarding the roughness, as presented in Table 1, G1 (control group), treated with siliconee polisher presented no differences among different treatment stages overtime ($p \geq 0.05$). The overall results showed that for the other groups, the roughness tended to decrease over time after polishing. All groups were significantly smoother when compared to their initial situations and didn't differ from each other, except for G1, which was comparatively rougher.

Table 2 shows that the micro-abrasion was able to provoke wear in all the groups, including G1, treated with silicone polisher only. After polishing, only G4 showed significantly more wear after its respective 120 s-assessment. When the groups were compared at each stage, G2 and G4 presented significantly greater wear after 60 s. After 120 s, all products showed significantly greater wear when compared to G1 (control), according to the particular comparison between the baseline and after polishing stages, considering neither the 60

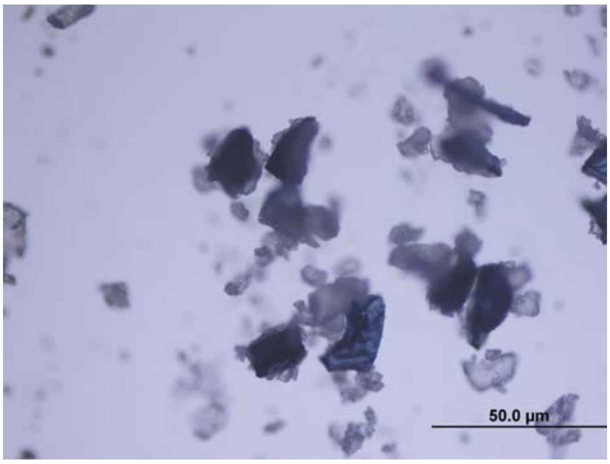

Figure 2- Micropol - irregular silicone carbide particles

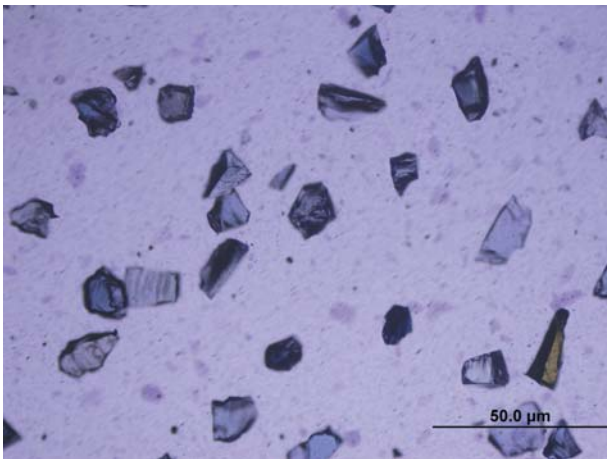

Figure 3- Opalustre - irregular silicone carbide particles

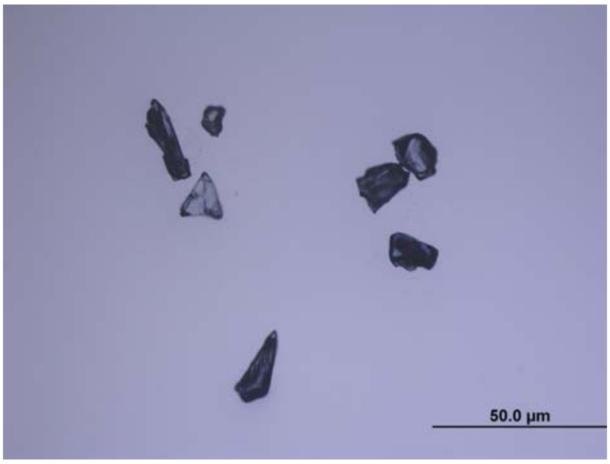

Figure 4- Whiteness RM - irregular silicone carbide particles

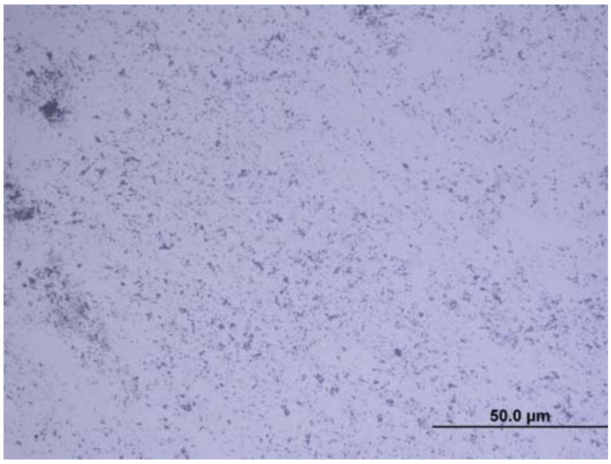

Figure 5- Pumice - small rounded particles

s nor 120 s time evaluation, for all groups, except for G1.

DISCUSSION

Investigations about the consequences to the enamel surface from different chemical-mechanical challenges have been extensively performed using bovine teeth since it can represent human type tissue[12,14]. For many of the evaluated properties, a flat surface is essential for the roughness and wear assessments, as previously reported[14,15]. Since the enamel presents a hierarchical and regular distribution[7], the preparation of the flat surfaces do not provide significant influences.

Many factors are reported that can interfere with the enamel surface after micro-abrasion, such as manual or mechanical techniques, amount of application, interval between applications, mechanical speed, and pressure. More particularly, acid type and concentration, and type and granulation of the abrasive particles are also relevant to determine the effectiveness and consequences to the micro-abraded enamel[2,4,11,21].

In the present study, technical factors were standardized as the amount of applications, intervals, and pressure. The slurries, which varied according to the chemical and abrasive characteristics, are presented in Table 1.

It can be observed from Table 2 that the initial roughness for all specimens did not differ from each other, regardless of the treatment. It is important to highlight that all the data is reliable because all treatments began from a standardized condition. Also, it is particularly noted that the control group (G1), which had an enamel surface that was solely mechanically treated, presented the same roughness through all of the evaluated stages. This suggests that the chemical features were determinant.

Specimens treated with phosphoric acid (G2) or hydrochloric acid in different concentrations (G3, G4, and G5) produced different outcomes after the micro-abrasion. However, all produced smoother surfaces. After polishing, all treatments obtained smoother surfaces when compared to their initial assessment. The results recorded are in accordance with previous studies that reported a glass-like surface, called the enamel glaze effect[1,3,5].

According to previous studies[2,18], different acids promote distinct demineralization patterns on enamel surfaces, which can, in part, explain the distinct reactions of the specimens treated with phosphoric or hydrochloric acids. In general, phosphoric acid promotes a less aggressive decalcification, with a selective pattern. On the other hand, hydrochloric acid was not selective, dissolving the entire enamel surface after the micro-abrasion. Furthermore, the influence of the abrasive materials also needs to be considered. Figures 2 to 5 illustrate the abrasive particles presented in the tested products. Except for pumice, all other particles were greater and with a similar magnitude. Another difference is that pumice was associated with phosphoric acid while the other abrasives were associated with hydrochloridric acid.

When the wear was observed, all products showed enamel loss, which was significantly greater after 120 s. After polishing, all products, except G4, presented significant amounts of wear. In the literature[11], these amounts varied greatly, being reported at 142.87 mm and 295.5 mm for the pumice + 37% phosphoric acid and pumice + 18% hydrochloric acid, respectively after 10 5 s-applications, totaling 50 s. This may explain the greater amount of wear when compared to the present study.

Previous studies highlighted a more aggressive action of HCl-based products compared to H_3PO_4, which was not observed in the present study. This may be attributed to the difference of the abrasive content. In previous studies, the pumice was combined to HCl instead of silica carbide[2,11].

Abrasives play a relevant role in the clinical performance of the slurry, allowing greater attrition to the surface and resulting in a smoother superficial enamel layer, called "enamel glaze"[1]. It was highlighted in the present study that the size and shape of abrasive particles influenced the wear of the enamel. Figures 2 to 4 illustrate, respectively, Micropol, Opalustre and Whiteness RM, which are based on irregular silicone carbide particles with similar size. All are greater when compared to the pumice dimensions (Figure 5).

The larger and irregular abrasive agents determined the worn surfaces. When we evaluated the proportion of wear to enamel thickness, we observed about 10% of enamel wear to all tested groups, which suggests a safe and conservative procedure. These results agree with previous studies that assessed the enamel wear using scanning electronic microscopy, which observed a wear range of between 12 and 46 µm, when performed between 1 and 10 5-second applications with HCl and pumice[16]. Using the same slurry, this assessment, under polarized microscopy, was evidenced by enamel wear ranges between 25 and 140 µm after 3 and 15 applications, respectively[20].

Regardless of the superficial surface, it can be verified by previous studies that roughness tends to decrease with multiple micro-abrasions[11], as was also noted in the present study. After the micro-abrasion, the enamel surfaces became smooth and lusterous[8]. This is favorable, as it can reduce bacteria colonization on the enamel surface, mainly *S. mutans*[17]. Bacterial plaque formation is modified when enamel surface free energy is reduced, as well as diminishing bacterial adhesion to the surface[13].

The enamel characteristics change after the micro-abrasion, resulting in a different optical effect, with the formation of an artificial dark zone that refracts light in a different way, and is able to mask the spot[16]. This may occur due to a gradual formation of a compact, mineralized, and polished superficial layer deposited on the enamel, called "enamel glaze". This enamel glaze is about 15 µm thick, and is composed of a mixture of residues of abrasives and a smear layer that impregnates micro-porosities of the sub-superficial layer of enamel created during acid erosive action[6].

Based on the results, all tested abrasive agents/techniques showed the potential to determine a safe and conservative wear and the ability to modify the surface roughness, resulting in a smoother surface.

CONCLUSIONS

Within the limitations of this *in vitro* study, enamel micro-abrasion seems to be a conservative approach, regardless of the type of the paste compound. The use of phosphoric acid and pumice stone showed similar results to commercial products for the micro-abrasion with regard to the surface roughness and wear.

ACKNOWLEDGMENTS

This investigation was supported in part by CNPq as MCR fulfillment 2007.1.2858.25.6.

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