Roughness and Wear on Enamel Treated with a Microabrasive Agent

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Abstract

Microabrasion is a technique to improve the appearance of teeth with fluorosis, which is based on the chemical (acid) and mechanical (abrasive) removal of opacities using a gel. This study evaluated changes in enamel roughness and wear by means of a focal variation microscope when using a microabrasion system.

Ten extracted third molars were used. Two sessions (t1 and t2) of the microabrasive agent were carried out for 60s and 30s respectively, on the vestibular surface of all teeth and a final polishing with the rubber cup recommended by the manufacturer for 15s. A parallelometer with adapted micro-motor was used for standardized microabrasion. A focus variation microscope was used to measure roughness (Sa, Sq, Sp and Sv) and surface wear. For statistical analysis Spearman's correlation test were used.

The results expressed in µm were: t1 (Sa: 2.31, Sq: 3.0, Sp: 11.31, Sv: 12.7) and t2: (Sa: 1.6, Sq: 2.1, Sp: 11.0, Sv: 8.5). The wear with respect to initial values was t1: -11.86 and t2: -33.24. Significant correlations were not observed.

It can be inferred that although wear could increase with a greater number of sessions, but an increase in roughness would not necessarily be expected.

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Introduction

Dental fluorosis (DF) is an alteration in the development of enamel caused by prolonged exposure to high levels of fluoride during the dental formation stage,[1] clinically it is observed as a white opacity in a linear way, in mottling, patches or total coverage, which is caused by a hypomineralization of the enamel, in severe fluorosis there are superficial losses of the enamel that are brown in color due to secondary staining.[2] Treatments for DF depend on its severity and range from teeth whitening, micro-abrasion, a combination of the two techniques, physical abrasion of the enamel with a diamond bur, use of infiltrating resin, to restorations such as cosmetic veneers and crowns in the most severe cases.[3]

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Microabrasion is a technique performed to improve the appearance of teeth with fluorosis[4] that is based on the chemical and mechanical removal of opacitie using gel containing an acid and an abrasive compound.[2] In the early 1900s, Kane reported the use of 36% hydrochloric acid (HCl) with manual application to remove fluorosis stains.[5] In 1941, the use of 18% hydrochloric acid was suggested in order to reduce the risk of injury from handling the acid.[6] The mechanical application using low speed micromotor was indicated for the first time in the 1970s[6] and it was not until 1982 that the combined use of 36% hydrochloric acid, with an abrasive agent (pumice stone) emerged.[7] In 1986, Croll and Cavanaugh suggest the use of an abrasive paste (18% HCl, pumice stone and water) applied with a low-speed handpiece.[8] Since 1989, the use of 37% phosphoric acid (H_3PO_4) has been proposed, this has proven to be an efficient technique and easily available in dental offices.[9] Currently the most used acid component is HCl at different concentrations and the most widely used abrasive compound is silicon carbide, but the particle size varies in the content of each product.[6,10]

The changes that occur in the tooth surface after microabrasion has been analyzed,[2,11] showing that the technique affects roughness and generates enamel wear. The studies consulted report roughness values using the Ra parameter (arithmetic mean height of the profile of the study area),[11,12] the Ra parameter has the limitation of measuring linear roughness in objects with flat and continuous geometry, but in dental surfaces, this is not fulfilled, so selecting a single profile of affectation can be a limitation.[13] On the other hand, the S parameters, for example Sa, evaluate a selected area, allowing information to be obtained from various profiles, which could be considered more accurate for studies in teeth.[13] The objective of this study was to evaluate changes in roughness and enamel wear by means of a focal variation microscope when using a microabrasion system. Two null hypotheses were considered for this research: 1) H_0: the average roughness values before and after the treatment would be statistically equal. 2) H_0: the average enamel wear values at the beginning and end of the treatment could be considered statistically equal.

Materials and methods

10 partially or totally erupted third molars were obtained, with prior written approval from the patients. The reasons for their extraction were due to dental malpositions, malocclusion, or orthodontic reasons. Teeth with opacities compatible with caries, affectations in their structure due to caries, fractures, fillings, developmental defects, or the use of forceps during extraction were excluded. This research was approved by the ethics committee of the Faculty of Dentistry, Universidad Nacional de Colombia (Resolution 8430/1993). The teeth were stored in 0,5% Chloramine T for seven days.[14] Subsequently, soft tissue such as periodontal ligament and pulp tissue were removed using curettes and files and irrigating the canals with 0.5% sodium hypochlorite. The root apex was sealed with self-curing acrylic (Veracril®, Guarne, Antioquia, COL), taking care not to affect the dental crown, the samples were washed with distilled water and stored in a non-commercial artificial saliva substitute (Cl, Na, Ca, Mg, P, <5%, a carboxymethylcellulose and propylene glycol, pH = 6,0-7,8). The root portion of each tooth was embedded in self-curing acrylic cubes (1.5 cm). Three hemispheres were made with a round diamond bur size 006 (Jota®, Rüthi, Rheintal, CHE), on the vestibular surface of the teeth, two on the crown to delimit the working area and one more at 2mm from the cemento-enamel junction on the root surface to be used as a reference parameter, as it is not affected by the applied treatment. A prophylaxis with a fluoride-free prophylactic paste (SylkaPro, Prodont® Scientific, Bogotá D.C, COL) was performed on all teeth. An initial scan of all samples was performed for control, using a focal variation microscope (FVM) InfiniteFocus® G5 Microscope, (IFM, Alicona Imaging, Grambach, Graz, AUT), with a 20x objective (Objective 20x), a lateral resolution of 1,7 µm, a vertical resolution of approximately 0,100 µm and an external ring of light (RingLightHP®).

The first application session of the microabrasive agent (Opalustre®, Ultradent Products, Inc, South Jordan, UT, USA) was carried out, using an abrasive silicone cup (OpalCups®, Ultradent Products, Inc, South Jordan, UT, USA), during 60 s. An electric motor (Marathon Champion®, Saeyang Microtech©, Dalseo-gu, Daegu, KOR) was used for the application, with a micromotor (MAX-88E®, MicroNX, Dong-gu, Daegu, KOR) and a contra-angle (NAC-EC®, NSK, Kanuma, Tochigi, JPN) adapted to the arm of a William's type parallelometer (JT-09, Technoflux®, Gabriel Benmayor SA, Barcelona, Catalonia, ESP); This made it possible to standardize the rpm and the pressure applied during each session. Each sample was washed with pressurized water with a triple syringe for 10 s, and a final polish with the finishing cup (OpalCups®, Ultradent Products, Inc, South Jordan, UT, USA) for 15 s was performed. A second wash with water spray was performed for 10 s and all samples were stored in the artificial saliva substitute for 72 hours. For analysis by 3D scanner (3D focal variation microscopy), the samples were dried with compressed air at 10 cm for 5 s (Treatment session 1 = t1) and the three demarcations were taken as reference. The second session (t2) was carried out under the same parameters of t1, but a time of 30 s was used. Similar parameters for the 3D scanner analysis of t1 were used for t2. The DataSet or point cloud image were processed using the program's *3D Editor®* tool (IF-MeasureSuite 5.3, Alicona, Graz, Styria, AUT) to select the measurement area between the two demarcations made in the tooth crown. Using the *Form removal* tool, each image was adjusted to the same plane or profile (polynomial form removal) without distorting the data. An area of approximately 600 x 2400 µm and an Lc of 800,000 µm were used, according to ISO 25178. DataSet were processed with Surface Texture Measurement module for area roughness. Only the parameters Sa: Average height of selected area, Sq: Root-Mean-Square height of selected area, Sp: Maximum peak height of selected area, Sv: Maximum valley depth of selected area were considered. This process was carried out for t0, t1 and t2. To quantify wear, the difference was obtained by superimposing images using the *Difference Measurement* module (IF-MeasureSuite 5.3, Alicona, Graz, Styria, AUT) comparing t0 with t1 and t0 with t2 (Fig 1). The data were expressed in mean deviation (*Dmean*), to obtain an average amount of the entire surface in µm. Descriptive statistics, Wilcoxon test and Spearman's correlation were used. A significance of 95% was set ($p<0.05$). The software used for the statistical analysis was SPSS version 23.0 (IBM, Armonk, NY, USA).

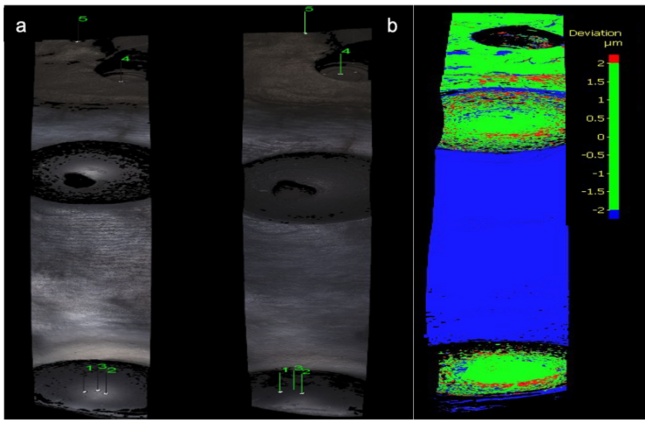

Figure 1. Wear measurement (a) Selection of reference points of the surface to compare. (b) Mean deviation µm.

Results

Roughness was measured at three moments (t0, t1 and t2) through the parameters *Sa*, *Sq*, *Sp* and *Sv* (Table 1). A tendency to decrease in roughness was observed for the four S parameters. For t0, t1 and t2 statistically significant differences, in the parameters *Sa*, *Sv* and *Sq*, were observed (Wilcoxon test).

Roughness parameters		t0	t1	t2
Sa	Mean (SD)	2.67 ± 0.83	2.31 ± 0.74	1.68 ± 0.54
	Median	2.84[a]	2.55[b]	1.52[c]
	Min	1.60	1.38	0.96
	Max	3.73	3.41	2.70
Sq	Mean (SD)	3.46 ± 1.16	3.00 ± 1.02	2.17 ± 0.75
	Median	3.65[a]	3.27[b]	1.96[c]
	Min	2.02	1.77	1.25
	Max	5.32	4.80	3.71
Sp	Mean (SD)	13.32 ± 5.91	11.31 ± 5.09	10.00 ± 7.51
	Median	12.08[a]	10.77[a]	7.14[a]
	Min	6.98	5.87	5.47
	Max	25.07	19.56	30.62
Sv	Mean (SD)	15.26 ± 9.00	12.71 ± 6.96	8.50 ± 3.11
	Median	13.93[a]	10.53[b]	7.43[c]
	Min	7.22	6.13	5.14
	Max	36.99	29.01	14.52

Table 1. Roughness for each session (µm).
**Sa:* Average height of selected area, *Sq*: Root-Mean-Square height of selected area, *Sp:* Maximum peak height of selected area, *Sv:* Maximum valley depth of selected area. t0: initial measurement, t1:1 session(60s), t2: 2 session(30s). Different superscript letters in the medians, indicates significant differences ($p<0.05$) according to Wilcoxon Test, for each roughness parameter (interpret for each row).

	Dmean	
	Δ (t1 - t0)	Δ (t2 - t0)
Mean (SD)	-11.86 ± 4.24	-33.24 ± 10.85
Median	-11.61[a]	-33.13[b]
Min	-18.61	-51.94
Max	-6.63	18.17

Table 2. Wear difference for each session (µm).
*Dmean = Mean deviation, refers to the average wear in µm. Negative values indicate a wear in µm of the surface with respect to the initial value (t0). Different superscript letters in the medians, indicates significant differences ($p<0.05$) according to Wilcoxon Test ($p=0.005$).

The mean deviation of wear reported a significant decrease in t1 and t2 compared to t0 (table 2). According to the Spearman's correlation coefficient when evaluating the association of the variables roughness (*Sa*) and wear (Dmean) for t0 with t1, a result of 0,49 was obtained and for t0 with t2 a result of 0,62 was observed. Therefore, there is no linear relationship between the two variables, but a positive association determined as weak was observed (Table 3).

Rho de Spearman		Dmean (t1-t0)	ΔSa (t1-t0)
Dmean (t1-t0)	Correlation coefficient	1.00	0.49
	Sigficance		0.15
ΔSa (t1-t0)	Correlation coefficient	0.49	1.00
	Sigficance	0.15	
Rho de Spearman		**Dmean (t2-t0)**	**ΔSa (t2-t0)**
Dmean (t2-t0)	Correlation coefficient	1.00	0.62
	Sigficance		0.05
ΔSa (t2-t0)	Correlation coefficient	0.62	1.00
	Sigficance	0.05	

Table 3. Correlation between surface roughness and wear.

*Δsa: the roughness difference of the Sa parameter between t1-t0 and t2-t0, Dmean = Mean deviation, refers to the average wear. A weak positive association between ΔSa and Dmean was observed.

Discussion

Generally, in microabrasion studies, the R parameters, specifically (*Ra*), have been used to measure roughness. The roughness values after the application of *in vitro* microabrasion can vary widely, values between 0,14µm and 1,92µm have been reported.[11,13,15,16] Probably the range of variation of these values is determined by the composition of the microabrasive agent,[12] the speed of the rotating equipment,[17,18] the pressure exerted,[16,17] the application time,[17] the performance or not of final polishing,[10] the roughness measurement equipment and parameter used.[12,15]

In the present study, two microabrasion sessions were carried out with a product based on HCl 6,6% and silica carbide under controlled manual pressure and constant low speed. A decrease in roughness was found with respect to the initial control values, observing a median roughness of 2,55µm/60s and 1,52µm/30s for each treatment session. Finding similar to that obtained by Fragoso *et al.* and Rodrigues *et al.* who observed a decrease in roughness when using phosphoric acid with pumice stone, Whiteness RM® and Opalustre®, on blocks prepared from bovine enamel.[10,16] In contrast, other studies reported an increase in roughness when evaluating similar microabrasive agents in bovine enamel blocks, even when a final polishing was performed.[11,19] Probably the pressure and speed differences during rotary application of the microabrasive agent and the final polishing are responsible for the increase or decrease in roughness. Another variable to highlight is the magnitude of the values in µm of roughness reported in these studies,[11,16] which were much lower than those of the present investigation. This can be explained by the methodological differences of the treated enamel surface, this study was developed on an intact enamel, without alteration of its planimetry, thanks to the geometric correction allowed by the FVM software that does not require sample preparation, providing all functionalities for dimensional measurement, characterization and analysis of surfaces, becoming an excellent method for the quantitative evaluation of surface topography in dental studies,[20] since it also has the advantage of the ability to measure inclined surfaces.[21] Currently the IFM is one of the few commercial focus variation microscopes calibrated to ISO standards for characterizing surface texture.[22] One of the disadvantages of FVMs has been reported to be that translucent materials cause measurement problems, this has been observed for bone and tooth samples, however the IFM has a polarized lighting system and an external light ring (RingLightHP®) with high-power LEDs that illuminate reflective surfaces, reduces shadows, detects edges and highlights the roughness of the surface, allowing to overcome this limitation of scattered light.[23] Additionally, the IFM has a lateral resolution of (~10 µm) and a high vertical resolution of up to 10 nm depending on the objective of magnification used.[24] The use of a higher vertical resolution implies a longer measurement time,[22] this was a parameter considered in order not to extend the observation times for each sample, we consider that this should not be understood as a limitation of the investigation, but it is extremely important that this is reported. When comparing optical methods with contact profilometers, it should be considered that although contact methodologies may have higher vertical resolution (2 nm), the dimensions of the analyzer tip (stylus radius), generally 2,5 µm, would define the minimum possible of measurable roughness,[25] compared to the FVM where, for example with an objective 20x the minimum measurable roughness (*Sa*) is 0,075 µm.[26] Additionally, the use of contact profilometers is described as a destructive technique so attempting to involve the same surface for a second measurement is not possible. However, the literature reports that between both methods there are only slight differences with respect to Ra in dental enamel, so both methodologies are accepted.[25] With respect to other optical methods such as white light interferometry, this may present errors measurement for Ra between 50 and 300 nm, or when the surfaces are not smooth and geometrically simple,[27] limitations that the FVM does not have. The use of S parameters such as Sa, Sv, Sc, Sz, Sdr by means of optical interferometric profilometry at 20x has been explored to measure the effects of bracket debonding in lingual enamel, obtaining significant differences in roughness before and after removal of the brackets.[28] 3D optical interferometric profilometry to evaluate stripping has also been used with similar S roughness parameters.[29] In the present study, Sa, Sp, Sv, Sq parameters were used, reporting a similar behavior in the four parameters.

On the other hand, the storage medium of the teeth after the microabrasive treatment could influence the roughness results. Storing teeth in human saliva at different times has shown a decrease in roughness values without polishing at one and seven days.[18] This is probably another justification given the decrease in roughness obtained in the present investigation, where storage was carried out for 72 h in an artificial saliva substitute. It is suggested that future research evaluate the effects of longer storage, which, although it was not the main objective of this work, is of interest for future research on the subject.

There are multiple techniques and instruments reported to quantify the wear of enamel by microabrasion: Olympus BH2 compound microscope,[30] image analyzer,[31] portable profilometer,[16] atomic absorption spectrophotometry (AAS), stereomicrocope adapted to a digital camera,[15] metal calibrator and scanning electron microscopy (SEM) to make a qualitative observation of wear.[32,33] A wear of 12 to 360 µm has been reported, which could be associated with the microabrasion protocols used, the pressure during the application, acid concentration, time, use or not of rotary instruments and abrasive tips and the hardness of the tooth. In the present investigation, wear of 11,61 µm and 33,13 µm was reported for each treatment session. The use of the FVM has been reported to quantify wear in dental erosion/abrasion procedures, one of them took an unaffected surface as a reference and they observed wear in µm represented in the 3D reconstruction with different colors.[34] Other reports have suggested the use of the Pz parameter, representing the average depth of erosion/abrasion.[21] In this research, the proposal to quantify wear included the comparison of surfaces, carried out by the IFM software. This methodology turned out to be another useful alternative that should be compared in future studies with other methodologies. A limitation of our research was that the parallelometer, when performing a displacement lock, limited the amount of pressure exerted by the operator's hand, these quantitative wear results must be considered with care, so they do not necessarily represent the clinical situation and may be the explanation for the little wear reported.

In the present investigation, a weak positive association was observed with the absence of linear correlation between the wear and roughness variables. This could be interpreted as that both variables could increase without having a clear correlation or proportion, in other words, the greater the wear, not necessarily the greater the roughness. An *in vitro* evaluation of multiple toothpastes on enamel, reported a very slight and non-significant negative correlation between roughness and wear, which can be tried to explain as more abrasive toothpastes can cause greater wear, but not necessarily produce enamel surfaces with better polishing.[35,36,37]

Absence of correlation between roughness and wear has also been observed on surfaces of resin cements after abrasive cycles of tooth brushing.[37,38,39] This can probably be explained by the fact that in general microabrasion systems tend to increase the roughness of the enamel, and it is the final polishing where it is possible to improve the surface finish, in addition to that the effectiveness of this polishing also depends on the type of microabrasive agent used.[19] In this investigation, a final polishing was performed with the OpalCups for 15 seconds, which most likely contributed to altering the final roughness result, however, it was considered necessary to be closer to the clinical circumstances.

Conclusions

With the limitations of the present study, it can be concluded that after performing microabrasion sessions with a final polish, lower roughness values are to be expected than the values of the initial or untreated enamel. By not finding a direct correlation between wear and roughness, it can be inferred that although wear could increase with a greater number of sessions, an increase in roughness would not necessarily be expected. The focal variation microscope is a measurement alternative for dental enamel with the advantage of being able to record the information of the planimetry or natural morphology. It seems that there is no need to flatten or geometrically simplify the enamel surface, however, more comparative studies with other techniques are required in the future.

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Declaration of Interest

The authors report no conflict of interest.

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