

Quantitative analysis of dental enamel removal during a microabrasion technique

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ABSTRACT | *Objective:* To quantify, by means of profilometry, the removal of dental enamel during the use of a microabrasion technique involving the use of hydrochloric acid and manual abrasion with a plastic spatula. *Method:* Thirty six specimens obtained from human third molars were polished to obtain flat surfaces and divided into 3 groups (n = 12) according to the different treatments received: A placebo treatment with deionized water as a negative control (CG); microabrasion with 6.6% hydrochloric acid, Opalustre™ (G1); and microabrasion with 6% hydrochloric acid, Whiteness RM™ (G2). The microabrasion was performed in a standardized manner by submitting the specimens to 4 cycles of 10 seconds each and manual abrasion using a plastic spatula (200 g load). The loss of enamel surface was measured after each cycle of treatment by contact profilometry. *Results:* Enamel loss was already observed after the first 10 seconds of abrasion with hydrochloric acid in both treated groups (G1 and G2). After 4 abrasions of 10 seconds each, the average final enamel losses in the treated groups were 46.04 μm (G1) and 54.65 μm (G2). In the G1 and G2 groups, a significant increase in enamel wear was detected in each cycle in comparison to the control group (p ≤ 0.05). A significant difference in enamel loss between G1 and G2 was found after 30 and 40 seconds of microabrasion. *Relevance:* The results of this study provide objective data for safely performing the microabrasion technique on dental enamel using hydrochloric acid and manual abrasion using a plastic spatula.

DESCRIPTORS | Dental Enamel; Hydrochloric Acid; Enamel Microabrasion.

RESUMO | **Análise quantitativa da remoção de esmalte dental durante a técnica de microabrasão** • *Objetivo:* Quantificar, por meio de perfilometria, a profundidade de esmalte dental removido durante o emprego de uma técnica de microabrasão utilizando-se ácido clorídrico e abrasão manual com espátula plástica. *Método:* Trinta e seis espécimes obtidos de terceiros molares humanos foram polidos, para obtenção de superfícies planas, e divididos em 3 grupos (n = 12) de acordo com os diferentes tratamentos recebidos: tratamento placebo com água deionizada, como controle negativo (CG); microabrasão com ácido clorídrico a 6.6%, Opalustre™ (G1); e ácido clorídrico a 6%, Whiteness RM™ (G2). A microabrasão foi realizada, de forma padronizada, submetendo os espécimes a 4 ciclos de 10 segundos cada e abrasão manual utilizando-se uma espátula plástica com carga de 200 g. A perda da superfície de esmalte foi medida após cada um dos ciclos de tratamento por meio de perfilômetro de contato. *Resultados:* Após os primeiros 10 segundos de abrasão, já foi encontrada perda de esmalte em ambos os grupos tratados (G1 e G2). Nos grupos G1 e G2, a cada ciclo de 10 segundos, foi observado um aumento significativo na perda de esmalte (p ≤ 0.05). Após 4 abrasões de 10 segundos cada, as médias de perda de esmalte nos grupos tratados foram 46.04 μm (G1) e 54.65 μm (G2). Foi encontrada uma diferença significativa entre G1 e G2 com relação à perda de esmalte após 30 e 40 segundos de microabrasão. *Relevância:* Os resultados deste estudo fornecem referências para a realização do procedimento de microabrasão em esmalte dental com segurança, utilizando-se ácido clorídrico e abrasão manual com espátula plástica.

DESCRITORES | Esmalte Dentário; Ácido Clorídrico; Microabrasão do Esmalte.

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• Received Dec 17, 13 • Accepted May 7, 14
• DOI <http://dx.doi.org/10.11606/issn.2357-8041.clrd.2014.69159>

INTRODUCTION

Enamel microabrasion is a conservative technique that uses strong acids in association with abrasive agents to remove an outer layer of enamel.¹⁻³ It is indicated to correct surface irregularities and for the removal of superficial stains on the dental enamel due to imperfect amelogenesis, fluorosis, hyperplasia, or other conditions.⁴⁻⁸ The use of acids to remove stains on enamel was first described in 1916.⁹ A correct diagnosis is the first step to a successful approach, since different levels of compromised dental structure require different decisions to avoid sub- or over-treatment.¹⁰ Initially, the enamel microabrasion technique used a finishing and polishing bur at high speed on the altered surface with a highly concentrated acid solution (18% hydrochloric acid).¹¹ Later on, weaker acids were used with smaller abrasive particles, which were soluble in water and easy to apply, without the use of a finishing bur.^{5, 12}

Today, microabrasion techniques typically use hydrochloric acid at concentrations in the order of 6%, mixed with an abrasive agent containing small particles of silicon carbide. According to Chandra and Chawla (1975), the use of an abrasive substance increases the speed of stain removal by mechanical action.¹³

Although microabrasion is a conservative procedure, knowledge of the technique is fundamental to perform it correctly. Since there is a structural loss of enamel, prolonged enamel microabrasion may lead to marked enamel structure wear and cause excessive tooth color alteration.¹⁴ When a tooth surface is microabraded, the thickness of enamel is reduced and the color of the dentin becomes more pronounced.¹⁴ Some authors have reported a darker or yellowish color on teeth subjected to enamel microabrasion.¹⁴ According to Lynch and McConnell (2003),² based on laboratory studies,¹⁵ enamel removal varying from 45.5 μm to more than 100 μm is not clinically significant. On the other hand, ac-

ording to Shillingburg *et al.* (1973), the removal of more than 0.13 mm (130 μm) may be clinically significant, especially in repeated treatments.¹⁶ So, based on the information above, we may assume that enamel removal below 100 μm is not clinically significant,² and, above 130 μm , it may be clinically significant.¹⁶

Data can be found in the literature on the amount of enamel removal after microabrasion with hydrochloric acid (6%–18%) in association with application of a low speed handpiece and rubber cups at several rotations per minute.^{3, 10, 11, 17-19} The microabrasion technique can also be performed with manual abrasion, using a plastic spatula, with satisfactory results.²⁰ Among some of the positive points supporting the application of manual abrasion using a plastic spatula during microabrasion are the ability to control the scattering of HCl over the enamel surface, to manage the exact stained enamel areas to be abraded, and to control the intensity of the procedure by the operator. There is little information in the literature about the amount of enamel loss after microabrasion when hydrochloric acid (6%) is used and abrasion is performed manually with a plastic spatula. Additionally, to the best of our knowledge, the profilometry method has not yet been used to precisely measure hard tissue loss and to identify the limits to a microinvasive clinical application. Since manual abrasion is a possible alternative in the microabrasion technique, and since the amount of enamel wear when the technique is performed combining 6% HCl with manual abrasion is not known, the aim of the present study was to investigate through profilometry the amount of enamel surface loss after a microabrasive treatment using two commercially available gels and manual abrasion using a plastic spatula.

The hypothesis of the study was that enamel microabrasion using 6%–6.6% HCl, at a 200 g load,

manually rubbed using a plastic spatula, during 4 cycles of 10 seconds each, would remove an amount of enamel that is clinically acceptable.

MATERIAL AND METHODS

Sample Preparation

After receiving the approval of the ethics committee of the School of Dentistry, University of São Paulo, Brazil (#08044212.8.0000.0075), eighteen extracted human third molar crowns were selected for this study. Each crown was cut in the buccolingual direction into two halves (Isomet, Buehler, IL, USA). The samples were glued onto a plastic plate measuring 50 × 100 × 2 mm (Exakt GmbH, Norderstedt, Germany) using transparent adhesive (Technovit 7230VLC, HeraeusKulzer GmbH, Wehrheim, Germany) keeping the enamel facing up. The specimens were then serially polished using silicon carbide paper (grit 800, 1200 and 4000; Buehler, IL, USA) under water refrigeration and, subsequently, using a 1 µm diamond paste (Buehler, IL, USA) and felt disk (Buehler, IL, USA). Between each series of polishing, samples were washed in deionized water for 3 minutes. The blocks were cleaned properly and

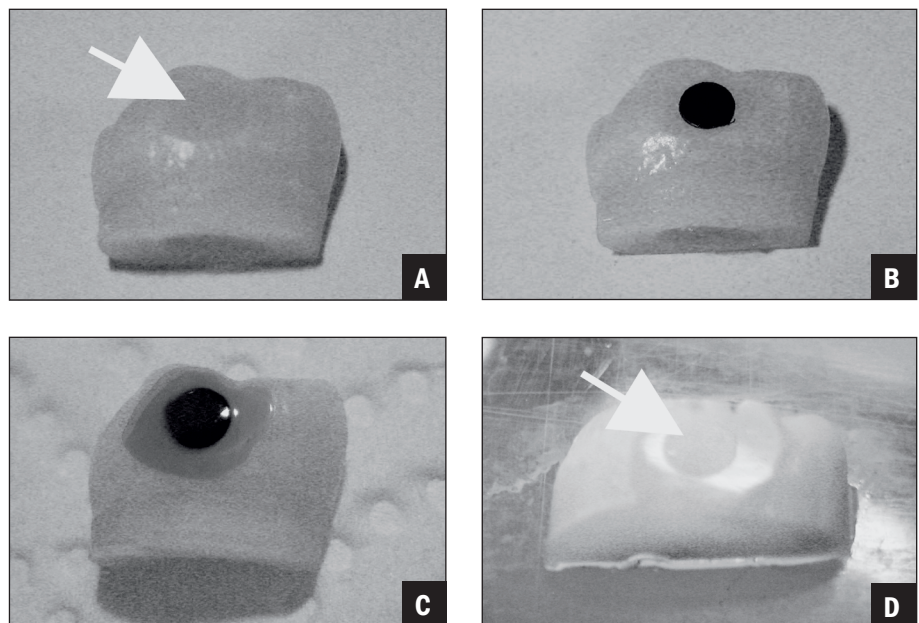
observed through a stereomicroscope to ensure the absence of structural defects and then stored in deionized water. A disk of adhesive tape (Scotch Rubber Tape 2242, 3M, St Paul, MN, USA) with a diameter of 2.5 mm was attached to the center of the enamel surface, and the rest of the block was covered with an acid-resistant varnish (Figures 1 A, B and C). After drying, the tape was removed and the surface was cleaned with cotton, soaked with deionized water to remove any remaining adhesive. Samples were stored in deionized water at 4°C and randomly allocated into the study groups, according to Table 1.

Table 1 | Group distribution and treatment applied.

Group	Composition of microabrasion products applied according to manufacturer
Control (CG; n = 12)	-
Experiment 1 (G1; n = 12)	6.6% hydrochloric acid and microparticles of water-soluble silicon carbide paste (granulation: 20–160 µm), pH < 1. Opalustre™, Ultradent, South Jordan, UT, USA
Experiment 2 (G2; n = 12)	6% hydrochloric acid and silicon carbide (granulation: 82 µm). Propylene glycol USP, thickener and deionized water, pH < 1. Whiteness RM™, FGM, Joinville, SC, Brasil

Figure 1 | Sample preparation (A-C).

A: Polished area (arrow); **B:** Adhesive disk in position; **C:** Area covered with acid-resistant varnish. Sample after microabrasion procedure (D). **D:** After microabrasion and removal of acid-resistant varnish, enamel loss in the area submitted to microabrasion can be observed (arrow).



The steps of sample preparation and treatments are illustrated in Figure 2.

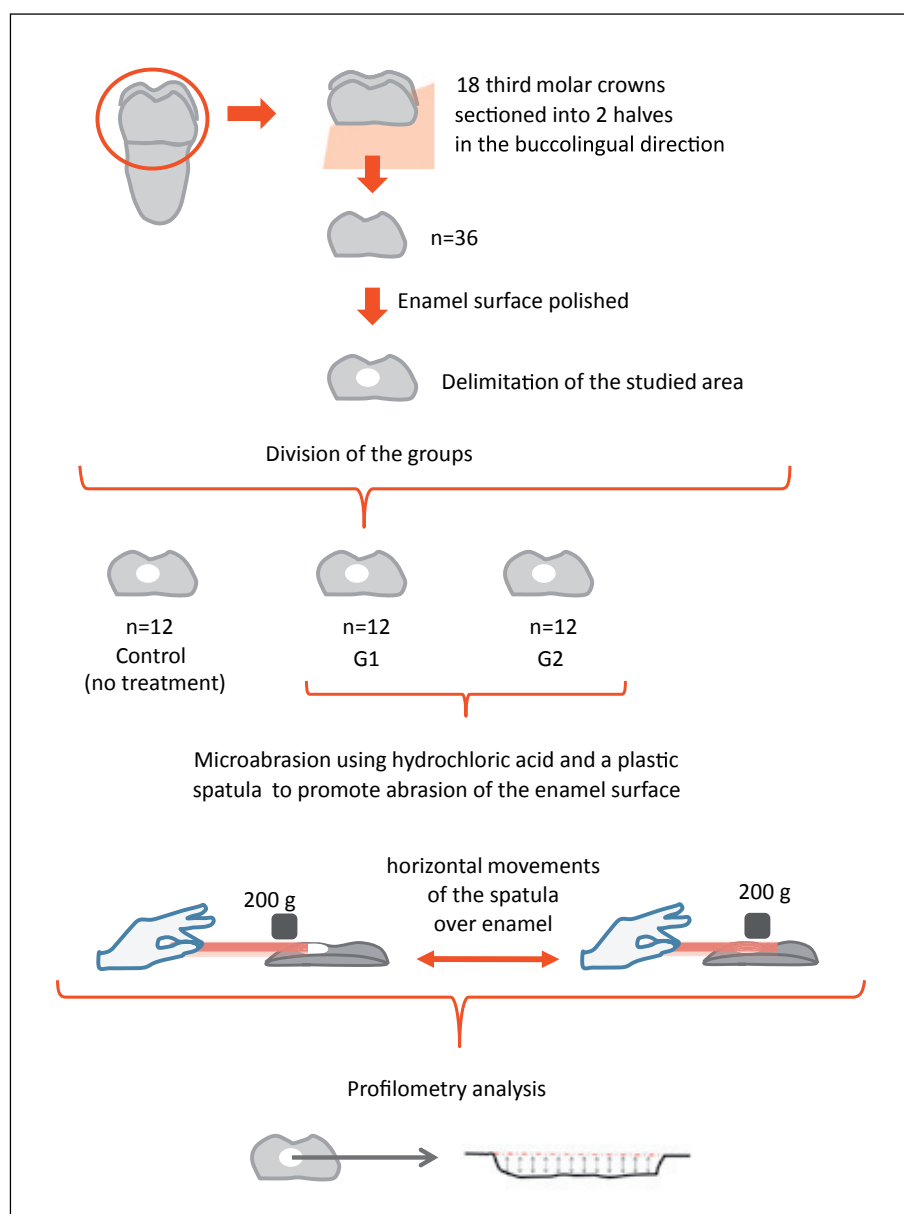
Microabrasion

The enamel surfaces were dried with absorbent paper and the exposed enamel in the experimental groups (G1 and G2) was covered with microabrasion gel. Immediately after that, the gel was rubbed onto the enamel surface for 10 seconds with a plastic spatula and under a standardized 200 g

load (controlled using a 200 g metal piece attached to the spatula). The operator made only horizontal movements to promote microabrasion, moving the spatula as illustrated in Figure 2. One movement back and forth was performed per second, for a total of 10 movements each 10 seconds.

After the first application, samples were washed in deionized water and dried. The varnish was removed and the surface loss was measured through profilometry. After the first cycle, another three cy-

Figure 2 | Methodology applied in the study.



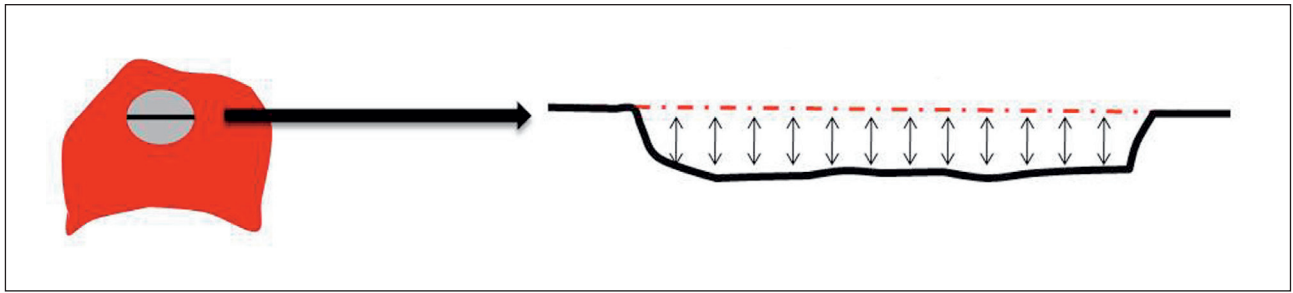


Figure 3 | Illustration of depth measurements made using profilometry of enamel after microabrasion. Twelve depth measurements were made over the extension of a perpendicular line from the surface to the bottom of the enamel lesion formed.

Table 2 | Average (μm) and standard deviation of enamel removal quantified using profilometry.

Duration	Control group	Group 1	Group 2
10 s	0.10 \pm 0.05 ^a	12.23 \pm 2.38 ^b	11.11 \pm 2.73 ^b
20 s	0.12 \pm 0.10 ^a	23.09 \pm 4.00 ^b	22.77 \pm 4.97 ^b
30 s	0.22 \pm 0.12 ^a	35.95 \pm 3.36 ^b	42.69 \pm 6.31 ^c
40 s	0.18 \pm 0.11 ^a	46.04 \pm 5.29 ^b	54.65 \pm 9.15 ^c

Statistically significant difference between treatments at each microabrasion cycle is indicated by different letters ($p \leq 0.05$).

cles of microabrasion were repeated, and, between each one, new measurements of enamel loss were made. In the control group (CG), the same procedures were performed; however, deionized water was used instead of hydrochloric acid.

Profilometry analysis

The enamel surface loss was analyzed using a contact digital profilometer (Konturenmessgerät - MarSurf XC2, Hersteller Firma Mahr GmbH, Mahr GmbH, Göttingen, Germany) with the aid of software (Konturenmessgerät - MarSurf XC2, Hersteller Firma Mahr GmbH, Mahr - GmbH, Göttingen, Germany). The surface scanning was conducted under a 0.7 mN load with a tungsten carbide tip and a 25 μm radius. The scanning line started at the reference surface on the left side of the treated area and continued through the whole treated surface, ending at the next reference enamel surface on the right side of the sample, as previously described.^{21,22} Under each scanning line, twelve measurements of depth were made as illustrated in Figure 3.

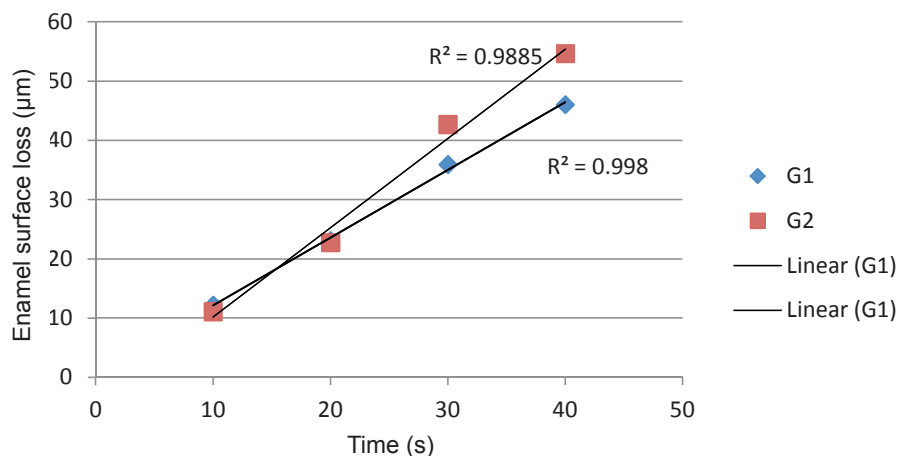
Statistical analysis

The mean values obtained of the depth of enamel surface loss for each sample at each experimental time were used for the statistical analysis. Since the data of all groups showed homoscedasticity, they were statistically analyzed using ASSISTAT (version 7.7) software by means of 2-way RM ANOVA and post-hoc Tukey tests at a 5% significance level.

RESULTS

The removal of enamel was already detected after the first 10 seconds of hydrochloric acid contact with the enamel in association with manual abrasion in the G1 and G2 groups (Table 2, Figure 4). In all treated groups, after every 10 seconds of treatment, a significant increase in removal of enamel was observed ($p \leq 0.05$; Table 2). After the third and fourth cycle of microabrasion, enamel surface loss was also observed for both treated groups (G1 and G2, $p \leq 0.05$; Figure 4). The G2 group showed greater enamel loss in comparison to the G1 group ($p \leq 0.05$). After 4 cycles of abrasion, the high-

Figure 4 | Graph showing enamel surface loss (μm) over time (s). The increase in surface loss appeared to have a linear trend for both groups ($R^2 = 0.998$ and 0.9885 respectively for G1 and G2).



est average loss of enamel was found to be $46.04 (\pm 0.29) \mu\text{m}$ in the G1 group and $54.65 (\pm 9.15) \mu\text{m}$ in the G2 group (Table 2).

DISCUSSION

Microabrasion is a well-defined technique to remove superficial enamel stains caused by several etiologies, such as fluorosis, amelogenesis imperfecta and decalcification defects.^{2,6,20,23-25} The literature presents some clinical assessment,^{2,6,8,20,24,26} microscopic surface evaluations,^{5,27} and hardness measurements of the enamel surface,²⁷ as well as enamel wear after microabrasion techniques,^{3,10,11,17,18} which provide references for technique development. However, although microabrasion should be considered a micro-invasive method, clinical application should be used with caution to avoid excessive substance removal.³ Excessive enamel removal can lead to esthetic damage and increase dentin sensitivity.^{7,18}

Many factors are reported that can interfere with enamel surface wear after microabrasion, such as manual or mechanical techniques, amount of application, interval between applications, mechanical speed and pressure.¹⁰ Different enamel loss values have been reported in the literature following microabrasion with different hydrochloric acid concentrations, using manual abrasion or a

low-speed torpedo-shaped silicone rubber cup for abrasion.^{3,10,11,17,18,20,28} However, results seem difficult to compare, since different methodologies, acid concentrations and acid types were tested. Additionally, most studies that have quantified structural loss after microabrasion used hydrochloric acid at a higher concentration than that currently recommended.^{11,18,19,28} Currently, the hydrochloric acid concentration applied for enamel microabrasion is approximately 6%. Additionally, most of the studies that evaluated enamel removal after microabrasion with 6% hydrochloric acid used low-speed rubber cup abrasion.^{3,10,17} Manual abrasion with a plastic spatula, for example, seems to be a good alternative in microabrasion technique.²⁰ Since enamel thickness varies in different regions of the crown, removal of the same amount of enamel in different regions of the crown could lead to different treatment outcomes.¹⁸ In gingival regions, deeper removal of enamel may cause a problem of dentinal sensitivity.¹⁸ A clinical study by Kilpatrick and Welbury (1993) reported that, after 2.7 years, 10% of patients submitted to enamel microabrasion reported sensitivity to cold.²⁹ Additionally, stains on the enamel surface, due to fluorosis, amelogenesis imperfecta, hyperplasia, or other conditions, can appear in localized areas of the enamel. Therefore, dentists should perform microabrasion

only in compromised regions of the enamel. The precision of the abrasion is an important factor to be considered when performing the enamel microabrasion technique. In some clinical conditions, manual abrasion could be an alternative method in performing microabrasion.

Regarding enamel removal using microabrasion with high concentrations of hydrochloric acid (18%) in association with abrasion performed using a low-speed handpiece and a silicone rubber cup, values of 7–22 μm , 160 μm , 36–62 μm , 156 μm and 360 μm of enamel removal were obtained after abrasion during 5, 10, 25, 50 and 100 seconds, respectively.^{11,18,30} When manual abrasion was applied by Dalzell *et al.* (1995)²⁸ with 18% HCl after 100 seconds, a 250 μm enamel loss was obtained. So, despite the differences in methodology applied, the use of manual abrasion seemed to remove less enamel structure after 100 seconds²⁸ than abrasion using a low-speed handpiece and a silicone rubber cup¹⁸ when performing enamel microabrasion.

Concerning enamel loss during microabrasion with around 6% hydrochloric acid and slight manual abrasion using a plastic spatula, a clinical report by Ramalho *et al.* (2010)²⁰ observed 40 μm of enamel loss after 50 seconds of abrasion. The final result was considered esthetically successful.² The images of the initial and final enamel profiles showed no alteration in the original anatomy of the tooth.²⁰ In laboratory studies, Paic *et al.* (2008)³ performed microabrasion for 40 seconds under standardized conditions (300 rpm) using 6.6% hydrochloric acid and an application force of 100 g. Enamel loss was calculated to be 53.1 μm .³ In a study by Schmidlin *et al.* (2003),¹⁷ surface loss was 134.8 μm after 20 seconds of microabrasion with 6.6% HCl, performed using a 1,000 rpm low-speed contra-angle hand piece and an application force of 200 g.¹⁷ A study by Schmidlin *et al.* (2003)¹⁷ applied another important variable by using previously demineral-

ized enamel, not applied by other studies,^{10,19,28,31} nor by the present study. A comparison of the published data^{3,17} and the results of the present study suggests that some of the technical variables, such as application force, type of abrasion (mechanical or manual) and duration of procedure, can directly affect the amount of tissue removed.

A significant difference in enamel loss between groups G1 and G2 was found after 30 and 40 seconds of microabrasion. According to manufacturers' instructions, both products tested have similar hydrochloric acid concentrations; however, the G1 group uses hydrochloric acid at a concentration of 6.6% and the G2 group, 6%. Nevertheless, despite the minor hydrochloric acid concentration difference, group G2 had significantly higher enamel loss. It should be pointed out that this difference may not be clinically significant, since the mean difference between both groups was only 8.61 μm at the end of the microabrasion cycles. It can be speculated that this difference occurred due to different granulation sizes of the silicon carbide microparticles of the two products tested. The manufacturer of the gel used in the G1 group indicates a greater variation of silicon carbide granulation (20–160 μm) than indicated for the product used in the G2 group (82 μm). The variation in silicon carbide granulation and the presence of larger particles in the G1 group may have been responsible for the difference in enamel removal found. Despite this, the results found in both treated groups seemed to be appropriate with regard to maximum enamel removal.¹⁶ The average enamel loss in both treated groups after 40 seconds of microabrasion can be considered safe and clinically acceptable.^{2,3}

Enamel microabrasion is a procedure that has precise indications and several advantages, but it requires caution and special care by both the professional and patient. According to Shillingburg *et al.* (1973), given that enamel thickness is approximately 1 mm, removal of 0.13 mm may be clinically

significant, especially in repeated treatments.¹⁶ Therefore, clinicians must be aware of the remaining enamel thickness when treating discolored areas.³ The removal of excessive enamel can lead to color alteration, esthetic damage and high tooth sensitivity. The results of this study showed that during microabrasion treatment approximately 12 to 14 μm were lost during each 10 second rubbing cycle when gels containing approximately 6% of hydrochloric acid were used, and the increase of enamel surface loss appears to have a linear trend ($r^2 = 0.9$, Figure 4).

It should be pointed out that in the cases where microabrasion is indicated (fluorosis staining, hyperplasia, hypomineralized defects in enamel), the mineralized structure of the enamel is compromised and hypomineralization is found. In these specific cases of hypomineralized enamel, a different effect of microabrasion in comparison to sound enamel could be expected. Most studies in the literature used sound enamel to assess enamel wear during microabrasion.^{3,10,11,19} The study by Schmidlin *et al.* (2003)¹⁷ performed enamel microabrasion of previously demineralized enamel with 6.6% hydrochloric acid for 20 seconds and under a 200 g load, resulting in 134.8 μm of enamel wear. Nevertheless, the authors used mechanical abrasion at 1,000 rpm and, therefore, results seem difficult to compare to those of the present study, that used

sound enamel. This difference would seem to be an important factor to be considered by future studies.

Within the limitations of this study and based on its results, it may be concluded that, *in vitro*, the number of rubbing cycles performed during the microabrasion treatment increases surface loss, and that, for gels containing 6% to 6.6% hydrochloric acid, significantly higher surface loss can be expected for those containing silicon carbide particles of 82 μm (G2) than for those with the same particles but with a larger variation in granulation (20–160 μm ; G1). The hypothesis of the study was confirmed since *in vitro* enamel microabrasion using 6%–6.6% hydrochloric acid and a 200 g load, rubbed manually using a plastic spatula, during 4 cycles of 10 seconds each removed an amount of enamel that is clinically acceptable.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to FGD (Forschungsgemeinschaft Dental, #360303, Germany) for the financial support, to the START Program of the Medical Faculty of the RWTH Aachen University (#AZ43/09, Germany), and to CNPq (#305574/2008-6, Brazil). We are also thankful to Mrs. Patricia Butler-Bücher and Mr. Thomas Fischer (Institute of Metrology and Quality Management of RWTH Aachen University) for the laboratorial support.

REFERENCES

1. Croll TP. Enamel microabrasion: the technique. *Quintessence Int.* 1989 Jun;20(6):395-400.
2. Lynch CD, McConnell RJ. The use of microabrasion to remove discolored enamel: a clinical report. *J Prosthet Dent.* 2003 Nov;90(5):417-9.
3. Paic M, Sener B, Schug J, Schmidlin PR. Effects of microabrasion on substance loss, surface roughness, and colorimetric changes on enamel *in vitro*. *Quintessence Int.* 2008 Jun;39(6):517-22.
4. Killian CM, Croll TP. Enamel microabrasion to improve enamel surface texture. *J Esthet Dent.* 1990 Sep-Oct;2(5):125-8.
5. Allen K, Agosta C, Estafan D. Using microabrasive material to remove fluorosis stains. *J Am Dent Assoc.* 2004 Mar;135(3):319-23.
6. de Macedo AF, Tomazela-Herndl S, Corrêa MS, Duarte DA, Santos MT. Enamel microabrasion in an individual with Cohen syndrome. *Spec Care Dentist.* 2008 May-Jun;28(3):116-9.

7. Balan B, Madanda Uthaiah C, Narayanan S, Mookal-amada Monnappa P. Microabrasion: an effective method for improvement of esthetics in dentistry. *Case Rep Dent.* 2013;2013:951589.
8. Celik EU, Yildiz G, Yazkan B. Comparison of enamel microabrasion with a combined approach to the esthetic management of fluorosed teeth. *Oper Dent.* 2013 Sep-Oct;38(5):E134-43.
9. McCloskey RJ. A technique for removal of fluorosis stains. *J Am Dent Assoc.* 1984 Jul;109(1):63-4.
10. Rodrigues MC, Mondelli RF, Oliveira GU, Franco EB, Baseggio W, Wang L. Minimal alterations on the enamel surface by micro-abrasion: in vitro roughness and wear assessments. *J Appl Oral Sci.* 2013 Mar-Apr;21(2):112-7.
11. Tong LS, Pang MK, Mok NY, King NM, Wei SH. The effects of etching, micro-abrasion, and bleaching on surface enamel. *J Dent Res.* 1993 Jan;72(1):67-71.
12. Levy SM. An update on fluorides and fluorosis. *J Can Dent Assoc.* 2003 May;69(5):286-91.
13. Chandra S, Chawla TN. Clinical evaluation of the sandpaper disk method for removing fluorosis stains from teeth. *J Am Dent Assoc.* 1975 Jun;90(6):1273-6.
14. Sundfeld RH, Croll TP, Briso AL, de Alexandre RS, Sundfeld Neto D. Considerations about enamel microabrasion after 18 years. *Am J Dent.* 2007 Apr;20(2):67-72.
15. Welbury RR, Shaw L. A simple technique for removal of mottling, opacities and pigmentation from enamel. *Dent Update.* 1990 May;17(4):161-3.
16. Shillingburg HT Jr, Grace CS. Thickness of enamel and dentin. *J South Calif Dent Assoc.* 1973 Jan;41(1):33-6 passim.
17. Schmidlin PR, Göhring TN, Schug J, Lutz F. Histological, morphological, profilometric and optical changes of human tooth enamel after microabrasion. *Am J Dent.* 2003 Sep;16 Spec No:4A-8A.
18. Kendell RL. Hydrochloric acid removal of brown fluorosis stains: clinical and scanning electron micrographic observations. *Quintessence Int.* 1989 Nov;20(11):837-9.
19. Waggoner WF, Johnston WM, Schumann S, Schikowski E. Microabrasion of human enamel in vitro using hydrochloric acid and pumice. *Pediatr Dent.* 1989 Dec;11(4):319-23.
20. Ramalho KM, Eduardo Cde P, Rocha RG, Aranha AC. A minimally invasive procedure for esthetic achievement: enamel microabrasion of fluorosis stains. *Gen Dent.* 2010 Nov-Dec;2010; 58(6):e225-9.
21. Esteves-Oliveira M, Pasaporti C, Heussen N, Eduardo CP, Lampert F, Apel C. Prevention of toothbrushing abrasion of acid-softened enamel by CO₂ laser irradiation. *J Dent.* Sep;39(9):604-11.
22. Ramalho KM, Eduardo Cde P, Heussen N, Rocha RG, Lampert F, Apel C, et al. Protective effect of CO₂ laser (10.6 μm) and fluoride on enamel erosion in vitro. *Lasers Med Sci.* Jan;28(1):71-8.
23. Bertassoni LE, Martin JM, Torno V, Vieira S, Rached RN, Mazur RF. In-office dental bleaching and enamel microabrasion for fluorosis treatment. *J Clin Pediatr Dent.* 2008 Spring;32(3):185-7.
24. Higashi C, Dall'Agnol AL, Hirata R, Loguercio AD, Reis A. Association of enamel microabrasion and bleaching: a case report. *Gen Dent.* 2008 May;56(3):244-9.
25. Setien VJ, Roshan S, Nelson PW. Clinical management of discolored teeth. *Gen Dent.* 2008 May;56(3):294-300; quiz 1-4.
26. Croll TP, Killian CM, Miller AS. Effect of enamel microabrasion compound on human gingiva: report of a case. *Quintessence Int.* 1990 Dec;21(12):959-63.
27. Fragoso LS, Lima DA, de Alexandre RS, Bertoldo CE, Aguiar FH, Lovadino JR. Evaluation of physical properties of enamel after microabrasion, polishing, and storage in artificial saliva. *Biomed Mater.* 2011 Jun;6(3):035001.
28. Dalzell DP, Howes RI, Hubler PM. Microabrasion: effect of time, number of applications, and pressure on enamel loss. *Pediatr Dent.* 1995 May-Jun;17(3):207-11.
29. Kilpatrick NM, Welbury RR. Hydrochloric acid/pumice microabrasion technique for the removal of enamel pigmentation. *Dent Update.* 1993 Apr;20(3):105-7.
30. Mendes RF, Modelli J, Freitas CA. Avaliação da quantidade de desgaste do esmalte dentário submetido a microabrasão. *Rev Fac Odontol Bauru.* 1999 Jan-Jun;7(1/2):35-40.
31. Price RBT, Loney RW, Doyle G, Moulding B. An evaluation of a technique to remove stains from teeth using microabrasion. *J Am Dent Assoc.* 2003 Aug;134(8):1066-71.

