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ORIGINAL ARTICLE

Márcio de Menezes · Cecilia Pedroso Turssi · Anderson Takeo Hara · Danielle Cristine Furtado Messias · Mônica Campos Serra

Abrasion of eroded root dentine brushed with different toothpastes

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Abstract This study evaluated the surface roughness change and wear provided by different dentifrices on root dentine previously exposed to erosive challenges. According to a randomized complete block design, 150 slabs of bovine root dentine (6×3×2 mm) were ground flat and polished. In an area of 4×3 mm on the dentine surface, specimens were submitted to five erosive/abrasive events, each one composed by: exposure to Sprite Diet or distilled water for 5 min, then to a remineralizing solution for 1 min, and simulation of 5,000 brushing strokes. Four dentifrices—regular (RE), baking soda (BS), whitening (WT) and tartar control (TC)—and distilled water (CO), used as control, were compared. Final texture and the wear depth were evaluated using a profilometer. ANOVA did not show significant interaction, indicating that the effect of dentifrices on both surface roughness change and wear did not depend on whether or not the dentine was eroded ($p>0.05$). There was no difference between abrasion of eroded and sound dentine. The Tukey's test revealed that WT, BS and TC provided the highest increase in surface roughness differing from RE and CO. TC yielded the deepest wear of root dentine, whereas RE and CO, the shallowest. No significant difference in wear among BS, TC and WT were observed. Within the limitations of this study, the data showed that abrasion of both eroded and sound root dentine was dependent on the dentifrice used.

Keywords Abrasion · Dentifrices · Erosion · Surface roughness · Wear

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M. de Menezes · D. C. F. Messias · M. C. Serra (✉)
Department of Restorative Dentistry,
School of Dentistry of Ribeirão Preto,
University of São Paulo,
Ribeirão Preto, São Paulo, Brazil
e-mail: mcserra@forp.usp.br
Tel.: +55-16-6024075
Fax: +55-16-6330999

C. P. Turssi · A. T. Hara
Department of Restorative Dentistry,
School of Dentistry of Piracicaba,
State University of Campinas,
Piracicaba, São Paulo, Brazil

Introduction

The increase in the rate of consumption of soft drinks, snacks and foodstuffs has promoted a high frequency of acidic substances in contact with dental hard tissues, predisposing teeth to erosion [26]. The pathology of such noncarious lesions encompasses demineralization and softening [19].

Although the early superficial dissolution of enamel caused by acidic substances may be repaired by saliva [11, 15], dentine is more vulnerable and difficult to be protected [30]. While the critical pH for enamel demineralization in saliva has been calculated to be around 5.2–5.5 [23], for dentine it is about 6.7 [14]. Consequently, under mechanical forces such as that provided by toothbrushing, the eroded dentine is more susceptible to wear than the sound counterpart [1, 7].

Toothbrushing abrasion depends not only on the dental substrate but also on the abrasiveness of the dentifrice used. Indeed, tooth wear may be influenced by the presence of fluoride ions in the environment during the erosive and/or abrasive challenges [5]. It has been shown that fluoride toothpastes could reduce the toothbrushing abrasion of the softened dental hard tissues [7, 25].

In addition to basic ingredients (a fluoride source, abrasive or polishing components, detergents, binding and flavoring agents, and humectants) a number of therapeutic agents, additional cleansing and whitening products have been added to toothpastes [10, 24, 27]. Ideally, such ingredients should provide their benefits without undue detrimental effect to dental hard tissues, especially to eroded dentine. However, the information available regarding the role of different dentifrices on abrasion of previously eroded root dentine is scarce. Therefore, this in vitro study was conducted to evaluate the surface roughness change and abrasive wear of root dentine subjected to brushing with different toothpastes immediately following erosive events.

Materials and methods

Experimental design

This study consisted of a factorial 2×5, conducted according to a randomized complete block design. The factors under study were *acidic treatment* at two levels (Sprite Diet and distilled water, as control) and *dentifrice* at five levels (Table 1). Combination of these two factors originated ten experimental groups, in which 150 specimens were sorted (n=15). The order in which the ten treatments were performed within each one of the fifteen blocks was randomly determined. The quantitative response variables were surface roughness change (micrometers) and wear depth (micrometers).

Preparation of dentine specimens

Seventy-five freshly extracted bovine incisors were cleaned to remove tissue remnants and stored in a 0.1% thymol solution. Each tooth was sectioned at the cementum-enamel junction (Fig. 1a) using a low-speed water-cooled diamond saw (Minitom, Struers A/S, Copenhagen, Denmark) to obtain two root slabs measuring approximately 6×3×2 mm (Fig. 1b). The slabs were then flattened and serially polished with 320-, 400-, 600- and 1200-grit Al_2O_3-abrasive papers in a water-cooled mechanical grinder (Minitom, Struers A/S, Copenhagen, Denmark). Final polishing was performed with a 6-μm diamond abrasive paste on cloths (Fig. 1c). Subsequently, dentine slabs were rinsed with distilled water and ultrasonically cleaned (T1440D, Odontobrás Ltda, Ribeirão Preto, Brazil) for 10 min in distilled water. Each slab was inspected for surface defects under a stereomicroscope (Nikon 88286, Tokyo, Japan) at 40× magnification. One hundred and fifty root dentine slabs were randomly distributed to the fifteen blocks and then to one of the ten different groups according to a randomized complete block design. Specimens were stored at 37±1°C in 100% relative humidity.

Baseline surface roughness analysis

Each sample was gently dried with absorbent paper and surface roughness analyses were performed using a Surfcorder SE-1700 profilometer (Kosaka Corp, Tokyo, Japan) equipped with a diamond needle of 2-μm radius. To record roughness measurements, the needle moved at a constant speed of 0.05 mm/s with a force of 0.7 mN. The cut-off value was set at 0.25 mm and the surface roughness was characterized by the arithmetical mean of the absolute values of the profile departures within the evaluation length (Ra). Five tracings were performed on each specimen at different locations (Fig. 1d). The average of these five surface roughness measurements was used as the baseline measurement (Bm) for each sample.

Acidic treatment protocol and brushing abrasion

Dentine slabs of each experimental block were allocated to the toothbrushing machine and covered with an adhesive tape leaving an area of 4×3 mm window on the dentine surface. This procedure ensured the presence of reference surfaces to measure the depth of the abrasion grooves thereafter. Subsequently, specimens were cycled through the regime based in part on that described by Attin et al. [2]. The adopted protocol was as follows: each slab was individually exposed to 250 μl of Sprite Diet (Companhia de Bebidas Ipiranga, Ribeirão Preto, Brazil) or distilled water for 5 min; rinsed with distilled water for 20 s, blotted dry; exposed to 250 μl of remineralizing solution for 1 min (rinsed with distilled water for 20 s, blotted dry); and subjected to 5,000 brushing strokes (Fig. 1e). The soft drink was composed of carbon dioxide, citric acid, ascorbic acid, lemon juice, sodium citrate, sodium benzoate, saccharin, cyclamate, water, and flavor. The composition of the remineralizing solution was as follows: potassium chloride (150 mMol/l), calcium (1.5 mMol/l), phosphate (0.9 mMol/l) and hydroxymethyl-aminomethane (20 mMol/l) [28] at pH 7.0.

Brushing abrasion was performed with an automatic toothbrushing machine (MSEt—Marcelo Nucci ME, São Carlos, Brazil) with a motor that produced a reciprocating motion on ten soft nylon bristle toothbrushing heads (Colgate Classic, Colgate-Palmolive, Division of Kolynos do Brasil Ltda, S.B do Campo, Brazil), in a thermostatically controlled environment (37±0.5°C). Each toothbrushing head was loaded with a 300-g weight and traveled horizontally for 20 mm at a speed of 4.5 strokes per second. The abrasive slurry was prepared by mixing one of the dentifrices (Table 1) with distilled water at the ratio of 1:2 by weight [32]. Specimens were subjected to 5,000 brushing strokes using the different dentifrices: baking soda (BS), tartar control (TC), whitening (WT), regular (RE), as shown in Table 1, or distilled water (CO) as control.

Final roughness measurement and wear depth assessment

After five erosive/abrasive cycles, final measurements (Fm) of surface roughness were carried out as described in the Bm measurements (Fig. 1d). The subtraction between Fm and Bm was considered for data analysis (n=15).

Wear of the specimens in relation to the reference surfaces, previously covered by the tape, were evaluated with a profilometer (Surfcorder SE-1700, Kosaka, Tokyo, Japan). For each specimen ten parallel traces were made across the length of the worn surface (Fig. 1f) and the average was used as the wear depth value. As it was not possible to measure the wear depth of some specimens, five of the fifteen blocks were discarded, thereby a total of 100 experimental units (n=10) were considered for the statistical analysis.

Table 1 Dentifrices under investigation and their technical profiles

Dentifrice	Code	Basic composition[#]
Regular	RE	Sodium fluoride (1,500 ppm), PEG-12, carboxymethylcellulose, sorbitol, hydrated silica, sodium lauryl sulfate, sodium saccharin, flavor, water, blue 1
Baking soda	BS	Sodium monofluorophosphate (1,500 ppm), sodium bicarbonate, calcium carbonate, sodium lauryl sulfate, sodium saccharin, glycerin, sorbitol, carboxymethylcellulose, flavor, water
Whitening	WT	Sodium monofluorophosphate (1,500 ppm), calcium carbonate, aluminium oxide, carboxymethylcellulose, sodium lauryl sulfate, sodium saccharin, sodium silicate, flavor, methyl p-hydroxybenzoate, water
Tartar control	TC	Sodium monofluorophosphate (1,100 ppm), tetrassodium pyrophosphate, sorbitol, glycerin, sodium saccharin, carrageenan, PVM/MA copolymer, hydrated silica, sodium lauryl sulfate, PEG-12, flavor, water

[#] As provided by the manufacturer (Colgate-Palmolive, Division of Kolynos do Brasil Ltda, S.B do Campo, Brazil)

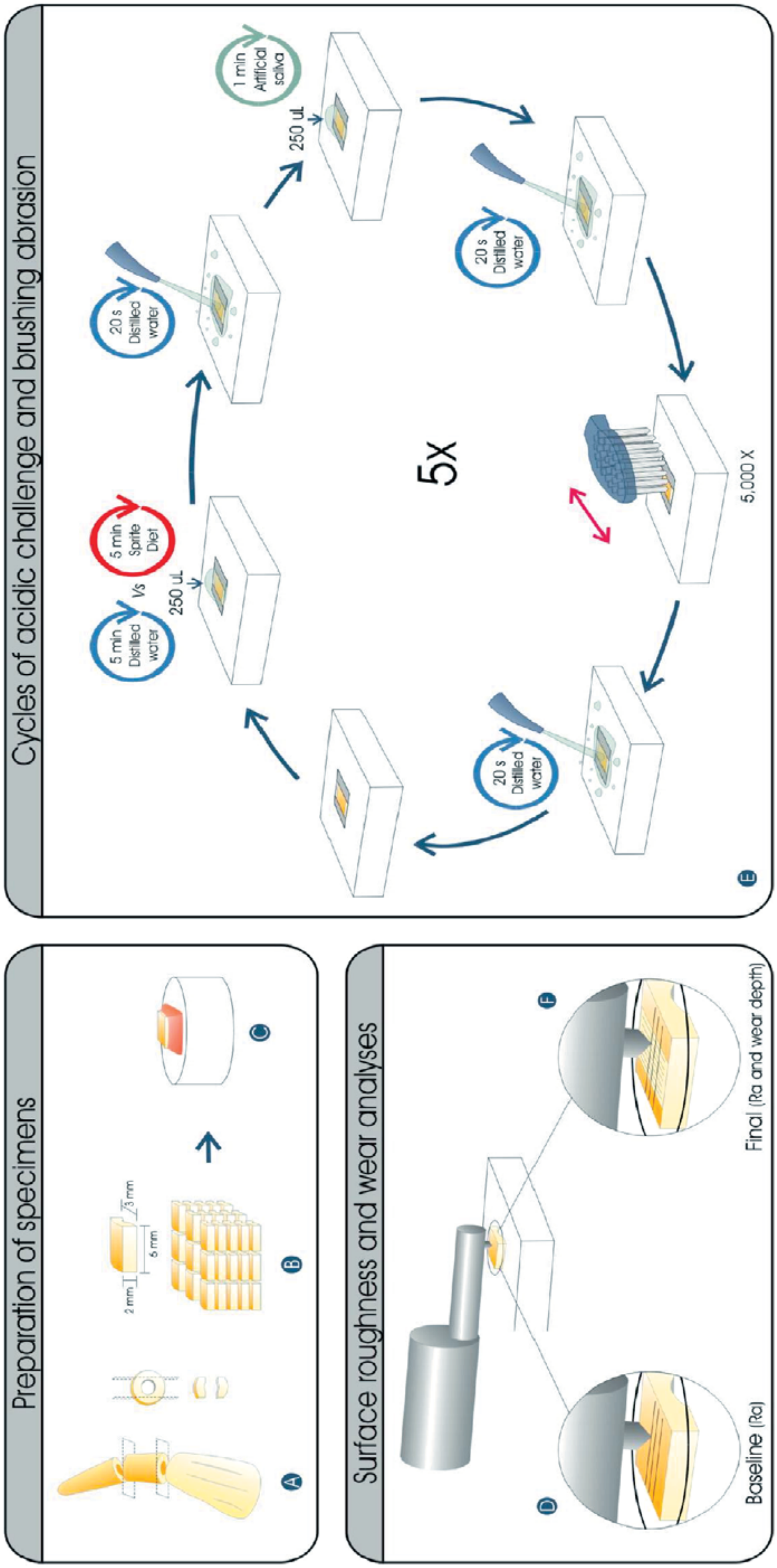

Fig. 1a–f Seventy-five bovine incisors were sectioned at the cementum-enamel junction (**a**) to obtain 150 dentine root slabs (**b**), which were then flattened and serially polished with 320-, 400-, 600- and 1,200-grit abrasive papers and a diamond abrasive paste (**c**). Three tracings were carried out on each specimen at five different locations and the average was used as the baseline measurements (**d**). Specimens were exposed to the acidic beverage and to a remineralizing solution, and subsequently brushed with one of the dentrifices under evaluation (**e**). Final measurements of surface roughness and wear analysis were performed (**f**)

Table 2 Mean values (micrometers) and standard deviation of the wear and the surface roughness change (log-transformed) provided by the different dentifrices

Dentifrice	Surface roughness change		Wear depth	
CO	0.7186 (0.0418)	A	2.21 (1.60)	A
RE	1.0063 (0.4082)	A	9.98 (6.73)	B
WT	1.6247 (0.7505)	B	14.07 (7.32)	BC
BS	1.5794 (0.7339)	B	13.11 (8.14)	BC
TC	1.5617 (0.7215)	B	17.64 (8.41)	C

Means followed by the same superscript letter are not significantly different ($p<0.05$). Least significant difference: surface roughness = 0.4725; wear depth = 6.3481. *CO* control, *RE* regular, *WT* whitening, *BS* baking soda, *TC* tartar control

Presumably, this problem arose because some samples showed wear depth outside the measurement range of the profilometer.

Statistical analysis

After the assumptions of homogeneity of variance and normal distribution have been checked by Hartley's test and Shapiro-Wilks test, respectively, two-way analyses of variance were applied to the data at a significant level of 5%. For significant factors, comparisons among experimental groups were performed with Tukey's test. The statistical calculations were carried out with the software SAS (SAS Institute Inc., Cary, USA).

Results

Due to the lack of homogeneity of variance, a logarithmic transformation was applied to the surface roughness data to stabilize variance. Two-way ANOVA applied to the wear (p=0.9342) and surface roughness change (p=0.4653) data did not show significant interaction between the two factors, acidic treatment and dentifrice (p>0.05). No significant differences in wear (p=0.8333) and texture change (p=0.1304) were observed between the dentine submitted to the erosive treatment or left uneroded. Statistical analysis revealed a significant difference among dentifrices for the response variables wear (p=0.0001) and surface roughness change (p=0.0001).

The values of surface roughness change were obtained by subtracting Fm from the respective Bm for each specimen. Tukey's test showed that the WT, BS and TC produced the highest increase in the surface roughness and were statistically different from CO and RE, which did not differ from each other (Table 2).

Tukey's test evidenced that TC toothpaste provided higher dentine wear than did RE and CO, which had the lower value. TC, BS and WT did not differ from each other, nor did BS; WT and RE were different from each other (Table 2).

Discussion

Different methods such as profilometrical tracing [2, 3, 29] and microradiography [12] have been used to evaluate the abrasive resistance of eroded dentine. One advantage of using profilometry is that the actual depth of dentine loss can be measured in a relatively simple way [8]. In addition, by such technique it is possible to assess the texture of the worn surface, which may play an important role in characterizing the abrasion resistance of dental hard tissues [8]. Another benefit in measuring dentine wear and surface roughness relies on the fact that, in terms of abrasion, data obtained from roots of bovine incisors can be extrapolated to human teeth [15]. This aspect is particularly relevant considering not only the difficulties in collecting a sufficient number of noncarious extracted human teeth for in vitro studies, but also the difficulties to manipulate and standardize the human root dentine substrate.

Since dietary acids are the major etiological factor for tooth erosion and one of the most frequently consumed erosive acids are soft drinks [16], Sprite Diet was used to provide the acidic challenges. Indeed, this beverage has a higher erosive potential as compared with other drinks, due to its low pH (ranging from 2.61 to 2.79), calcium and fluoride concentration, and buffer capacity [20].

The experimental strategies used in this investigation did not show significant effect for the factor acidic treatment for both response variables. Two hypotheses were formulated to explain such findings. First, the high number of brushing strokes (5,000), intended to highlight the abrasiveness of dentifrices, might disguise the effect of the acidic beverage. Second, the contact of the low volume (250 μl) of Sprite Diet with the dentine would raise the pH of this beverage, reducing its softening effect. Nevertheless, additional tests did not support such an assumption. In monitoring the pH of the soft drink before, throughout (after every 1 min) and after 5 min of contact with dentine, no change from the original pH was observed at any time. Likewise, but on enamel, Barbour et al. [4] and Eisenburger et al. [9] did not verify an increase in the pH of acid citric solutions after 120 s or 2 h of contact. Presumably, then, dissolution of apatite took place over the exposure time (5 min) in the present study but the pH of the soft drink did not shift to higher values, probably as a result of its buffering effect. Therefore, it seems more likely that the abrasion masked the erosive challenges.

Seeking therapeutic and cosmetic benefits, toothpastes are being formulated with different ingredients. However, their degree of abrasivity should not provide excessive removal of the dentine. As shown in Table 2, root dentine was less worn away by RE than by TC. The lower change in surface roughness and wear promoted by the RE dentifrice, when compared with TC, might be due to their components. While the former (RE) has only silica, TC also contains tetrassodium pyrophosphate. This salt has a strong binding affinity to surfaces with little soluble calcium salts such as calcium phosphate [21], inhibiting mineralization by saliva [18, 31]. In this manner, it was hypothesized that the remineralization after the acidic challenges might be impaired.

Despite the fact that there are speculative reports on the capacity of toothpastes to neutralize acids [22], no significant difference was observed between wear of the groups brushed with BS and RE. In fact, in a previous study, Cury et al. [6] found that BS did not significantly enhance the ability of a fluoride dentifrice to reduce demineralization and increase remineralization. On the other hand, by the surface roughness analysis the BS toothpaste provided a higher change to root dentine than RE. Such unmatched results could be ascribed to the fact that when surface roughness is assessed, changes are verified in a micromorphological scale.

With respect to wear, there was no significant difference between WT and RE. Joiner et al. [17] also found no difference between a standard and two whitening toothpastes. However, in the same study another brand of whitening dentifrice showed significantly higher wear. Thus, the tooth wear seems to be not directly related to the whitening agent and may depend on the formulation of the dentifrice used [17].

Although it is likely that the artificial saliva could have demonstrated a degree of remineralizability following each acidic event, under clinical situations saliva could exert important protective roles by forming the acquired pellicle, as well as by its clearance and buffering capacity [13, 33], which is hard to assess in a laboratory investigation. Therefore, other studies such as those using in situ models should be performed to validate the present results.

Conclusion

Within the limitations of this study, the data suggested that the surface roughness change and abrasive wear of root dentine depended on the toothpaste used and were not influenced by previous erosive events.

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