# Effect of Whitening Dentifrices on the Superficial Roughness of Esthetic Restorative Materials

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ABSTRACT

*Purpose:* The purpose of this study was to investigate the surface roughness (Ra) of different esthetic restorative materials following simulated toothbrushing using different whitening dentifrices.

*Materials and Methods:* Cylinders of Esthet-X (Dentsply Caulk, Milford, DE, USA), Durafil VS (Heraeus Kulzer, Wehrheim, Germany), and Vitremer (3M ESPE, St. Paul, MN, USA) were made using molds (4 mm in diameter for 2 mm in height). The superficial roughness was evaluated using a profilometer (Ra) with a cutoff length of 0.25 mm and a speed of 0.1 mm/s. The specimens ($N = 13$) were submitted to 7,500 brushing cycles using five different toothpastes: (1) Crest Regular (control; Procter & Gamble): silica abrasive (C); (2) Crest Extra Whitening (Procter & Gamble, Cincinnati, OH, USA): bicarbonate + calcium pyrophosphate (CE); (3) Dental Care A & H (Arm & Hammer, Camilla, GA, USA): bicarbonate (DC); (4) Rembrandt Plus Whitening (Oral B Laboratories, Belmont, CA, USA): carbamide peroxide + alumina/silica (RP); and (5) experimental: hydrogen peroxide + calcium carbonate (EX).

*Results:* The data were analyzed by analysis of variance and Tukey's test ($\alpha = .05$) for each restorative material, and the results [difference between final and initial roughness: Ra(F) – Ra(I) in µm] were as follows: Esthet-X: EX = $0.15 + 0.07^{a}$; RP = $0.29 + 0.16^{a}$; CE = $0.96 + 0.33^{b}$; C = $1.03 + 0.29^{b}$; DC = $1.48 + 0.37^{b}$; Durafil VS: RP = $0.09 + 0.07^{a}$; EX = $0.55 + 0.23^{abc}$; C = $0.96 + 0.26^{bc}$; CE = $1.03 + 0.33^{cd}$; DC = $1.09 + 0.37^{d}$; and Vitremer: EX = $0.10 + 0.08^{a}$; RP = $0.26 + 0.19^{a}$; CE = $0.94 + 0.27^{b}$; DC = $1.13 + 0.46^{bc}$; C = $1.50 + 0.32^{c}$ (different letters mean differences among groups).

*Conclusion:* It was verified that the dentifrices containing carbamide or hydrogen peroxide along with alumina + silica and calcium carbonate, respectively (groups 4 and 5), produced minor changes in Ra when compared with the control group and with those dentifrices containing bicarbonate (groups 2 and 3).

CLINICAL SIGNIFICANCE

The results of this study indicate that whitening dentifrices evaluated containing silica or calcium carbonate were less abrasive when used on the resin-based esthetic restorative materials than those that contain sodium bicarbonate.

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The increasing emphasis on dental esthetics has made tooth whitening an important function of dentifrices.[1,2] Thus, in the last 10 years, dentifrices have become more specialized and can be classified as either therapeutic or cosmetic.[3] As therapeutic agents, there are some that exhibit the capacity to reduce plaque, calculus, and caries, as well as some that can help reduce dentin sensitivity.[4–6] Regarding cosmetic function, one of the most important characteristics is the capacity to prevent or remove stains on the tooth surface, consequently whitening the teeth.[2,7]

A large number of dentifrices containing different formulations have been introduced in the marketplace, each trying to improve the efficiency of cleaning or promoting tooth whitening.[8] These dentifrices often contain hydrogen peroxide, carbamide peroxide, sodium bicarbonate, hydrated silica, or aluminum oxide, separately or in various combinations.[2,8]

In addition to bleaching agents such as hydrogen and carbamide peroxides, abrasive components also can promote tooth whitening. The abrasiveness of a dentifrice depends not only on the inherent hardness of the particles but also on the particle size and shape of the abrasive components.[9]

A positive correlation has been observed between the abrasiveness of the dentifrice and a decrease in superficial stains.[10] However, the data comparing different abrasives are inconclusive.[10] It has been demonstrated that the larger the size of the abrasive particles, the greater the abrasiveness of the dentifrice,[9] although when particles of the same size are compared based on compositions, the particles of silica showed more abrasiveness than those of calcium carbonate.[9]

Dentifrices containing a high content of sodium bicarbonate have demonstrated more effectiveness in whitening teeth than those containing silica or calcium phosphate.[10] This likely can be explained by the lower abrasiveness and intrinsic hardness and the high solubility of the calcium phosphate. Sodium bicarbonate also is lower in cost, making it an attractive, cost-effective ingredient.[2]

Nevertheless, it is not totally clear how the abrasiveness of a dentifrice and the presence of bleaching agents can specifically affect the tooth surface and the surface of tooth-colored restorative materials. It would be expected that the abrasives act by reducing or eliminating extrinsic stains and that bleaching agents would be more effective in counteracting intrinsic stains. It has been demonstrated that changes in the superficial roughness of some resin composite restorations may have negative effects on the quantity and quality of subgingival plaque.[11]

The purpose of this study was to investigate the surface roughness (Ra) of different esthetic restorative materials following simulated toothbrushing using different whitening dentifrices. The null hypothesis to be tested is that whitening dentifrices of various compositions will present the same effect on Ra as a regular dentifrice (control) containing a silica abrasive when used on different esthetic restorative materials.

## MATERIALS AND METHODS

Five dentifrices and three esthetic restorative materials were evaluated in this study; their manufacturers and batch numbers are listed in Table 1.

An acrylic mold 2 mm high and 4 mm in diameter was used to prepare 65 standardized specimens for each of the three restorative materials. These restorative materials were placed by use of titanium-coated instruments (Brillant Esthetic Line Composite Instrument, Coltene AG, Altstatten, Switzerland). Samples were made by placing the respective materials into the mold sandwiched between a matrix strip and two glass plates. The smoothest surfaces were obtained by curing the materials against a matrix strip. In accordance with the manufacturers' specific directions, specimens were polymerized for 40 seconds with a wide-tipped QTH light-curing unit (XL 3000, 3M Dental Products Division, St. Paul, MN,

**TABLE 1. DENTIFRICES AND RESTORATIVE MATERIALS EVALUATED.**

| Restorative Material | Particle Type | Manufacturer | Batch No. |
|---|---|---|---|
| Esthet-X | Microhybrid | Dentsply | 0111092 |
| Durafil VS | Microfill | Heraeus Kulzer | 130028 |
| Vitremer | GIC | 3M ESPE | 20020508 |
| Dentifrice | | | |
| Crest Regular (control) | Silica | Procter & Gamble | 3001 GA |
| Crest Extra Whitening | Bicarbonate | Procter & Gamble | 3040 GE |
| Dental Care | Bicarbonate | Arm & Hammer | E 0001 |
| Rembrandt Plus Whitening* | Alumina/silica | Oral B | 0764050203 |
| Experimental whitening† | Ca carbonate | Proderma Ltd. | Exp 001 |

GIC = glass ionomer cement.
*Hydrogen peroxide 3.6% as the active ingredient.
†Hydrogen peroxide 1.5% as the active ingredient.

USA) at 600 mW/cm$^2$ (Radiometer, Demetron, Danbury, CT, USA). After that the samples were stored in tap water for 24 hours at 37°C before the Ra evaluation.

For the initial surface roughness analysis, each sample was gently dried with absorbent paper and the specimens were evaluated using a profilometer (Surfcorder SE-1700 profilometer, Kosaka Corp, Tokyo, Japan) with a diamond stylus with a 1.5 µm radius moved at a constant speed of 0.1 mm/s with a force of 0.7 mN. The cutoff was set at 0.25 mm, and the surface roughness was characterized by the arithmetic mean of the absolute values of the profile departures within the evaluation length (Ra).

Three tracings were performed on each specimen at different locations. The average of these three Ra measurements was used as the initial measurement [Ra(I)] for each sample. The Ra(I) was obtained measuring the Ra produced by the Mylar strips.

Afterward, the specimens were subjected to 7,500 brushing cycles using an automatic toothbrushing simulation machine (MSEt, Marcelo Nucci ME, Sao Carlos, Brazil) in which the different dentifrices were used on the surface of the restorative material samples ($N$ = 13). Brushing abrasion was performed with a motor that produced a reciprocating motion on 10 soft nylon bristle toothbrushing heads (Johnson & Johnson Extra Soft Toothbrush, Lot #1201, Johnson & Johnson Comércio e Distribuição Ltda, S. J. Campos, SP, Brazil) in a thermostatically controlled environment (37 ± 0.5°C). Each toothbrushing head was loaded with a 200 g weight and traveled horizontally for 20 mm at a speed of 250 strokes per minute. The abrasive slurry was prepared by mixing one of the dentifrices (see Table 1) with distilled water at a ratio of 1:3 by weight.[7,8,12] After the toothbrushing the samples were washed using tap water and stored again for 24 hours at 37°C before the final surface roughness [Ra(F)] evaluation.

After three erosive/abrasive cycles, the Ra(F) measurements were carried out as described above. The subtraction of the average between Ra(F) and Ra(I) was considered for data analysis and expressed in micrometers.

The data were checked to ensure their homogeneity of variance and normal distribution by Hartley's test and Shapiro-Wilks test, respectively. Afterward, a two-way analysis of variance test was applied to the data at a significance level of 5%. Specific differences within each restorative material and comparisons among dentifrices were performed using Tukey's test. The statistical calculations were carried out with *SPSS* (SPSS Inc., Chicago, IL, USA).

## RESULTS

The mean Ra values for each combination of restorative material and dentifrice groups are given in Tables 2 and 3. Statistical analysis was performed comparing the differences between Ra(I) and Ra(F) with respect to brushing simulation within restorative material–dentifrice combinations. It detected a statistically significant difference among dentifrices ($p$ = .00001) and in the interaction restorative material × dentifrices ($p$ = .0057). However, there was no statistically significant difference among restorative materials ($p$ = .805412).

In general, it is possible to observe that Rembrandt Plus Whitening and experimental whitening dentifrices presented the lowest means of roughness in all three restorative materials evaluated (see Table 2).

Tukey's test revealed that, when used on the microhybrid resin composite (Esthet-X, Dentsply), the experimental whitening and Rembrandt Plus Whitening dentifrices presented the lowest means of roughness based on the subtraction of F from I expressed in micrometers. However, statistically significant differences were noted with the other three dentifrices, Crest Extra Whitening (Procter & Gamble), Dental Care A&H (Arm & Hammer), and Crest Regular (Procter & Gamble) (see Table 2).

Regarding the microfill resin composite (Durafil VS, Heraeus Kulzer, Wehrheim, Germany), Rembrandt Plus Whitening (Oral B Laboratories, Belmont, CA, USA) showed the lowest means of roughness and did not present a statistically significant difference when compared with the experimental whitening dentifrice but differed statistically from the others. Regarding the experimental whitening dentifrice, there was no statistically significant difference when compared with Rembrandt Plus Whitening dentifrice, which presented the best results, or when compared with Crest Regular and Crest Extra Whitening dentifrices, which presented intermediary results. The worst result was observed for Dental Care A&H dentifrice, which presented statistically significant differences when compared with all dentifrices except Crest Extra Whitening dentifrice (see Table 3).

Regarding the resin-modified glass ionomer material (RMGIC) (Vitremer, 3M ESPE, St. Paul, MN, USA), the dentifrices basically

**TABLE 2. MEAN ROUGHNESS OF THE RESTORATIVE MATERIALS AFTER BRUSHING WITH DIFFERENT DENTIFRICES.**

| Dentifrice | Restorative Material | Ra[(F) – (I)] (SD) |
|---|---|---|
| DC A&H | Esthet-X | 1.03 (0.51)* |
| DC A&H | Durafil | 1.09 (0.38)* |
| DC A&H | Vitremer | 1.13 (0.32)* |
| Crest Regular | Esthet-X | 1.48 (0.74)† |
| Crest Regular | Durafil | 0.96 (0.37) |
| Crest Regular | Vitremer | 1.50 (0.42)† |
| Crest EW | Esthet-X | 0.96 (0.45)‡ |
| Crest EW | Durafil | 1.06 (0.56)‡ |
| Crest EW | Vitremer | 0.94 (0.46)‡ |
| Remb PW | Esthet-X | 0.44 (0.36)§ |
| Remb PW | Durafil | 0.23 (0.29)§ |
| Remb PW | Vitremer | 0.34 (0.26)§ |
| Exp WTP | Esthet-X | 0.34 (0.30)‖$ |
| Exp WTP | Durafil | 0.66 (0.41) |
| Exp WTP | Vitremer | 0.25 (0.35)‖$ |

DC A&H = Dental Care Arm & Hammer; EW = Extra Whitening; Exp WTP = experimental whitening toothpaste; Ra(F) = final surface roughness; RA(I) = initial surface roughness; Remb PW = Rembrant Plus Whitening.
Statistical analysis (Tukey's test) demonstrated significant differences among groups ($p$ < .05) where the same symbol means no statistically significant difference for each dentifrice.

**TABLE 3. MEAN ROUGHNESS VALUES COMPARING THE DIFFERENT DENTIFRICES WITHIN THE RESTORATIVE MATERIALS.**

| Restorative Material | Dentifrice | Abrasive | Ra[(F) – (I)] (SD) in μm | $\alpha = 0.05$ |
|---|---|---|---|---|
| Esthet-X | Experimental Whitening | Calcium carbonate | 0.15 (0.07) | a |
| | Rembrandt Plus Whitening | Alumina and silica | 0.29 (0.16) | a |
| | Crest Extra Whitening | Bicarbonate/Ca pyrophosphate | 0.96 (0.33) | b |
| | Dental Care A&R | Bicarbonate | 1.48 (0.37) | b |
| | Crest Regular | Silica | 1.03 (0.29) | b |
| Durafil VS | Rembrandt Plus Whitening | Ca carbonate | 0.09 (0.07) | a |
| | Experimental whitening | Alumina and sílica | 0.55 (0.23) | abc |
| | Crest Regular | Bicarbonate/Ca pyrophosphate | 0.96 (0.26) | bc |
| | Crest Extra Whitening | Bicarbonate | 1.03 (0.33) | cd |
| | Dental Care A&H | Silica | 1.09 (0.37) | d |
| Vitremer | Experimental whitening | Ca carbonate | 0.10 (0.08) | a |
| | Rembrandt Plus Whitening | Alumina and sílica | 0.26 (0.19) | a |
| | Crest Extra Whitening | Bicarbonate/Ca pyrophosphate | 0.94 (0.27) | b |
| | Dental Care A&H | Bicarbonate | 1.13 (0.46) | bc |
| | Crest Regular | Sílica | 1.50 (0.32) | c |

Ra(F) = final surface roughness; RA(I) = initial surface roughness.
Statistical analysis (Tukey's test) demonstrated significant differences among groups ($p < .05$) where different letters mean differences among groups.

presented the same behavior as was observed for the resin composites. The experimental whitening and Rembrandt Plus Whitening dentifrices did not present statistically significant differences between them and showed the lowest roughness mean values. However, there were statistically significant differences observed when these two dentifrices were compared with Crest Extra Whitening, Dental Care A&H, and Crest Regular dentifrices (see Table 3).

## DISCUSSION

In this study, the smoothest surfaces were produced by curing the materials against a matrix strip. This procedure was done in agreement with previous studies on resin composites.[13,14] The smoothness obtained with matrix strips could not be reproduced by any of the finishing/polishing systems.

The incorporation of abrasives in specific dentifrices might help physically remove stain, but since virtually all dentifrices contain abrasives, some degree of stain removal may be expected even with regular products. The concept of whitening formulations containing specific chemicals that reduce or inhibit stain, independent of a physical effect, would appear to be particularly attractive since reduced staining may be apparent in sites of the dentition where the abrasive effects of the dentifrice would be less obvious.[15]

It has been demonstrated that toothbrushing can abrade the surface of resin composite-based materials with a three-body wear process.[16] Toothbrushing can erode the softer polymer matrix, leaving the harder reinforcing particles standing higher in relief. Toothbrushing also can increase this roughening effect because the bristles would not abrade the surfaces as evenly as flat disks or rubber cups would do in finishing procedures.[16]

In this study a toothbrushing machine was used to simulate the in vivo condition. As demonstrated in other studies, it seems to be a very good method to evaluate the effectiveness of different abrasives used in the dentifrice formulations[4,17,18] and to check the Ra of the restorative materials.[19–21]

As noted early, for this study three different resin-based restorative materials were evaluated: Esthet-X, a microhybrid composite; Durafil VS, a microfill resin composite; and Vitremer, a resin-modified glass ionomer material. Microfilled and hybrid resin composites are recommended for restorations in esthetically critical areas of the mouth. Moreover, it has been suggested that they may experience fewer adverse effects relative to Ra than restorations of resin-modified glass ionomer cement if bleaching procedures are to follow.[22] Also, different dentifrice formulations using different abrasives and bleaching agents were used to evaluate how these dentifrices could affect the Ra of the materials. This is an important aspect to be considered since many whitening toothpastes have been introduced on the market to be used especially during and after bleaching treatments either in office or at home as a complement.

The abrasiveness of the dentifrices should not result in excessive removal of material, especially the polymer matrix. As demonstrated in the results, the subtraction between F and I indicates for all restorative materials studied that Rembrandt Plus Whitening and the experimental whitening presented the lowest values of Ra when compared with the other dentifrices. This result means that these two materials were the least aggressive at removing restorative material.

According to the results of this study, dentifrices containing alumina and silica (Rembrandt Plus Whitening) and calcium carbonate (experimental whitening) as abrasives resulted in lower Ra. These findings are in agreement with other studies that demonstrated that dentifrices containing a high content of sodium bicarbonate have shown more effectiveness in whitening teeth than those containing silica or calcium phosphate.[2] Moreover, the abrasiveness of a dentifrice depends not only on its inherent hardness but also on its particle size and shape, as well as the pH of the dentifrice itself.[23]

A positive correlation has been observed between the abrasiveness of the dentifrice and the decrease in superficial stains.[3] Also, the larger the size of the abrasive particles, the greater is the abrasiveness of the dentifrice.[9] However, when the particles are of the same size, the silica showed more abrasiveness than calcium carbonate.[9] Based on this observation, the results obtained in this study confirm that dentifrices containing silica, bicarbonate, and the combination of bicarbonate with calcium pyrophosphate are more abrasive than those presenting with the combination of alumina and silica or calcium carbonate as an abrasive.

As noted earlier, the whitening dentifrices can act in two different ways: physically remove superficial stains by the action of the abrasives or act chemically by the effect of peroxides, such as carbamide or hydrogen peroxide. Basically, the whitening dentifrices Dental Care A&H and Crest Extra Whitening appear to remove stains primarily based on abrasive action, whereas Rembrandt Plus Whitening and the experimental whitening dentifrices, being inherently less abrasive, may rely largely on the peroxides for stain removal.

Even though the concentration of peroxide present in these two toothpastes is low, it is important to consider that the effect of bleaching agents on the Ra of restorative materials is material and time dependent.[23] It has been demonstrated that bleaching agents, which contain 10% carbamide peroxide, caused only slight changes to the surface of microfilled resin composite after immersion of 4 hours daily in fresh bleaching gel.[24] Also, bleaching agents with a concentration of 16% carbamide peroxide did not cause significantly higher roughness than the other bleaching agents with a concentration of 10%.[23]

In addition, it has been speculated that the resin composite and glass ionomer materials exposed to bleaching agents for extended periods may increase the risk of clinical failure.[23] Hydrogen peroxide is known to have high capacities for oxidation and reduction and may generate free radical species. Hydrogen peroxide and these high-energy free radicals may have an adverse effect on the resin-filler interface and cause a filler-matrix debonding. This action would result in further crack propagation, leading to a significant increase in Ra.[22] Nevertheless, the results of this study showed that in low concentration, as observed for the experimental whitening (hydrogen peroxide 1.5%) and Rembrandt Plus Whitening (hydrogen peroxide 3.6%) dentifrices, hydrogen peroxide did not significantly affect the Ra of the resin-composite materials or the resin-modified glass ionomer cement.

Nowadays it is very important to consider the possible adverse effects of dentifrices, not only on tooth structure but also on restorative materials, especially since many dentifrices have high abrasiveness. Based on the results of this study, it can be concluded that whitening dentifrices containing silica or calcium carbonate were less abrasive when used as dentifrices on the resin-based esthetic restorative materials evaluated than those that use sodium bicarbonate.

## DISCLOSURE

The authors do not have any financial interest in the companies whose materials are discussed in this article.

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