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Effects of Charcoal Toothpaste on the Surface Roughness, Color Stability, and Marginal Staining of Resin Composites

GF Bragança • PB Ferreira Soares • J Simeão Borges
AB Fernandes Vilela • PC Santos Filho • CJ Soares

Clinical Relevance

Charcoal toothpastes cause roughness in resin composites similar to control toothpastes; however, some types of toothpastes can change the color and cause marginal staining of the resin composite restorations.

SUMMARY

Objective: This study was designed to evaluate the effects of charcoal toothpaste on the surface roughness, color stability, and marginal staining of resin composite restorations.

Methods: A total of 100 bovine incisors was collected. The crowns were sectioned and randomly divided into 10 groups (n=10) according to two study factors: toothpaste groups and nanoparticle resin composite groups. Five toothpastes—Bianco Pro Clinical (Bianco Oral Care, Uberlândia, MG, Brazil) - Control group; Bianco Carbon (Bianco Oral Care); NAT, Natural Suavetex Carvão Ativado (Suavetex, Uberlândia, MG, Brazil); Nano Action Black Be Emotion (Polishop, Jundiaí,

Gabriel Felipe de Bragança, DDS, MSc, PhD student, Department of Operative Dentistry and Dental Materials, School of Dentistry, Federal University of Uberlândia, Uberlândia, Minas, Gerais, Brazil

Priscilla Barbosa Ferreira Soares, DDS, MSc, PhD, professor, Department of Periodontology and Implantology, School of Dentistry, Federal University of Uberlândia, Uberlândia, Minas, Gerais, Brazil

Juliana Simeão Borges, DDS, PhD student, Department of Periodontology and Implantology, School of Dentistry, Federal University of Uberlândia, Uberlândia, Minas Gerais, Brazil

Andomar Bruno Fernandes Vilela, DDS, MSc, PhD student, Department of Operative Dentistry and Dental Materials, School of Dentistry, Federal University of Uberlândia, Uberlândia, Minas, Gerais, Brazil

Paulo Cesar Santos Filho, professor, Department of Operative Dentistry and Dental Materials, School of Dentistry, Federal University of Uberlândia, Uberlândia, Minas Gerais, Brazil

*Carlos José Soares, DDS, MS, PhD, School of Dentistry, Federal University of Uberlândia, Uberlandia, Minas Gerais Brazil

*Corresponding author: Avenida Pará 1720, Bloco 4L, Anexo A, Sala 42, Campus Umuarama, Uberlândia, Minas Gerais, Brazil, CEP 38400-902 e-mail:carlosjsoares@ufu.br

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SP, Brazil); and BIW, Black is White (Curaprox, Curaden AG, Kriens, Switzerland)—and two resin composites—Z350XT (Filtek Z350XT, 3M Oral Care) and Vittra (Vittra APS FGM, Joinville, SC, Brazil)—were used. Circular cavities with a diameter of 4 mm and a depth of 1 mm were prepared on the buccal face of the tooth crowns and restored with resin composites. The specimens were subjected to three months of simulated toothbrushing. The surface roughness (right angle [Ra], in micrometers [μm]) of the resin composites was measured before and after toothbrushing in five areas per specimen. The resin composite color and luminosity changes (ΔE and ΔL, respectively) were measured using reflectance spectroscopy (Vita EasyShade). Macro photographs were taken before and after toothbrushing to qualitatively analyze the marginal staining (MSt) of the resin composite restorations. Scanning electron microscopy (SEM) was performed before and after the simulated toothbrushing. Ra data were analyzed using two-way analysis of variance with repeated measures and the Tukey HSD test; MSt was analyzed using Kruskal-Wallis and Dunn tests (α=0.05), and the resin composite color change was analyzed using the clinically unacceptable level of ΔE > 3.3.

Results: Simulated brushing increased Ra irrespective of the resin composite or toothpaste used. No significant differences were found in Ra between the control group and all groups on which the charcoal toothpastes were tested. A clinically unacceptable level of resin composite color change (ΔE>3.3) was found after the use of most charcoal toothpastes. Use of Bianco Carbon resulted in marginal staining similar to that of the control group and was lower than that of the other charcoal toothpastes. Vittra brushed with black toothpaste showed the highest marginal staining.

Conclusion: Use of charcoal toothpaste resulted in Ra values of resin composites similar to those found with conventional toothpastes. Charcoal toothpaste generally resulted in clinical resin composite color changes (ΔE). All charcoal toothpastes, except Bianco Carbon, caused marginal staining of the resin composite restorations.

INTRODUCTION

Resin composites are the first choice for direct restorations in daily practice.[1] They are commonly used as substitutes for enamel and dentin[2] for diastema closure procedures, dental fractures, and direct veneers.[3] However, resin composite restorations are prone to staining, changing color, and wearing out due to many intrinsic and extrinsic factors,[4] such as photoinitiator system type, resin matrix degradation, insufficient irradiation time, and low irradiance of the light-curing unit used for polymerization.[5] Additionally, the oxidation of monomers or catalysts, exposure to thermal, mechanical, and chemical challenges in the oral environment, [6,7] and absorption of extrinsic stains can contribute to these alterations of resin composites.[8] Shrinkage stress is another relevant side effect that can be generated during light-curing of resin composites,[9] These stresses are linked to the creation or propagation of enamel cracks, which can lead to esthetic problems such as stained cracks.[10]

The loss of gloss and darkening in resin composite restorations creates negative esthetics.[11] Surface roughness is the major contributor to the extrinsic discoloration of resin composite restorations,[12] and this roughness is related to the organic matrix, inorganic filler composition, finishing and polishing procedures, and challenging processes that occur in the oral environment.[13,14] A high surface roughness can increase biofilm accumulation, mineral loss, topography alteration, and altered light reflectance from the enamel.[15] On resin composites, increased roughness can lead to staining or discoloration of the body and margins of restorations or, in more severe cases, even cause gingivitis, caries, and recurrent caries.[16]

Recently, charcoal-based toothpaste has been developed and commercialized for oral hygiene; it is considered fashionable toothpaste.[17] Charcoal-based products for dental hygiene can be produced in various formulations, such as powder form or even coal ashes.[18-20] The manufacturers of charcoal-based toothpastes claim that they have stain-removal and whitening effects, and these purported esthetic effects are used in promotions to customers. However, there is still a lack of evidence to support such claims for these products.[21] Instead, the opposite effect may occur, such as marginal staining of resin composite restorations and laminate veneers.[17] This might be an important drawback because marginal staining is often erroneously used as a criterion for the replacement of indirect and direct resin composite restorations.[9]

No scientific evidence is available to support the benefits of the charcoal-based toothpastes that are currently marketed.[21] Thus, it is clinically important to evaluate the effects of brushing teeth using different charcoal-based types of toothpaste on resin composite restoration surfaces. To the best of our knowledge, no other study has verified these effects for resin composite surfaces. Therefore, this study was aimed to evaluate the effects of charcoal-based toothpaste on the surface roughness, color stability, and marginal staining of two nano-filled resin composites. The null hypothesis was that toothbrushing with charcoal toothpaste would not affect the surface roughness or cause color changes or staining of the margins of resin composite restorations.

METHODS AND MATERIALS

One hundred bovine incisors of similar shapes and colors were collected for use as substitutes for human teeth.[22,23] The specimens were stored in distilled water at 37°C before preparation and between all procedures. After prophylaxis, the roots of the teeth were removed using a high-speed water-cooled diamond disc (American Burrs, Palhoça, SC, Brazil). The crowns were embedded in epoxy resin (Buehler, Lake Bluff, IL, USA), and the buccal surface was finished with 600-grit sandpaper (3M, Sumaré, SP, Brazil) to obtain a parallel surface for cavity preparation. The teeth received circular cavities with a diameter of 4 mm and a depth of 1 mm, performed by inserting the entire head of a wheel diamond bur at a high speed (No 3053, KG Sorensen, Cotia, São Paulo, Brazil). The burs were replaced after 10 cavity preparations. A restorative procedure was performed by selective etching of the enamel with 37% phosphoric acid (Condac 37, FGM,) for 30 seconds. The cavities were washed using a water spray for 30 seconds and excess water was removed with absorbent paper. A self-etching adhesive (Ambar Universal APS, FGM) was applied in two layers onto the enamel and dentin surfaces with a microbrush (Cavibrush, FGM), followed by a light jet of air for 10 seconds to facilitate the evaporation of the solvent and light-curing for 10 s with an LED light-curing unit (LCU; Bluephase G2, Ivoclar Vivadent, Schaan, Liechtenstein) at 1400 mW/cm², checked using a MARC Resin Calibrator (BlueLight, Halifax, Canada). The specimens were randomly divided into 10 groups (n=10); half of the specimens were restored with two increments of the nano-filled resin composite Filtek Z350 XT (A2E shade, 3M Oral Care, St Paul, MN, USA), and the other half were restored with the nano-filled resin composite Vittra APS (EA2 shade, FGM) and light-cured for 20 seconds for each increment. Descriptions of the resin composites are listed in Table 1. After the restorative procedure, the specimens were submitted to a finishing procedure using 600, 800, 1000, and 1200-grit sandpaper (3M, Sumaré), followed by polishing with 6-μm, 3-μm, 1-μm, and 1/4-μm grit diamond polishing pastes with the respective polishing cloths (Arotec, Cotia, SP, Brazil) for 2 minutes with each paper by a trained operator at the same rotation speed as in the metallographic polishing machine (Arotec). After each polishing step, the specimens were ultrasonically cleaned (Thornton, Vinhedo, SP, Brazil) in deionized water for 10 minutes to remove debris.

The surface roughness (Ra, μm) was analyzed before and after the toothbrushing cycles using a profilometer (SJ-301, Mitutoyo, Kanagawa, Japan). Five measurements were performed on the resin composite surface for each specimen at different positions using a cutoff length of 0.25 mm, speed of 0.25 mm/s, and length of 0.8 mm. Measurements were taken perpendicular to the direction of brushing. The Ra value for each specimen represented the mean Ra of five measurements.[24]

Blind measurements with a reflectance spectrophotometer (Vita EasyShade Advance 4.0, Vident, Brea, CA, USA) were used to evaluate surface color changes (ΔE) and luminosity changes (ΔL) of the resin composite restorations due to brushing

Table 1. *Resin Composites Used in this Study*

Resin Composites	Type	Shade	Monomers	Filler Type	Filler Volume (%)	Filler Weight (%)	Manufacturer	Batch Number
Filtek Z350XT	Nanoparticle	A2E	bis-GMA, UDMA, TEGDMA, bis-EMA	Silica, zirconia, aggregated zirconia/ silica clusters	63.3	78.5	3M Oral Care, St Paul, MN, USA	1901600177
Vittra APS	Nanoparticle	EA2	Methacrylate monomers mixture	Silica, zirconia	52-60	72-82	FGM, Joinville, SC, Brazil	051216

Abbreviations: bis-GMA, bisphenol A-glycidyl methacrylate; UDMA, urethane dimethacrylate; TEGDMA, triethylene glycol dimethacrylate; bis-EMA, bisphenol A diglycidyl methacrylate ethoxylated.

with charcoal toothpaste. The device was calibrated before the measurement of each specimen, and the color parameters were recorded before (baseline) and immediately after the toothbrushing cycles. Three measurements of the center of the resin composite restoration were performed for each specimen in the same position, and the mean of the three readings was calculated. ΔE and ΔL were chosen for analyzing the effects of any color changes. Tooth color was analyzed based on ΔL, Δa, Δb, and ΔE coordinates from the CIE $L^*a^*b^*$ color system, in which L^* values represent luminosity (a value of 100 corresponds to perfect white, while 0 indicates black); a^* indicates red (positive values) and green colors (negative values); b^* represents yellow (positive values) and blue (negative values).[25,26] The color change (ΔE) was determined using the following formula[27,28]: $\Delta E^*=[(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2]^{1/2}$. Three intervals were used to classify the color changes of the resin composite restoration: $\Delta E<1.0$, imperceptible to the human eye; $1.0<\Delta E<3.3$, discernible by a skilled person and clinically acceptable; and $\Delta E\geq 3.3$, easily observed and clinically unacceptable.[26,29]

Marginal staining (MSt) was evaluated qualitatively by analyzing macro photographs taken before and immediately after the toothbrushing cycles. Photographs were taken by one operator using a digital single-lens reflex (DSLR) camera (Canon T5, Canon, Ota, Tokyo, Japan) with a macro lens (100 mm, Canon) and a macro ring flash (YN-14EX, Shenzhen Yongnuo, Futian District, Shenzhen, China). The same focal distance and photo parameters were used for all photographs. The photographs were saved and randomized using codes with letters and numbers for blind identification of the photographs. The photographs were analyzed by three trained operators. The resin composite restoration image was divided into four quadrants for analysis. The operators evaluated the MSt, and the sum of the stained quadrants was classified as Score I: 0 quadrants stained, II: 1 quadrant stained, III: 2 quadrants stained, IV: 3 quadrants stained, and V: 4 quadrants stained. Each evaluation was performed independently to avoid any influences of the other operators. During the evaluation, the resin composites or toothpastes evaluated with each specimen were unknown to the operators. In case of disagreements regarding score punctuation, the lowest rating was recorded.

The toothpastes selected for this study were a conventional toothpaste without charcoal, Bianco Pro Clinical, BPC (Bianco Oral Care) as control group and four charcoal toothpastes—Bianco Carbon, BCA (Bianco Oral Care), Natural Suavetex Carvão Ativado, NAT (Suavetex), Nano Action Black Be Emotion, NAB (Polishop), and black, white, BIW (Curaprox). Information about the toothpastes used is listed in Table 2. The specimens, embedded in polystyrene resin cylinders, were assembled on a matrix attached to a toothbrushing machine (Odeme Dental Research, Luzerna, SC, Brazil) with the resin composite surface restorations facing up. A mixture of toothpaste and artificial saliva (ratio 2:1, 8 g/4 mL by specimen)[30,31] was dispensed onto the matrix to cover the surface of the specimen. Heads of soft-bristle toothbrushes (Colgate Pro Cuidado, Colgate-Palmolive Co., New York, NY, USA) were cut and attached to the device. Specimens were subjected to 21,960 cycles,[31] simulating three months of toothbrushing, with a vertical loading of 200 g over the toothbrush heads and at a controlled temperature (25°C±1°C). A linear motion was performed over the surface of the specimens, as shown in Figure 1. After each specimen cycle, the toothbrush and toothpaste mixture were replaced, and

Table 2. *Toothpastes Used in this Study*

Toothpastes	Code	Main Components	Manufacturer
Bianco Pro Clinical (Control)	BPC	Tricalcium phosphate 3%	Bianco Oral Care, Uberlândia, MG, Brazil
Bianco Carbon	BCA	Tricalcium phosphate 3%, charcoal powder	Bianco Oral Care, Uberlândia, MG, Brazil
Natural Suavetex com Carvão Ativado	NAT	Charcoal powder, bambusa vulgaris extract, punica granatum extract, salvia sclarea extract	Suavetex, Uberlândia, MG, Brazil
Nano Action Black Be Emotion	NAB	Charcoal powder, cocos nucifera oil, sodium monofluorophosphate, 1192 ppm fluoride	Polishop, Jundiaí, SP, Brazil
Black is White	BIW	Hydroxyapatite, activated carbon, 1450 ppm fluoride, enzymes, 15000 ppm nano-hydroxyapatite, Prestige Sparkling Blue	Curaprox, Curaden AG, Kriens, Switzerland

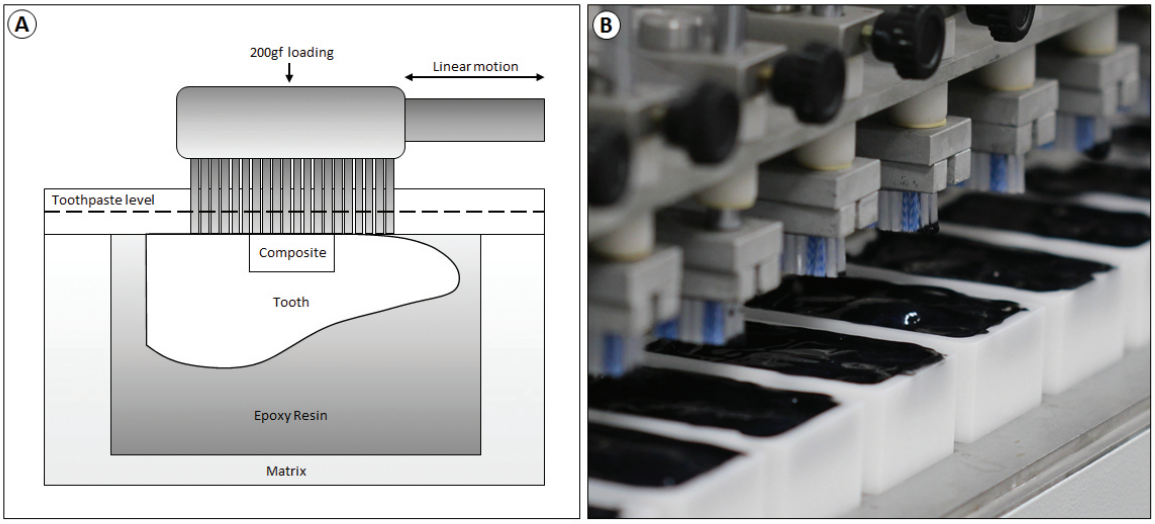

Figure 1. *Toothbrushing methodology. (A): Diagram of the toothbrushing method; (B): Specimens on the toothbrush machine.*

the brushing machine was completely cleaned using distilled water. After the brushing cycles, the specimens were washed with distilled water for 2 minutes, and the final photographs were taken. Color evaluation and Ra measurements were performed again using the same parameters. Representative specimens of each group were fixed on stubs and analyzed using scanning electron microscopy (Tescan Company, Brno, Czech Republic) with a 1000× magnification pre-brush to visualize the shape, quantity, and size of the filler content of the resin composites and a 100× magnification post-brush to verify the differences in roughness on the resin composite surface.

The Ra data (μm) were tested for normal distributions (Shapiro-Wilk) and equality of variances (Levene test), followed by parametric statistical tests using two-way repeated measures analysis of variance (ANOVA), followed by Tukey test. MSt was analyzed using the Mann-Whitney, Kruskal-Wallis, and Dunn's tests (α=0.05). The resin composite color change was analyzed qualitatively for the presence of a clinically unacceptable level ($\Delta E>3.3$)[26,29] and positive or negative values of ΔL.

RESULTS

The mean and standard deviations of the surface roughness (Ra, μm) before and after brushing are shown in Figure 2 and Table 3. Two-way ANOVA of repeated measurements demonstrated a significant influence of the resin composite type ($p<0.001$) and

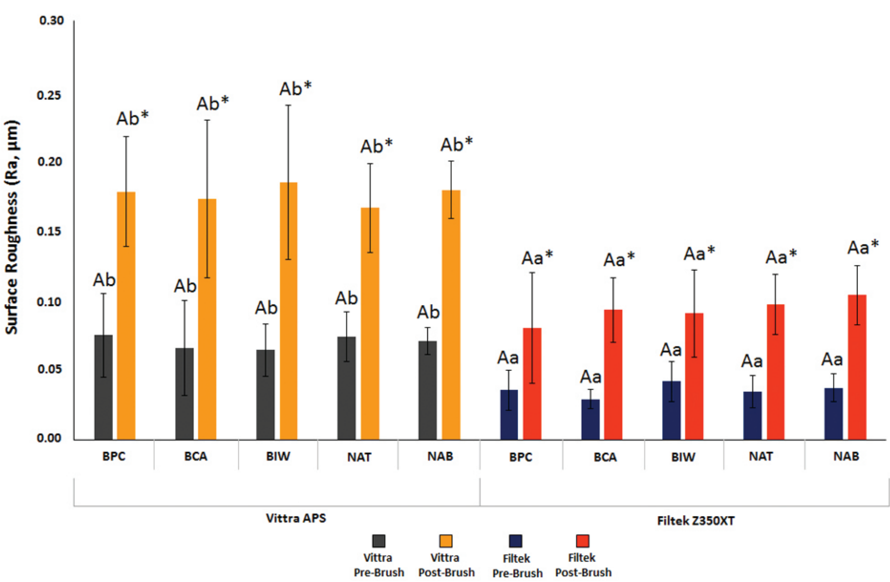

Figure 2. *Mean and standard deviation values of surface roughness before and after brushing. Different letters indicate significant differences (p<0.05); uppercase letters are used for comparing toothpastes; lowercase letters are used for comparing composite resins at each moment; and * is used for comparing pre- and postbrushing data. BPC, Bianco Pro Clinical (Bianco Oral Care) - control group; BCA, Bianco Carbon (Bianco Oral Care); NAT, Natural Suavetex Carvão Ativado (Suavetex); NAB, Nano Action Black Be Emotion (Polishop); BIW, Black is White (Curaprox).*

Table 3. *Mean and Standard Deviation Values for the Surface Roughness (Ra - µm) of Resin Composite Restorations Before and After Toothbrushing*

Toothpastes	Vittra APS (n=10)[a]		Filtek Z350XT (n=10)[a]	
	Prebrush	Postbrush	Prebrush	Postbrush
Bianco Pro Clinical	0.08 (0.03) Ab	0.18 (0.04) Ab[b]	0.04 (0.01) Aa	0.08 (0.04) Aa[b]
Bianco Carbon	0.07 (0.03) Ab	0.17 (0.06) Ab[b]	0.03 (0.01) Aa	0.09 (0.02) Aa[b]
Curaprox Black is White	0.06 (0.02) Ab	0.18 (0.06) Ab[b]	0.04 (0.01) Aa	0.09 (0.03) Aa[b]
Natural Suavetex	0.07 (0.02) Ab	0.17 (0.03) Ab[b]	0.03 (0.01) Aa	0.10 (0.02) Aa[b]
Nano Action Black Be Emotion	0.07 (0.01) Ab	0.18 (0.02) Ab[b]	0.04 (0.01) Aa	0.10 (0.02) Aa[b]

[a] *Different letters indicate significant differences (p<0.05). Uppercase letters are used for comparing toothpastes, lowercase letters are used for comparing composite resins at each moment*
[b] *For comparing pre- and postbrushing data.*

toothpaste type (p<0.001). All groups showed increased Ra after the toothbrushing cycles regardless of the toothpaste or resin composite used. Z350XT had lower Ra values before and after brushing than Vittra. Comparison of the BPC toothpaste control groups with all four charcoal toothpaste groups tested showed no significant difference in Ra values (p>0.160).

The color change (ΔE) and luminosity change (ΔL) results are shown in Figures 3 and 4, respectively. All resin composite restorations brushed with charcoal toothpaste presented clinically unacceptable color changes (ΔE>3.3), except for the combination of Z350/BCA (Figure 3). In the ΔL analysis, more visible alterations in luminosity were observed when charcoal toothpaste was used. Brushing with conventional BPC toothpaste caused no significant color or luminosity alterations.

The marginal staining results of the resin composite restorations are shown in Table 4, and representative images of all groups are shown in Figure 5. The Mann-Whitney test showed a significant difference only for the BIW toothpaste, with Vittra (p=0.008) showing the highest MSt level. The Kruskal-Wallis test showed no significant difference between BPC and BCA for both resin composites. However, the Dunn test showed a significant difference between BCA and BPC with BIW, NAT, and NAB, which exhibited different levels of MSt, indicating darkening of the margins of the restoration.

SEM images of all groups are shown in Figure 6. Z350XT presented lower irregularities compared with Vittra, irrespective of the toothpaste used. The control group, BPC, resulted in lower irregularities on the resin composite surfaces than the charcoal toothpastes tested (Figure 6). SEM images of Z350XT showed a more homogeneous distribution and smaller filler particle sizes than Vittra, which presented a more heterogeneous distribution with larger filler particles among the inorganic fillers (Figure 6A, 6B).

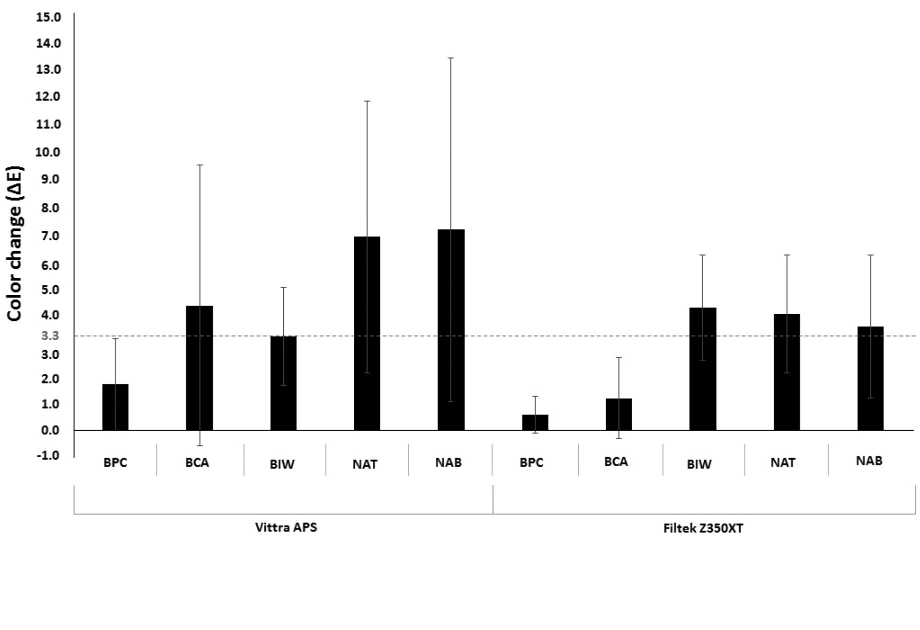

Figure 3. *Mean and standard deviation values of resin composite color changes (ΔE). The red dotted line (ΔE>3.3) indicates clinically unacceptable color change values. BPC, Bianco Pro Clinical (Bianco Oral Care) - control group; BCA, Bianco Carbon (Bianco Oral Care); NAT, Natural Suavetex Carvão Ativado (Suavetex); NAB, Nano Action Black Be Emotion (Polishop); BIW, Black is White (Curaprox).*

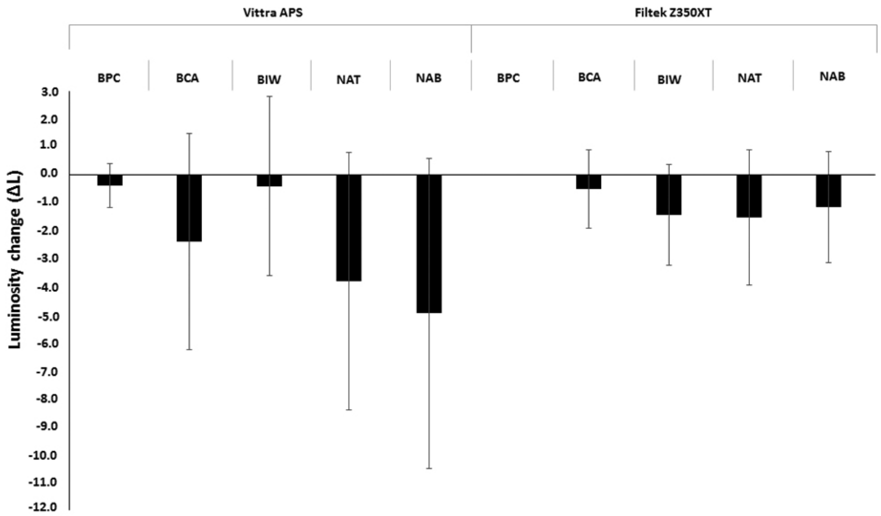

Figure 4. *Mean and standard deviation values of resin composite luminosity changes (ΔL).*

DISCUSSION

This *in vitro* study evaluated the effects of charcoal toothpaste brushing on the surface roughness, color stability, and marginal staining of resin composite restorations. According to the results of this study, charcoal toothpastes affected the surface roughness of the resin composites compared with the control toothpaste, stained the margins of the resin composite restorations, and produced color changes on the resin composite, requiring the null hypotheses to be rejected. Z350XT showed lower Ra values before and after the toothbrushing cycles than the Vittra specimens. This might be attributed to the smaller and more homogenous filler particles of Z350XT, as shown in Figure 7. This characteristic facilitates better polishing and a smoother resin composite surface[32] and may also result in more esthetic restorations. Although both resin composites tested were nanoparticulated resin composites, according to the manufacturers, Z350XT presented 20-nm silica fillers and 4-11-nm zirconia fillers, while Vittra presented 100-200-nm silica-zirconia fillers. Thus, Vittra contained a larger and more heterogeneous distribution of the filler elements, which accords with the Ra values obtained in this study.

The Ra values of both resin composite restorations increased after toothbrushing, regardless of the toothpaste used. Soft-bristle toothbrushes were used in this study.[33-35] The soft-bristle toothbrush under 200 g loading using conventional toothpaste (control group, BPC) caused a small increase in the Ra of the

Table 4. *Marginal Staining of Resin Composite Restorations Evaluated by a Qualitative Analysis of Stained Quadrants After Toothbrushing*

Toothpastes	Vittra APS[a]						Filtek Z350XT[a]					
	I	II	III	IV	V		I	II	III	IV	V	
Bianco Pro Clinical (control)	10	0	0	0	0	Aa	10	0	0	0	0	Aa
Bianco Carbon	10	0	0	0	0	Aa	10	0	0	0	0	Aa
Black is White	1	2	2	3	2	Bb	6	3	0	1	0	Aab
Natural Suavetex Carvão Ativado	4	4	2	0	0	Aab	3	0	2	5	0	Ab
Nano Action Black Be Emotion	2	4	3	1	0	Ab	3	3	3	0	1	Aab

Abbreviations: I, 0 quadrants stained; II, 1 quadrant stained; III, 2 quadrants stained; IV, 3 quadrants stained; V, all margins stained.
[a]Uppercase letters are used to analyze the difference between columns (each toothpaste for both composites). Lowercase letters are used to analyze the difference between rows (composite for all toothpastes).

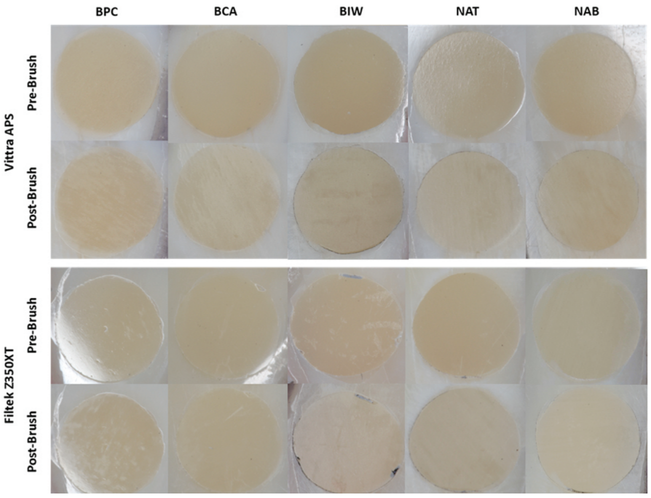

Figure 5. *Marginal staining of representative specimens of each resin composite restoration group.*

resin composite restorations, similar to the charcoal toothpastes tested. Follow-up and possible new finishing and polishing of the resin composite restorations are strongly recommended. Even the control toothpaste contains abrasive materials such as silica and hydrated silica,[36] which may increase the roughness of the resin composite surface. Increasing surface roughness can contribute to faster colonization by and maturation of biofilms, increasing the possibility of resin composite degradation and the risk for caries and periodontal inflammation.[37] An increase in Ra values equal or superior to 0.2 μm leads to greater biofilm retention, and when Ra is higher than 0.3 μm, biofilm retention may be detected by patients' lips and tongues, causing discomfort.[37-39] Vittra and Z350XT restorations brushed with all toothpastes reached Ra values below the threshold of 0.2 μm, as shown in Figure 2.

The color changes in the resin composite restorations (ΔE) were higher for the specimens brushed with charcoal toothpastes, reaching clinically unacceptable values ($\Delta E>3.3$). This might be explained by the fact that some monomers, such as TEGDMA, are vulnerable to water sorption resulting in a higher level of staining caused by absorption of toothpaste components.[40,41] Charcoal particles and dark and gray pigments present in charcoal toothpastes are impregnated into the resin composite surface, changing the color. The dark pigments incorporated into the resin composites with increasing Ra caused darkening of the resin composites, as confirmed by negative ΔL values, which were more visible and significant in the charcoal toothpaste groups. The ΔE and ΔL values were higher in the Vittra groups, which might be due to the higher Ra of this resin composite, as higher surface roughness tends to increase staining susceptibility.[42-44]

The risk for marginal staining of resin composite restorations is a frequently asked question by patients, especially those that have esthetic restorations, who are considering the use of charcoal toothpastes. Except for BCA, all charcoal toothpastes presented MSt at different levels. The fact that BCA had no significant MSt might be due to the lower quantity of charcoal particles and lighter pigments contained, which resulted in the appearance of a gray rather than black color, as seen with the other tested charcoal toothpastes. The bonding agent used in this study was a self-etching adhesive containing the functional monomer 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP). Selective enamel etching with 37% phosphoric acid for 30 seconds preceded the application of the adhesive system. The bonding strategy used and the performance of this adhesive system result in stable dentin bonds with results comparable to those of gold standard materials, particularly when applied in the self-etch mode.[45,46] Therefore, this is not considered a factor biased toward marginal staining. Although not the aim of the study, the authors were able to visualize pigmentation in enamel microcracks in some specimens. This might be another important concern, as enamel microcracks are not easy to treat, and, when severely stained, they can lead to the necessity of restorative intervention.

In other *in vitro* studies with charcoal toothpastes, the surface roughness of the enamel was evaluated, verifying the loss of minerals on the enamel surface caused by the abrasive properties of the toothpaste.[21,36] However, this study focused on effects on the resin composites, and all groups brushed with charcoal toothpastes showed similar roughness of the resin composite as the group with the control toothpaste. This might be because the susceptibility of enamel to toothbrush abrasion is higher than that of the restorative materials.[47] This study had some limitations, including a lack of complete information about the toothpaste compositions, such as the percentage of each component or whether there was a component that was not listed; this drawback is similar to that in a previous study.[41] Although this *in vitro* study tried to replicate general conditions that occur in the mouth, other conditions that can enhance surface roughness and marginal staining were not replicated. An acidic diet, brushing force, salivary conditions, and amount of toothpaste used by each patient are variations that can be replicated in clinical studies. Second, even though the toothbrushes used in this study were considered soft, this study did not test the effect of different bristle types; therefore, the similar surface roughness found for all groups could also be related to the toothbrush. Further studies may

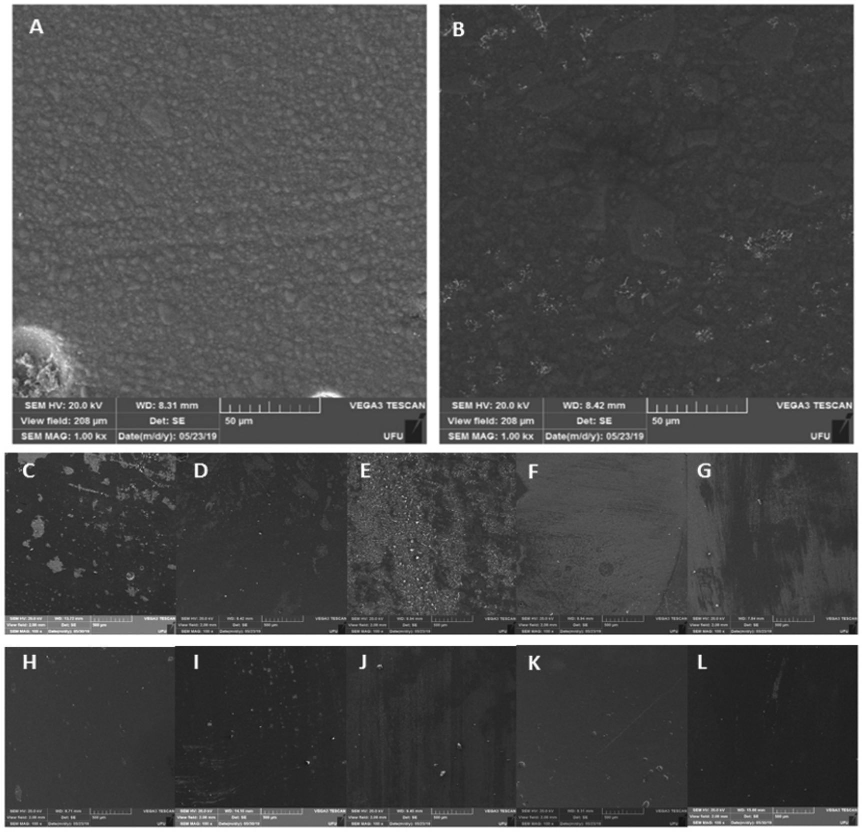

Figure 6. *Scanning electron microscopy images of resin composites before brushing (A-B: 1000x magnification) and after toothbrushing (C-L: 100x magnification). (A): Z350XT; (B): Vittra (1000X magnification); (C): Vittra/Bianco Pro Clinical; (D): Vittra/Bianco Carbon; (E): Vittra/Black is White; (F): Vittra/Natural; (G): Z350XT/Nano Action Black; (H): Z350XT/Bianco Pro Clinical; (I): Z350XT/Bianco Carbon; (J) Z350XT/Black is White; (K): Z350XT/Natural; (L): Z350XT/Nano Action Black (100X magnification).*

be conducted to assess the percentage and size of the toothpaste component particles and whether new finishing and polishing procedures can be performed to remove the marginal staining or reestablish the color of the resin composite restorations. In addition, studies focusing on different toothbrush bristles (hard, soft, and extra soft), staining cracks, or enamel microcracks should be conducted. However, the clinical relevance and timeliness of this study provoke a new line of thinking about the effects of charcoal toothpaste use on resin composite restorations.

CONCLUSIONS

Within the limitations of this *in vitro* study, the following conclusions can be drawn:

1. The Ra value results of the charcoal toothpastes were similar to those of the conventional toothpaste.
2. The charcoal toothpastes caused changes in the resin composite color, generally at a clinically unacceptable level ($\Delta E>3.3$) and tended to darken the restorations ($\Delta L<0$).
3. The charcoal toothpastes, except for BCA, caused dark marginal staining of the resin composite restorations.

Conflict of Interest

The authors have no financial interest in any of the companies or products mentioned in this article.

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