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BRISTLE SPLAYING AND ABRASIVE POTENTIAL ON ENAMEL AND RESIN COMPOSITE OF DIFFERENT TOOTHBRUSHES AFTER BRUSHING SIMULATION

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Trabalho de conclusão de curso apresentado à Faculdade de Odontologia da UFU, como requisito parcial para obtenção do título de Graduada em Odontologia.

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SUMÁRIO

Bristle splaying and abrasive potential on enamel and resin composite of different toothbrushes after brushing simulation

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Short title: Toothbrushes associated with enamel and resin composite

Keywords: Resin composites, toothbrush, bristle splaying, bristle wear, roughness, enamel

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ABSTRACT

Objective: This study aimed to evaluate the bristle splaying and abrasive potential on enamel and resin composite of different toothbrushes after simulated brushing.

Methods: Seventy bovine teeth were embedded in polystyrene resin and had a circular cavity on buccal flat surface restored with resin composite (Forma, Ultradent) and were submitted to a simulated brushing (n = 10) with 7 toothbrushes: ColorCare (Bianco Oral Care); DeliCare (Bianco Oral Care); Carbon-Magnetic (Bianco Oral Care); SlimSoft (Colgate Palmolive Company); Pro Cuidado (Colgate Palmolive Company); Curaprox 5460 (Curaden International AG) , and Curaprox 3960 (Curaden International AG). Brushing simulation was performed for 30, 90 and 180 days. At baseline and after 30, 90 and 180 days, the enamel and resin composite surface roughness (Ra, µm) were evaluated using a profilometer with 5 measurements performed on enamel and resin composite (n = 10). Wear index and wear rate were evaluated using macrophotographs and scanning electron microscopy (SEM) at 8x, 25x and 100x. Two-way RM ANOVA was performed for Ra and wear index followed by Tukey's test. Wear rate were analyzed using Kruskal Wallis and Duns tests. All tests employed α=0.05.

Results: Ra of resin composite significantly increased after 30 days with SlimSoft, after 90 days with SlimSoft, Pro Cuidado and Carbon, and after 180 days Colgate Pro Cuidado and CS3960 resulted in higher Ra (P <0.001). Ra of enamel significantly increased on all 3 moments. After 30 days no difference was observed on Ra of enamel among toothbrush, after 90 days Pro Cuidado resulted in higher Ra and after 180 days, Pro Cuidado and Carbon resulted in higher enamel Ra. CS5460 and Carbon presented the highest wear index differences. Wear rate was lower when macrophotographs were analyzed compared with SEM images. With 180 days SlimSoft and CS5460 presented higher wear rate.

Conclusion: Toothbrushes with more bristles and smaller diameter of filaments like CS5460, Carbon and SlimSoft showed a higher wear rate and wear index. The surface roughness at 180 days was higher with brushes with fewer bristles and larger filament diameters, Procuidado and CS3960 in composite resin and higher with Procuidado in enamel.

Clinical Relevance:Toothbrushes with a greater number of bristles and smaller diameter of the filaments can wear out faster and toothbrushes with fewer bristles and larger diameters can cause more roughness in the enamel and resin.

INTRODUCTION

The correct oral physiotherapy performed using toothbrushes is an essential to the removal and mechanical disorganization of dental plaque, a fundamental process for reducing of caries and periodontal disease.[1-2] Currently, different types of toothbrushes are commercially available, with different shapes, sizes, designs, handles, bristles and heads shape.[2-3] However, there is still no fully defined of an ideal toothbrush parameter.[3] Abrasive wear is defined as the physical loss of mineralized substance from the tooth caused by any objects other than the teeth.[4] Abrasion has a multifactorial origin involving several factors that directly or indirectly influence the degree of abrasion in enamel or resin composite.[5] Brushing technique, toothpaste, force used, duration and frequency of brushing, brush type, filament stiffness,[6] bristle design are factors that can potentialized the wear capacity of the toothbrushes.[5]

Increased surface roughness increases the area available for bacterial adhesion, and generally rougher surfaces tend to accumulate and retain more plaque than polished surfaces.[7] Furthermore, toothbrushes that have bristles with more abrasive potential have been associated with a greater ability to cause non-carious cervical lesions.[8-9] When the bristles slide over the interproximal space, they are bent and released with force over the side of the teeth, increasing the abrasion potential of the bristles, which can develop non-carious cervical lesions from the interproximal to the cervical space of a tooth.[10] Additionally, the wear caused by brushing can be considered etiological factors for the initiation of dentin hypersensitivity.[11]

The surface smoothness of the resin composite is important for clinical success of the restorations, because increasing roughness promote greater plaque accumulation, and consequently increasing the susceptibility to caries and gingival diseases are verified.[12-13] The abrasion caused by brushing decreases the brightness of the resin composite,[14] independent of finishing and polishing protocols used,[13] or the resin composite used, directly interfering with the esthetics of the restorations.[15] A widely accepted concept is that toothbrushes with stiff bristles cause more abrasion than softer ones.[16-17] On the other hand, when considering the use of toothpastes, soft bristles may contain a higher concentration than hard filaments in terms of quantity, duration and area of contact with the substrate surface, thus increasing the amount of toothpaste that moves over the surface, which may reflect a greater abrasion by the paste.[6-18]

Enamel abrasion caused by toothbrushing is mainly influenced by the abrasiveness of the toothpaste, but is modified by the stiffness of the toothbrush bristles.[19] Regarding the bristle design, brushes with flat finish bristles are considered relatively safe, promoting less abrasion compared to other models.[20] The bristle design, configuration and filament stiffness of different toothbrushes can influence abrasion in hard tissue and resin composite restoration.[6-20] However, the surface abrasion has not yet been well established.[5,6,18,20] This confirms the necessity of studies to clarify the correlation between the different designs of toothbrushes, the bristles characteristics with abrasion.[5-20] Therefore, the aim of this study was to evaluate the influence of different types of brushes, with different commercial brands, in relation to the wear of their bristles and promotion of roughness in enamel and resin composite, after being subjected to simulated brushing. The null hypotheses were that: 1) different toothbrushes would not promote alteration on the roughness in enamel and resin composite; 2) different toothbrushes would not present variation on wear index and wear rate and it will not be correlated with increasing on Ra values of enamel and resin composite.

METHODS AND MATERIAL

Seventy bovine incisor teeth with similar shapes, size and colors were collected. The teeth underwent prophylaxis, the roots were removed with a high-speed water-cooled diamond disc (American Burrs, Palhoça, SC, Brazil). The tooth crown was embedded in polystyrene resin (Redelease, São Paulo, Brazil) and the buccal surface was finished and polished with 600 sandpaper (3M, Sumaré, SP, Brazil), creating a flat surface. Circular cavity preparations with 4 mm in diameter and 2 mm in depth were made using round diamond bur (nº 3053, KG Sorensen, Cotia, São Paulo, Brazil). The restorations were made using selective enamel etching with 37% phosphoric acid (Condac 37, FGM, Joinville, SC, Brazil) for 30 seconds, washed with a water and air spray, the excess water removed using absorbent paper (Sorella, Canoinhas, SC, Brazil). The self-etching adhesive system (Ambar Universal APS, FGM, Joinville, SC, Brazil) was applied on enamel and dentin in two layers using a microbrush (Cavibrush, FGM, Joinville, SC, Brazil). Gently air jet was applied for 10 seconds for solvent evaporation and the adhesive layer was light cured for 20s using LED light curing unit (Bluephase G2, Ivoclar Vivadent, Schaan, Liechtenstein) with 1400 mW/cm², checked with MARC resin calibrator (BlueLight, Halifax, Canada). The resin

composite (Forma, shade A2, Ultradent, South Jordan, UT, USA) was inserted in a single increment and light cured for 40s. The restored tooth was finished with 600, 800, 1000 and 1200 sandpapers (3M, Sumaré, SP, Brazil) and polishing with a diamond polishing paste 6-µm, 3-µm, 1 - µm and 1 / 4 µm with the respective polishing cloths (Arotec, Cotia, SP, Brazil) for 2 minutes each using a metallographic polisher (Aropol VV, Arotec). After each step of the polishing procedure, the samples were cleaned by ultrasonic (Thornton, Vinhedo, SP, Brazil) in deionized water for 10 minutes to remove residues. During the entire process of making the samples, the specimens were stored in distilled water at 37 °C.

To assess surface roughness (Ra) of the enamel substrate and resin composite, a profilometer (SJ-301, Mitutoyo, Kanagawa, Japan) was used. Five measurements were made in different location on the resin composite and 5 measurements in the enamel per specimen totalizing 100 measurements per group and 700 measurements in total. The Ra value for each enamel and resin composite specimen was expressed by the Ra mean value of the 5 measurements. A cutting length of 0.25 mm and a speed of 0.25 mm/s and a length of 0.8 mm were used. Measurements were performed at baseline and after 1, 3 and 6 months of toothbrush simulation.

Seven soft or extra/ultra-soft toothbrushes were selected: ColorCare (Bianco Oral Care); DeliCare (Bianco Oral Care); Carbon-magnetic (Bianco Oral Care); SlimSoft (Colgate Palmolive Company); Pro Care (Colgate Palmolive Company); Curaprox 5460 (Curaden International AG) and Curaprox 3960 (Curaden International AG). The toothbrushes were named in groups (A to G) to facilitate the distribution at the time of brushing and for the blinded analyzes by the evaluators.

The brushing simulation was performed on a simulated brushing machine (Odeme Dental Research, Luzerna, SC, Brazil), where the specimens were mounted in a coupled matrix, with the flat surface of enamel and resin composite facing upwards. The toothbrush heads of each group were cut and adapted to the brushing machine. A mixture of toothpaste (Bianco Pro Clinical, Bianco Oral Care, Uberlândia, MG, Brazil) with artificial saliva, in the proportion of 2g of toothpaste to 4ml of artificial saliva (1:2)[21-22] was placed in the matrix to cover the surface of the specimens. Each group was submitted to 3 brushing cycles periods:[22-23] simulating 1 month - 7.320 cycles, 3 months - 21.960 cycles, and 6 months - 43.820 cycles. The vertical load was regulated to 200g on the brush heads, performing linear movements on the surface of the specimens, with controlled

temperature (25 ± 1 °C). After brushing each group, the brushing machine was cleaned and the dentifrice mixture replaced. In each brushing interval, the toothbrushes were washed with distilled water for 2 minutes to be analyzed.

To analyze the wear rate and splaying of the toothbrush bristles, an evaluation scale was used, which consists of a score with numbers, increasing from zero to three according to the increase in wear:[24]

0, it is not possible to define whether the toothbrush was been used or not;

1, the bristles are spread out, but limited to the tufts;

2, some tufts spread out and overlap others, with many tangled bristles;

3, most tufts overlap and many bristles are curled and bent.

The method consists of evaluation through visual inspection by 3 examiners in order to improve the evaluation and better visualize the toothbrush wear. Macrophotographs using DSLR camera with macro lens and scanning electron microscopy (SEM) at 8x (1 figure showing all the toothbrush), 25x (3 images, one per third of the toothbrush) and 100x (6 images showing 6 inner tufts of the toothbrush) were performed using a representative toothbrush of each group on all 4 stages of analysis (Figure 1). The purpose of using different image acquisition methods (DSLR camera and SEM) and different image magnifications was also to compare the methods tested and to verify the bristle clutter, analyze each tuft and deterioration of each bristle at highest magnification.

To complement the scores from the visual wear rate analysis of the toothbrush bristles, the Rawls Wear Index was also used, which is based on the use of various bristle measurements and the application of these values in the following formula:[24-25]

$$WI = \frac{FLL - BLL + FFL - BFL}{BRL \times 2}$$

Free long length (FLL) is the extent that the bristles splay, which is the maximum width of the side of the toothbrush. Base long length (BLL) is the width of the side of the toothbrush at the part that is fixed to the plastic. Front free length (FFL) is the extent that the bristles splay, which is the maximum width of the front of the toothbrush. Base free length (BFL) is the width of the front of the toothbrush at the part fixed to the plastic. Bristles' length (BRL) is the maximum length of the toothbrush bristles (Figure 2).[25]

The higher the value obtained, the higher the wear rate. For greater accuracy of measurements, photographs were taken from all necessary angles of the toothbrushes and

measurements were established using ImageJ software. The process was carried out in the 4 moments of analysis.

Statistical Analysis

The bristle splaying and Ra data were tested for normal distribution (Shapiro–Wilk) and equality of variances (Levene's test). Two-way analysis of variance (ANOVA) with repeated measurements was performed for each parameter. Multiple comparisons were made using Tukey's test. The bristles wear data were analyzed using Kruskal Wallis and Duns tests. All tests employed $\alpha = 0.05$ significance level and all analyses were carried out with the statistical package Sigma Plot version 13.1.

RESULTS

The mean and standard deviation Ra values of resin composite measured at baseline and after 30, 90 and 180 days of simulated toothbrushing are shown in Figure 3. The two-way RM ANOVA showed a significant effect of the toothbrushes ($P < 0.001$), the brushing time ($P < 0.001$) and also of the interaction between toothbrush and brushing time ($P < 0.001$). The Ra values were similar at baseline measurements for all groups ($P = 0.714$).

After 30 days of brushing simulation Colgate SlimSoft resulted in significantly higher Ra resin composite values than Bianco DeliCare, Curaprox 5460, Bianco ColorCare, Curaprox 3960 and Colgate Pro Cuidado ($P < 0.001$). After 90 days of brushing simulation the Colgate Pro Cuidado resulted in significantly higher Ra resin composite values than Bianco DeliCare and Curaprox 5460 ($P < 0.001$). After 180 days of brushing simulation the Colgate Pro Cuidado and Curaprox 3960 resulted in significantly higher Ra values than all other tested toothbrushes ($P < 0.001$).

The Ra of resin composite compared with baseline significantly increased after simulated toothbrushing for 30 days only when Colgate SlimSoft was used ($P < 0.001$), after simulated toothbrushing for 90 days when Colgate SlimSoft, Colgate Pro Cuidado and Bianco Carbon were used ($P < 0.001$), and after simulated toothbrushing for 180 days when all tested toothbrushes were used.

The mean and standard deviation Ra values of enamel measured at baseline and after 30, 90 and 180 days of simulated toothbrushing are shown in Figure 4. The two-way

RM ANOVA showed a significant effect of the toothbrushes ($P < 0.001$), the brushing time ($P < 0.001$) and also of the interaction between toothbrush and brushing time ($P < 0.001$). The enamel Ra values were similar at baseline measurements for all groups ($P = 0.714$).

After 30 days of brushing simulation no significant difference was observed among tested toothbrushes ($P = 0.398$). After 90 days of brushing simulation the Colgate Pro Cuidado resulted in significantly higher enamel Ra values than all others toothbrushes ($P < 0.001$). And after 180 days of brushing simulation the Colgate Pro Cuidado and Bianco Carbon resulted in significantly higher enamel Ra values than all others toothbrushes ($P < 0.001$).

All tested toothbrushes resulted in significant increased enamel Ra value already after 30 days of brushing simulation compared with baseline ($P < 0.001$). Comparing the Ra enamel values after 30 and 90 days of brushing simulation, only Colgate Pro Cuidado resulted in significant increased value ($P < 0.001$), and for all other toothbrushes the values tend to stabilize ($P = 0.476$). The Ra enamel values measured after 180 days of simulated toothbrushing were significantly higher than after all 90 days for all tested toothbrushes ($P < 0.001$).

The wear index means and standard deviation values for all tested toothbrushes are shown in Table 1. The two-way RM ANOVA showed significant effect of toothbrush ($P < 0.001$), and for time of brushing simulation ($P < 0.001$), however no significance was observed for interaction between toothbrush and time of brushing simulation factors ($P = 0.001$). The representative images of macrophotographs and different SEM magnifications (8, 25 and 100X) of each toothbrush for visual wear analyses were shown in Figure 5 and the scores assigned on the Table 2.

Analysis through macrophotographs showed less wear and disorganization of the bristles and tufts in general compared with SEM 8X (which also shows an image of the entire toothbrush), with groups presenting Scores 0 or 1. Analysis with SEM 25X (3 images, one per third of the toothbrush) showed higher scores just for Colgate SlimSoft with 90 and 180 days in comparison with 8x magnification (1 image showing the entire toothbrush) not presenting difference among the magnifications for the score classification for all other groups. With 180 days of brushing simulation, Bianco Delicare and Bianco Colorcare presented Score 1; Bianco Carbon, Colgate Pro Cuidado e CS3960 presented Score 2; and just only Colgate SlimSoft and CS5460 presented Score 3. However, the visual analysis with

SEM 100X (where 6 inner tufts were evaluated), Bianco Delicare presented Score 2 for 30, 90 and 180 days, while the other groups presented Scores 0 or 1.

DISCUSSION

The present study evaluated the effect of different types of toothbrushes regarding to the bristles wear rate and wear index and the enamel and resin composite Ra values at baseline and after brushing simulation. Different toothbrushes promote alteration of Ra of enamel and resin composite and toothbrushes presented variations on wear index and wear rating, therefore, rejecting the first and second null hypotheses.

According to the results of this study, at least in the first 30 days, the enamel seems to have maintained a higher wear pattern than the resin, regardless of the brush used.[26] The effect of abrasive challenges on enamel surface wear and three different restorative materials submitted to the abrasive challenge with an electric toothbrush with dentifrice for 2 minutes, three times a day for 7 days, demonstrated higher susceptibility to toothbrush abrasion on enamel compared to restorative materials.

In this study, the specimens were polished and their roughness values were standardized at the initial roughness, with the enamel with values between 0.2 and 0.3 µm and the resin between 0.5 and 0.6µm. Although the resin composite used was a nanohybrid resin, which contains smaller filler particles and consequently makes it easier to polish, with greater surface smoothness and better gloss maintenance.[27] Resin composite presented higher Ra values than enamel, as also founded by previous study that tested the effects of charcoal toothpaste on the surface roughness of resin composite.[23] It is important to correlate the surface roughness which increases over time using the same toothbrush with biofilm accumulation, therefore, showing the necessity of change the toothbrush until 90 days of use.

Although there is evidence that toothbrushes with a straight cut bristle design are relatively safer when it comes to abrasion,[20] in this study no correlation was found between bristle cut design and the enamel and resin composite wear levels. The Pro Cuidado presented higher Ra values in enamel and resin composite. This toothbrush does not have many bristles as the other toothbrushes tested in this study and it is the only one which presents spiral bristles. In the knowledge of the authors, there is no evidence of this type of bristle correlated with more abrasion or produces higher Ra values, however, this may be

an explanation to the results of this toothbrush in this study and needs more studies to evaluate this point.

According to the wear index, the difference on the initial values to 180 days of brushing simulation were higher in CS5460 and Carbon. Analyzing the wear rate at SEM 25x, CS5460 and Slimsoft presented the highest Score 3. There is a correlation between ultra-soft toothbrushes, with large amount of bristles and narrow diameter, with the splaying of bristles and the relation with wear rate of toothbrushes. Probably, those types of toothbrushes will present higher visual wear rate in shorter time compared with toothbrushes with fewer bristles with large diameter. With higher wear rate of toothbrush, the biofilm removal capacity may be decreased. On another hand, the toothbrushes that showed higher values in Ra are brushes with fewer bristles and greater diameter of the filaments, and there may be a relationship between the number and diameter of bristles and the promotion of enamel and resin roughness.Therefore, it is important to understand the correct indication of toothbrush based on the Ra, wear rate and association with biofilm removal capacity.

The formation of non-carious cervical lesions (NCCLs) can be attributed to several factors, such the stresses concentrated in the cervical region by the occlusal load itself during mastication, low pH, among others.[8-28] Abrasion/friction caused by brushing has been also identified as a contributor to the progression of such lesions.[8,10,28] Patients who brush the teeth with greater pressure tend to have NCCLs.[8-10] High frequency brushing could be also be associated with the prevalence of these NCCLs.[28] There is also a direct association between bristle hardness and NCCLslesion formation.[9] A brush that causes greater substrate loss will tend to contribute to the evolution of a lesion in an already weakened enamel region.

Limitations of this study include the factor that the brushing simulation was performed in only one linear direction with controlled load on the surface of specimens. Although this methodology was used in other studies.[21,22,23] It is important to standardize the specimens of the study, the information of this in vitro study must be analyzed with careful because clinical situations may be different in many ways which can cause different results in terms of toothbrush wear. In vivo situations, people have used different toothbrushing techniques, performing different pressure/load and with non-linear movements. Furthermore, in this in vitro study the samples were flat, presented a polished

and smooth surface with only 2 substrates (enamel and resin composite) which may be different in situations with misaligned teeth, irregular surfaces presented on anterior and posterior teeth, metallic and ceramic restorations, unsatisfactory restorations, interproximal areas, even patients who use the same toothbrush on removable dentures with metal clamps, presenting different conditions of toothbrushes wear over time.

Despite the use of artificial saliva to mixture toothpaste in the simulated brushing, the oral condition with oral microbiota, pH, and the remineralization effect of natural saliva over time were not simulated. Natural saliva contains and transports substances essential for promoting enamel remineralization such as calcium, calcium phosphates, polyphosphates, fluoride and natural products.[29-30] Over the simulated time, the increase in microhardness is not considered, and although there is evidence of the similarity of artificial saliva in the remineralization effect,[31] in simulated brushing there is not enough time elapsed for this effect to occur, probably influencing the results of Ra in this study.

CONCLUSION

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

1. Toothbrushes with higher amount of bristles and narrow diameter of filaments as CS5460, Carbon and SlimSoft presented higher wear rate and wear index.
2. The surface roughness with 180 days were higher in brushes with fewer bristles and larger filament diameter, Pro Cuidado and CS3960 in composite resin and higher with Pro Cuidado in enamel.
3. Wear rate evaluated with SEM magnifications were higher than the analysis with macrophotographs.

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FIGURES

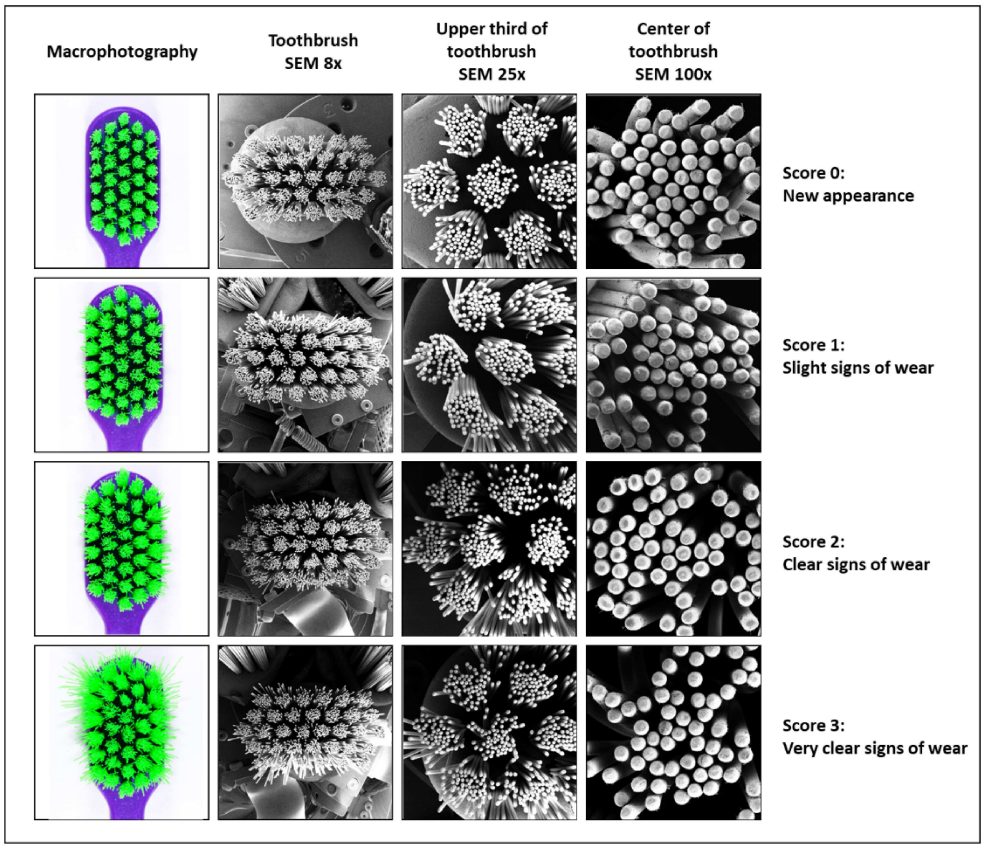

Figure 1. Representative image of the wear rate of toothbrushes on all 4 stages of analysis by macrophotographs, SEM 8x, 25x and 100x.

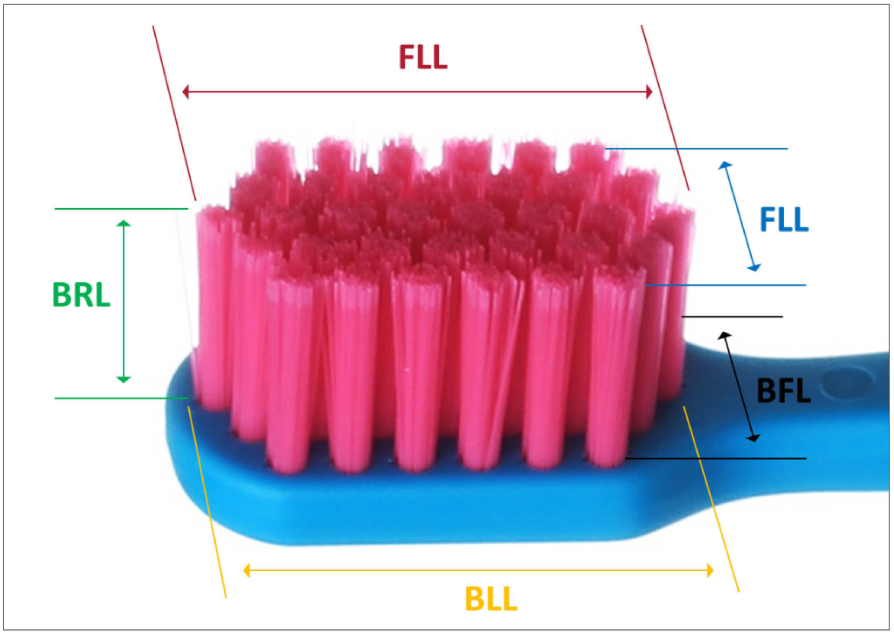

Figure 2. Schematic image of the measurements sites for the wear index.

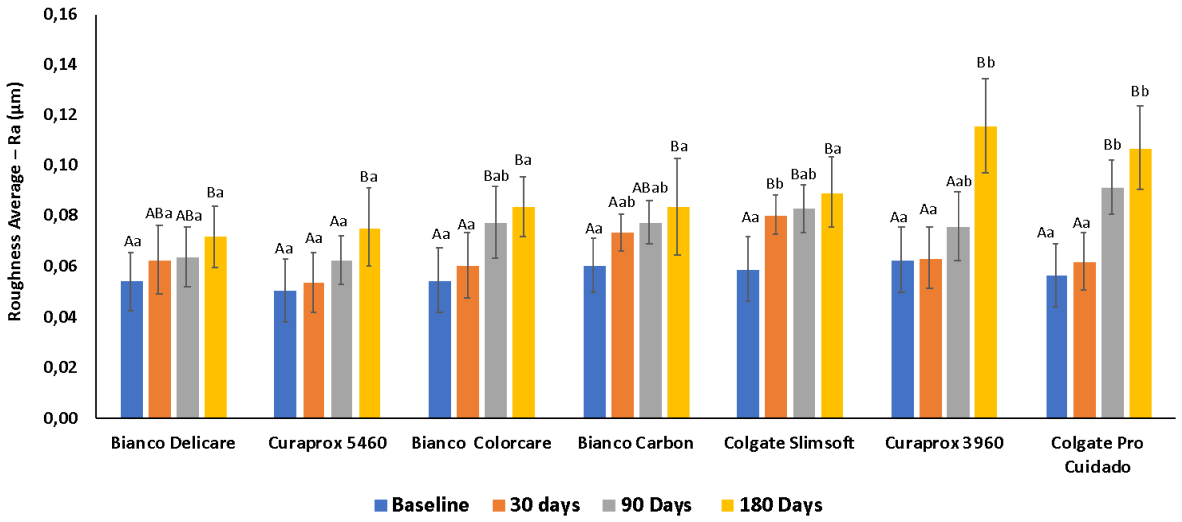

Figure 3. Surface roughness (Ra, µm) of resin composite means and standard deviation values for all tested toothbrushes at baseline and after simulated brushing for 30, 90 and 180 days. Different letters mean significant difference.

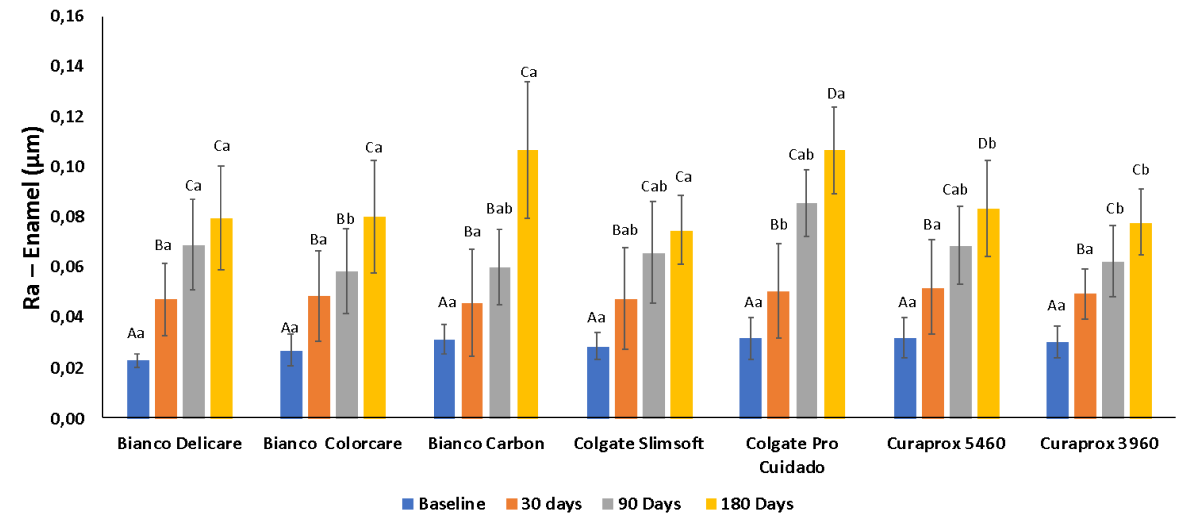

Figure 4. Surface roughness (Ra, µm) enamel means and standard deviations values for all tested toothbrushes at baseline and after simulated brushing for 30, 90 and 180 days.

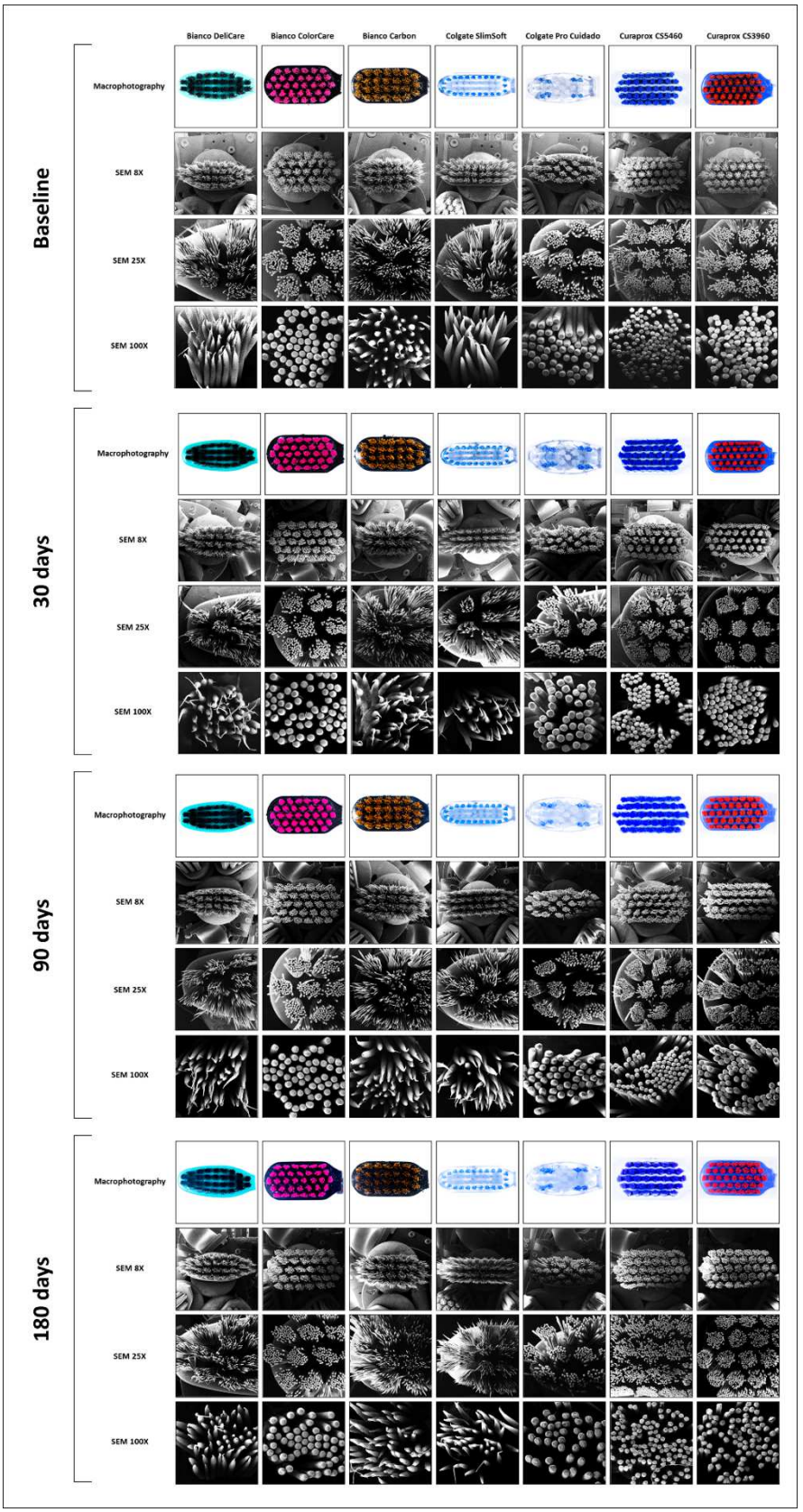

Figure 5. Representative images of wear rate using macrophotographs and SEM images at 8x, 25x and 100x at baseline and after 30, 90 and 180 days of brushing simulation.

TABLES

Table 1. Evaluation of wear index for 7 tested toothbrushes at baseline and after 30, 90 and 180 days of brushing simulation.

Toothbrushes	Baseline	30 days	90 days	180 days
Curaprox CS3960	0.05 (0.00) Aa	0.05 (0.01) Aa	0.06 (0.04) Aa	0.09 (0.04) Ab
Curaprox CS5460	0.17 (0.00) Ba	0.21 (0.03) Ba	0.21 (0.05) Ba	0.28 (0.08) Bb
Bianco Colorcare	0.25 (0.00) Ca	0.25 (0.01) Ca	0.27 (0.01) Ca	0.27 (0.01) Ca
Bianco Delicare	0.27 (0.00) Da	0.28 (0.01) Ca	0.29 (0.04) Ca	0.35 (0.04) Cb
Colgate Pro Cuidado	0.28 (0.00) Da	0.30 (0.02) Da	0.30 (0.02) Da	0.35 (0.08) Db
Bianco Carbon	0.34 (0.00) Ea	0.36 (0.04) Ea	0.43 (0.03) Eb	0.45 (0.04) Eb
Colgate SlimSoft	0.32 (0.00) Ea	0.35 (0.01) Ea	0.38 (0.00) Eb	0.40 (0.01) Eb

Table 2. Evaluation of wear rate for 7 tested toothbrushes at baseline and after 30, 90 and 180 days of brushing simulation, by macrophotographs, SEM 8x, 25x and 100x.

Toothbrushes	Macrophotography				SEM 8x			
	Baseline	30 days	90 days	180 days	Baseline	30 days	90 days	180 days
Bianco Delicare	0	0	0	0	0	1	1	1
Bianco Colorcare	0	1	1	1	0	1	1	1
Bianco Carbon	0	1	1	1	0	1	1	2
Colgate SlimSoft	0	0	0	0	0	0	1	2
Colgate Pro Cuidado	0	0	0	1	0	1	1	2
Curaprox CS5460	0	0	1	2	0	0	2	3
Curaprox CS3960	0	0	0	1	0	0	1	2