https://doi.org/10.54589/aol.38/1/39

Color change and surface degradation of esthetic brackets after exposure to cigarette smoke and two cleaning treatments

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ABSTRACT

Aim: *During orthodontic treatment, the presence of brackets increases the accumulation of biofilm, which can increase the surface degradation of brackets. Thus, cleaning methods must address removal of both biofilm and stains, specially acquired due to cigarette smoke. Therefore, color change and surface texture of esthetic brackets subjected to cigarette smoke were evaluated before and after use of different cleaning treatments.* ***Material and methods:*** *Three types of conventional esthetic brackets (slot size 0.022" x 0.028" and Roth prescription) were evaluated: polycarbonate/P (Composite/Morelli), polycrystalline ceramic/PC (Iceram/Orthometric) and monocrystalline ceramic/MC (Iceram-S/Orthometric). They were exposed to cigarette smoke (Marlboro Red Box) for 5 days in a machine that simulated the oral conditions of a smoker. Then, they were assigned to one of two different cleaning treatments (n=10): a) bicarbonate jet (sodium bicarbonate particles 4 µm in diameter, at pressure 2.3 bar, distance 5 mm, for 10 seconds), or b) Robinson brush, pumice stone and water. Color analyses (CIEL*a*b*, WI_D, ΔE_{ab}, ΔE_{00} and ΔWI_D) and surface micromorphology (500 x magnification) were performed before and after exposure to smoke, and after the cleaning treatments.* ***Results:*** *Mixed generalized linear models (α=0.05) showed that after exposure to smoke, all brackets showed a significant decrease in L* (p<0.0001) and WID (p<0.0001), and a significant increase in a* (p<0.05) and b* (p<0.0001), with greater staining for the P brackets (p<0.0001).* ***Conclusion:*** *After the cleaning treatments, it was not possible to recover the initial color of the P brackets with the use of a Robinson brush. Although the cleaning treatment partially or completely removed the surface staining, the P brackets showed more extensive surface degradation, especially with use of the bicarbonate jet.*

Keywords: *orthodontic brackets - color, cigarettes - smoke*

Alteração de cor e degradação superficial de bráquetes estéticos após a exposição por fumaça do cigarro e dois tratamentos de limpeza

RESUMO

Objetivo: *Durante o tratamento ortodôntico, a presença de bráquetes aumenta o acúmulo de biofilme, o que pode aumentar a degradação da superfície desses bráquetes. Assim, métodos de limpeza devem ser utilizados para remover tanto o buofilme como as manchas, especialmente aquelas advindas do cigarro. Assim, a alteração de cor e a textura superficial de bráquetes estéticos submetidos à fumaça de cigarro foram avaliadas antes e após o uso de diferentes métodos de profilaxia.* ***Materiais e Método:*** *Foram avaliados bráquetes estéticos de sistema convencional (tamanho de slot 0,022" x 0,028" e prescrição Roth): tipo policarbonato (Composite/Morelli), cerâmica policristalina (Iceram/Orthometric) e cerâmica monocristalina (Iceram-S/Orthometric). Estes foram expostos à fumaça de cigarro (Marlboro Red Box) durante 5 dias em uma máquina que simulava as condições bucais de um fumante. Cada tipo de bráquete foi subdividido de acordo com os diferentes métodos de profilaxia (n=10): a) jato de bicarbonato; b) profilaxia com escova Robinson, pedra-pomes e água. Análises de cor (CIEL*a*b*, WI_D, ΔE_{ab}, ΔE_{00} e ΔWI_D) e micromorfologia de superfície (ampliação de 500 x) foram realizadas antes, após a exposição à fumaça e após a profilaxia.* ***Resultados:*** *Modelos lineares generalizados mistos (α=0,05) mostraram que, após exposição à fumaça, todos os bráquetes apresentaram diminuição significativa em L* (p<0,0001) e WID (p<0,0001), em a* (p<0,05) e b* (p<0,0001), sendo o manchamento mais exacerbado para os bráquetes de policarbonato (p<0,0001).* ***Conclusão:*** *Após a limpeza, não foi possível obter a mesma cor inicial dos bráquetes de policarbonato com o uso da escova Robinson. Embora a profilaxia tenha minimizado ou removido manchas superficiais, os bráquetes de policarbonato apresentaram degradação superficial mais extensa, principalmente com o uso do jato de bicarbonato.*

Palavras-chave: *braquetes ortodônticos - cor - cigarros - fumaça*

To cite:
Quadros AR, Alvarez Ferretti M, Baggio Aguiar FH, Tarkany Basting R. Color change and surface degradation of esthetic brackets after exposure to cigarette smoke and two cleaning treatments. Acta Odontol Latinoam. 2025 Abr 30;38(1):39-48. https://doi.org/10.54589/aol.38/1/39

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Received: September 2024
Accepted: March 2025

INTRODUCTION

Adults are increasingly interested in undergoing orthodontic treatment, often for esthetic reasons, and since appearance is a cause for significant concern there is growing demand for minimally visible appliances[1,2].

Esthetic brackets can be made of polycarbonate or ceramic. Ceramic brackets may be polycrystalline or monocrystalline. Polycrystalline ceramics, especially those made by milling or machining procedures, are rougher and have a more porous surface than monocrystalline types[3,4] and therefore enable greater biofilm deposition and potential staining[4-6]. Polycarbonate brackets appear to be less resistant to staining than ceramic brackets due to their high capacity for water absorption, and their more extensive surface irregularities[7-9]. One of the issues in this regard is that bracket color may change over time as a result of staining by extrinsic substances from smoking or food and drinks containing dyes[2,10-12].

Smoking is relatively common among adults. The World Health Organization has estimated that there are approximately 1.3 billion smokers in the world[13]. Tobacco is one of the main agents that are toxic to humans. Tobacco smoke involves a complex matrix composed of a particulate phase and a gaseous phase, introducing several negative influences into the oral cavity[14], many of which have been extensively studied. However, there are few studies on cigarette smoke staining esthetic brackets. Some studies have shown that tobacco smoke causes chemical and mechanical changes in dental materials, especially composite resins[15,16], which can change the color and texture of the surface of composites[17] by deposition of yellow and black pigments[18].

It is worth emphasizing that orthodontic treatment increases the accumulation of biofilm, which can increase the surface degradation of brackets. Thus, cleaning methods must address removal of both biofilm and stains acquired due to eating habits[19]. One widely used cleaning method is a sodium bicarbonate jet, as it requires only a short time, and does not generate heat compared to cleaning with a rubber cup or Robinson brush and prophylactic paste[20]. Cleaning methods should be effective in removing pigmentation and biofilm without altering the surfaces of the tooth enamel or the orthodontic accessories[21,22].

Considering that adult patients undergoing orthodontic treatment with esthetic appliances may smoke, it is important to assess the degree of staining that occurs on different types of esthetic bracket materials, as well as the influence of stain removal methods on degradation of the surface of these materials.

The null hypotheses of this study were: H01) the color of esthetic brackets does not change after exposure to either cigarette smoke or cleaning methods; H02) the surface of esthetic brackets is not altered by cleaning methods.

MATERIALS AND METHOD

Bracket specifications and initial color evaluation

The sample consisted of 60 esthetic brackets of different brands and compositions: 20 each of polycarbonate (Composite/Morelli), polycrystalline ceramic (Iceram/Orthometric) and monocrystalline ceramic (Iceram-S/Orthometric). All brackets used in this study were of the conventional system, slot size 0.022” x 0.028”, Roth prescription, and indicated for use on the maxillary right central incisor[2,11,12].

Initially, the brackets were immersed in Eppendorf tubes containing artificial saliva[23] (1.5 ml), and stored at 37 ºC for 24 hours. After this, initial color was determined using a spectrophotometer (VITA Easyshade V, Vita, Baden-Württemberg, Bad Säckingen, Germany). The brackets were positioned in a reading chamber with a white background, with the active tip of the spectrophotometer positioned at an angle of 90 degrees to the buccal surface of the bracket[24]. The L*, a* and b* values according to the CIEL*a*b* system were measured three times in a row, and recorded in a spreadsheet to calculate the average.

Protocol of exposure to cigarette smoke and color assessment after staining

A smoke machine (registered under No. 01810012043 INPI - National Institute of Industrial Property) was used[18] to impregnate the brackets with the pigments and substances contained in cigarettes, with the aim of replicating *in vitro* the conditions in the oral cavity of smokers. The machine aspirated and conducted smoke through compartments to create a flow of smoke from the environment, thereby enabling the deposition of chemicals on the brackets. The cycle was programmed with a 3-second time interval, simulating normal smoker inhalation. The timer allowed ambient air to be inhaled every 10 seconds, thereby simulating the exhaustion and subsequent elimination of smoke.

Brackets were fixed with wax in a plastic holder with ten niches, and placed in the smoke machine[7]. Each niche corresponded to one of the holes where cigarettes were fastened to the machine. When the cigarettes were lit, these holes "smoked" them. The brackets were subjected to smoke from one packet of cigarettes (Marlboro Red Box, Philip Morris Brasil Ind. and Com. Ltda., Santa Cruz do Sul, RS, Brazil), corresponding to 20 cigarettes per day, for a total of 5 days[24]. Between simulations, the brackets were stored in artificial saliva at 37 °C. Every 24 hours, they were washed with distilled water and re-immersed in a new artificial saliva solution to prevent pigment sedimentation[25].

After staining, bracket color was evaluated again, following the protocol described.

Procedures for removing pigmentation (cleaning procedures) and final color assessment

After exposure to smoke, brackets of the same composition were divided into two subgroups (n=10), each of which was subjected to cleaning by either (a) bicarbonate jet or (b) Robinson brush, pumice stone and water.

Cleaning by bicarbonate jet was performed with a sodium bicarbonate device (Gnatus, Prophy Jet Gold Line, Barretos, SP, Brazil) using sodium bicarbonate particles (Maquira Airon, Maringá, PR, Brazil) 4 µm in diameter. The reservoir was filled to 50% of its total capacity with sodium bicarbonate. Airborne particle abrasion was applied perpendicularly to the brackets in a standardized manner at a pressure of 2.3 bar, from a distance of 5 mm, for 10 seconds.

Cleaning with pumice and water was performed using a Robinson brush (3R Ind. e Com. EIRELI, São Paulo, SP, Brazil) with a micromotor and contra-angle (Intramatic I 181D/ Kavo, Joinville, SC, Brazil), at a constant speed of 5,000 rpm for 5 seconds on each bracket. Pumice powder (Maquira, Maringá, PR, Brazil) with extra-fine particles was placed in a Dappen pot up to half its capacity, approximately 1.5 ml of its volume, together with 5 ml of water, to form a cleaning paste. The paste was distributed evenly over the bracket surfaces with the aid of a tamper-type spatula (Calcador 6337 Nº 02, FAVA, São Paulo, SP, Brazil), and then the brackets were brushed. One Robinson brush was used to brush 5 brackets. According to McCracken et al.[26], two minutes are sufficient for brushing 28 teeth of a patient, resulting in an approximate time of five seconds for each tooth/bracket. After this, the brackets were washed with distilled water and stored in artificial saliva for subsequent evaluation of the final color.

Color Assessment

Color changes were evaluated according to the CIEL*a*b* color space. L* represents the lightness or color value (from black to white) of an object, with pure black having an L* value equal to 0. When the object fully reflects the color, L* is equal to 100, which is pure white. The a* axis measures the values from green to red, with a+ (positive a*) being values that reflect red and a– (negative a*) values that reflect green. The b* axis measures the values from yellow to blue, where b+ (positive b*) is yellow and b- (negative b*) is blue.

After this, ΔL*, Δa* and Δb* were calculated for each group and time, and used to evaluate color change ΔE_{ab}) estimated by the formula[27]: $\Delta E_{ab} = \sqrt{((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)}$. The limits of perceptibility and acceptability considered for ΔE_{ab} were 1.2 and 2.7, respectively[27,28]. Color change was also evaluated by CIEDE2000 (ΔE_{00}), which uses h (hue) and C (chroma) values[29]. ΔE_{00} values of 0.8 and 1.8 were adopted as the perceptibility and acceptability limits[28]. Tooth staining was evaluated by the Whiteness Index for Dentistry (WI_D), in which the parameters L*, a* and b* were used in the following equation[30]: $WI_D = 0.511L^* - 2{,}324a^* - 1.100b^*$ Differences in WI_D between the initial and final assessments were calculated (ΔWI_D), using threshold values for ΔWI_D of 0.72 for perceptibility and 2.60 for acceptability[31].

Evaluation of surface micromorphology by scanning electron microscopy (SEM)

The surface micromorphology of three specimens of each type of bracket, chosen at random, was examined at baseline, after staining and after the cleaning treatments. The brackets were sputter coated with gold (gold layer thickness estimated at 200 Aº) using a sputter coater (Sputter Coater, EMITECH, K450, Kent, United Kingdom). Images of the surface micromorphology were acquired at 500x magnification with a high-resolution scanning electron microscope (Thermo Fisher Scientific, Model Quattro S, Thermo Scientific UltraDry, Brno, Czech Republic) with a voltage of 20 kV and a spot size of 32 pA. Qualitative analyses of the surface were performed to determine whether there was presence of erosion and/or irregularities.

Statistical Analysis

After descriptive and exploratory data analysis, mixed generalized linear models were applied for repeated measures over time for the L*, b* and WI_D values. Generalized linear models were also adjusted to analyze the variables ΔE_{ab} and ΔE_{00}. The variables of a* and ΔWI_D were analyzed by the Mann Whitney test to compare the two cleaning methods. Kruskal Wallis and Dunn tests were used to compare bracket types, and Friedman and Nemenyi tests were used to compare the values recorded at the three measurement times. The analyses were performed in the R Program (2022), with a level of significance of 5%.

RESULTS

Baseline L* was significantly lower for polycarbonate brackets than for the other types of brackets (p<0.05) (Table 1). After staining, L* decreased significantly for all brackets (p<0.05), and subsequently increased after cleaning (p<0.05).

Table 1. Mean (standard deviation) of L*, b* and WI_D values considering bracket composition, cleaning method and time

Parameter	Cleaning method	Composition of brackets	Time		
			Baseline	After staining	After cleaning
			Mean (standard deviation)		
L*	Bicarbonate jet	Polycarbonate	86.73 (5.13) Ab	55.41 (8.65) Bc	92.52 (7.34) Ab
		Polycrystalline ceramic	97.87 (2.54) Aa	75.95 (6.92) Ba	99.41 (0.97) Aa
		Monocrystalline ceramic	98.29 (1.75) Aa	65.90 (5.53) Bb	98.33 (1.92) Aa
	Robinson Brush	Polycarbonate	90.81 (4.25) Ab	* 69.64 (6.21) Cb	* 83.38 (4.26) Bb
		Polycrystalline ceramic	97.46 (2.19) Aa	78.22 (3.48) Ba	* 97.23 (3.14) Aa
		Monocrystalline ceramic	98.86 (1.75) Aa	63.85 (6.54) Cb	* 90.38 (10.41) Ba
b*	Bicarbonate jet	Polycarbonate	6.84 (1.31) Ca	21.65 (2.33) Aa	9.31 (3.86) Ba
		Polycrystalline ceramic	3.04 (0.70) Cc	14.57 (2.58) Ab	4.92 (0.85) Bc
		Monocrystalline ceramic	4.05 (0.66) Cb	16.33 (2.32) Ab	7.23 (1.17) Bb
	Robinson Brush	Polycarbonate	7.58 (0.56) Ca	20.69 (3.71) Aa	* 15.04 (2.46) Ba
		Polycrystalline ceramic	3.06 (1.03) Cc	13.10 (1.67) Ac	5.18 (1.83) Bb
		Monocrystalline ceramic	4.65 (0.51) Cb	17.45 (2.81) Ab	6.75 (2.29) Bb
WI_D	Bicarbonate jet	Polycarbonate	44.43 (2.17) Ab	- 10.73 (8.97) Bc	42.27(10.87) Aab
		Polycrystalline ceramic	52.42 (2.08) Aa	14.71 (8.50) Ca	48.01 (2.34) Ba
		Monocrystalline ceramic	52.67 (1.73) Aa	5.62 (6.20) Cb	44.83 (3.17) Bb
	Robinson Brush	Polycarbonate	45.75 (2.06) Ab	* 3.69 (10.17) Cb	* 24.52 (7.45) Bb
		Polycrystalline ceramic	52.06 (2.93) Aa	18.86 (5.24) Ca	46.40 (5.28) Ba
		Monocrystalline ceramic	51.95 (0.95) Aa	1.28 (6.78) Cb	40.17 (10.41) Ba

*Differs from the bicarbonate jet under the same bracket conditions and time within each variable (p≤0.05). Different letters (capitals in horizontal and lower case in vertical) comparing the brackets within each cleaning method) indicate statistically significant differences (p≤0.05).

For all types of brackets, L* was significantly higher after bicarbonate jet cleaning than after Robison brush cleaning ($p<0.05$) (Table 2). At the final time, once again, L* values were significantly lower for the polycarbonate brackets than for the other types of brackets ($p< 0.05$).

Baseline b* was higher for polycarbonate brackets than for polycrystalline ceramic brackets ($p<0.05$) (Table 1). For all three bracket types, b* increased significantly after staining and subsequently decreased after cleaning ($p<0.05$). Final b* for polycarbonate brackets was lower with bicarbonate jet treatment than with Robinson brush treatment ($p<0.05$). Final b* was higher for polycarbonate brackets treated with bicarbonate jet than for polycrystalline ceramic brackets ($p<0.05$). After cleaning with Robinson brush, b* was higher for polycarbonate than for the two ceramics ($p<0.05$).

Baseline WI_D was significantly lower for polycarbonate than for the two ceramics ($p<0.05$) (Table 1). WI_D was significantly lower after staining for all bracket types, and increased after cleaning ($p<0.05$). Final WI_D for polycarbonate brackets was higher with bicarbonate jet than with Robinson brush treatment. When bicarbonate jet treatment was used, final WI_D was higher for polycrystalline ceramics than for the monocrystalline types ($p<0.05$). When the Robinson brush was used, WI_D was lower for polycarbonate than for the two ceramics ($p< 0.05$).

Baseline a* was more negative for polycarbonate than for polycrystalline ceramic brackets ($p<0.05$) (Table 3). After staining, a* was significantly higher for all bracket types ($p<0.05$). Final a* for polycarbonate brackets was lower when cleaning was performed with bicarbonate jet than with Robinson brush. After bicarbonate jet cleaning, a* was lower for polycarbonate brackets than for monocrystalline ceramics ($p<0.05$). When cleaning was performed with Robinson brush, a* was higher for polycarbonate brackets than for polycrystalline ceramic brackets ($p<0.05$).

After bicarbonate jet cleaning, the change in color measured by ΔE_{ab} was significantly greater in polycarbonate brackets than in polycrystalline ceramic brackets ($p<0.05$) (Table 4). When Robinson brush was used, the variation in color after cleaning was greater in monocrystalline ceramic and smaller in polycarbonate brackets ($p<0.05$). For polycarbonate brackets, the variation in color after cleaning was significantly lower when a Robinson brush was used ($p<0.05$). After bicarbonate jet cleaning, the change in color measured by ΔE_{ab} was significantly greater in polycarbonate brackets than in monocrystalline ceramic brackets ($p<0.05$). When the Robinson brush was used, the variation in color was greater in monocrystalline ceramic than in the other bracket types. For polycarbonate brackets, ΔE_{00} was higher after treatment with bicarbonate jet than with Robinson brush ($p<0.05$).

After bicarbonate jet cleaning, ΔWI_D (57.28) was higher for polycarbonate than for polycrystalline ceramic ($p<0.05$). After Robinson brush cleaning, ΔWI_D was higher for monocrystalline ceramic than for polycarbonate brackets ($p<0.05$). Also for the polycarbonate brackets, ΔWI_D values were significantly higher following treatment with

Table 2. Median (minimum maximum) of ΔWI_D values considering bracket composition, cleaning method and time

Cleaning method	Composition of brackets	Time	
		After staining – Baseline	After cleaning- After staining
		Median (minimum; maximum)	Median (minimum; maximum)
Bicarbonate jet	Polycarbonate	-54.28 (-75.47; -43.76) b	57.28 (28.81; 68.98) a
	Polycrystalline ceramic	-39.82 (-48.19; -19.17) a	34.53 (20.39; 45.32) b
	Monocrystalline ceramic	-47.11 (-57.05; -38.81) ab	38.63 (30.94; 50.61) ab
p-value		0.0018	0.0049
Robinson Brush	Polycarbonate	* -40.90 (-61.85; -23.80) ab	* 20.22 (12.34; 32.86) b
	Polycrystalline ceramic	-32.70 (-45.24; -23.63) a	27.56 (15.93; 37.16) ab
	Monocrystalline ceramic	-48.26 (-61.26; -44.17) b	42.09 (18.61; 59.27) a
p-value		0.0002	0.0101

*Differs from the bicarbonate jet under the same bracket conditions and time ($p\leq0.05$). Different letters in the vertical (comparing the brackets within each cleaning method) indicate statistically significant differences ($p\leq0.05$).

Table 3. Median (minimum; maximum) a* values considering bracket composition, cleaning method and time

Cleaning method	Composition of brackets	Time			p-value
		Baseline	After staining	After cleaning	
		Median (minimum; maximum)			
Bicarbonate-jet	polycarbonate	-3.28 (-3.60; -2.95) Bb	6.58 (4.55; 9.25) Aa	-2.25 (-4.35; 0.50) Bb	0.0004
	Polycrystalline ceramic	-2.60 (-3.00; -1.65) Ba	3.68 (0.90; 5.05) Ab	-1.35(-1.95; -0.05) Bab	0.0001
	Monocrystalline ceramic	-2.90(-3.30; -2.70) Bab	4.33 (2.70; 5.90) Ab	-1.13 (-2.20;-0.45) Aba	<0.0001
p-value		0.0002	0.0002	0.0357	
Robinson Brush	Polycarbonate	-3.33 (-3.60; -2.80) Bb	* 4.03 (0.60; 7.20) Aab	* 1.05 (-1.90;1.95) ABa	<0.0001
	Polycrystalline ceramic	-2.60 (-3.25; -1.10) Ba	2.86 (1.65; 4.45) Ab	-0.85 (-2.25; 0.80) ABb	<0.0001
	Monocrystalline ceramic	-2.85 (-3.05; -2.50) Ba	5.10 (3.80; 7.20) Aa	2.0 (1.70; 1.70) ABab	<0.0001
p-value		0.0002	0.0009	0.0095	

*Differs from the bicarbonate jet under the same bracket conditions and time ($p \leq 0.05$). Different letters (capitals in horizontal and lower case in vertical) comparing the brackets within each cleaning method) indicate statistically significant differences ($p \leq 0.05$).

Table 4. Mean (standard deviation) of ΔE_{ab} and ΔE_{00} considering composition of the brackets, cleaning method and time

Parameter	Cleaning method	Composition of brackets	Time	
			After staining – Baseline	After cleaning - After staining
			Mean (standard deviation)	
ΔE_{ab}	Bicarbonate-jet	Polycarbonate	36.40 (10.24) a	40.20 (12.14) a
		Polycrystalline ceramic	25.57 (6.13) b	25.86 (6.73) b
		Monocrystalline ceramic	35.50 (6.27) a	34.21 (6.47) ab
	Robinson Brush	Polycarbonate	* 26.26 (6.45) b	* 15.43 (±5.53) c
		Polycrystalline ceramic	22.38 (4.51) b	21.01 (4.26) b
		Monocrystalline ceramic	38.32 (4.74) a	29.42 (12.18) a
	p-value		p(bracket)=0.0001; p(cleaning)= 0.0141; p(interaction)=0.0070	p(bracket)=0.0001; p(cleaning)= 0.0007; p(interaction)=0.0001
ΔE_{00}	Bicarbonate jet	Polycarbonate	28.52 (8.45) a	30.31 (9.55) a
		Polycrystalline ceramic	18.33 (4.48) b	17.59 (4.81) b
		Monocrystalline ceramic	25.46 (4.75) a	23.80 (4.93) ab
	Robinson Brush	Polycarbonate	* 19.10 (4.89) b	* 11.05 (4.45) b
		Polycrystalline ceramic	16.07 (3.12) b	14.37 (3.00) b
		Monocrystalline ceramic	27.51 (4.10) a	21.18 (8.61) a
	p-value		p(bracket)=0.0001; p(cleaning)= 0.0074; p(interaction)=0.0021	p(bracket)=0.0007; p(cleaning)<0,0001; p(interaction)=0.0001

*Differs from the bicarbonate jet under the same bracket conditions and time ($p \leq 0.05$). Different letters in the vertical (comparing the brackets within each cleaning method) indicate statistically significant differences ($p \leq 0.05$).

bicarbonate jet than with Robinson brush ($p<0.05$). The microscopy images (Fig. 1) show that the monocrystalline ceramic bracket had the greatest surface smoothness and uniformity, followed by polycrystalline ceramic brackets and polycarbonate brackets. In polycarbonate brackets, glass fibers were observed both before and after cleaning. After staining with cigarette smoke, the monocrystalline ceramic maintained its appearance of surface smoothness, contrarily to the polycarbonate and polycrystalline ceramic brackets, in which the appearance of the surface became more textured.

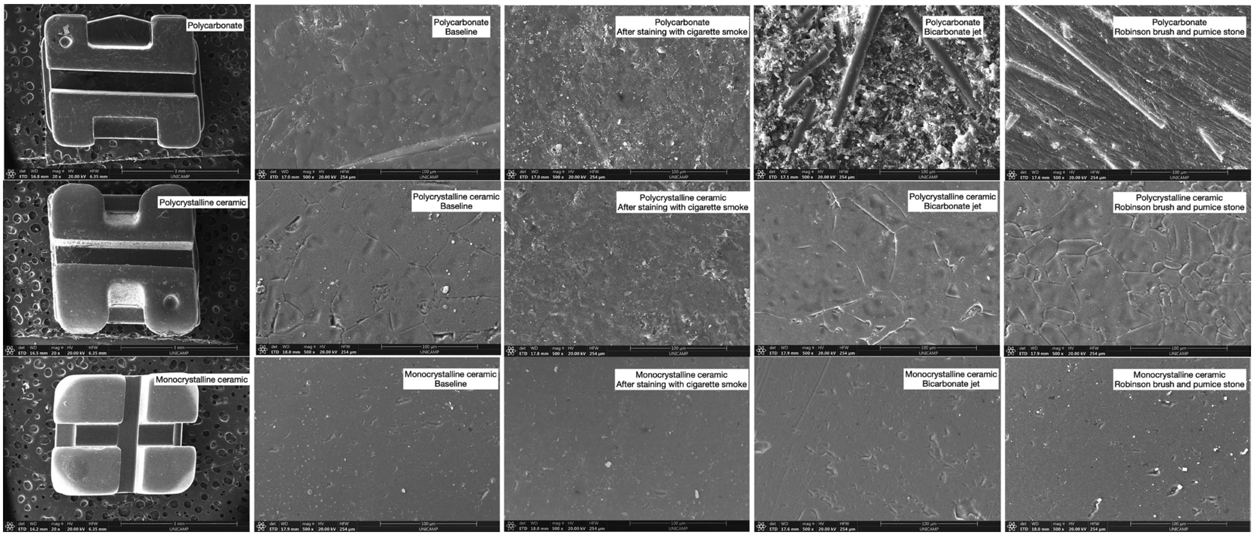

Fig. 1: Images of the surface micromorphology of brackets at different evaluation times.

Irrespective of the type of cleaning used, the smoothness and uniformity of the monocrystalline bracket surfaces did not change. For polycarbonate brackets, however, the bicarbonate jet led to more significant change on the surface, with evidence of glass fibers due to the removal of the most superficial resin matrix and caused porosity in this resin matrix. Cleaning with a Robinson brush and pumice stone not only produced more significant evidence of glass fibers on the surface, but also promoted wear of the resin matrix, including scratches. Although no scratches or irregularities were observed on the polycrystalline ceramic brackets, cracks appeared between the alumina crystals, possibly due to the absorption of water by the material.

DISCUSSION

The different types of esthetic brackets differ in terms of composition, and this is reflected in the differences found in the parameters L*, a*, b* and WI_D. In general, the polycarbonate brackets had the lowest values for L* (less lightness than the other brackets), a* (more "greenish") and WI_D (less bright), and the highest values for b* (more "yellowish" than the other brackets). The monocrystalline and polycrystalline ceramic brackets had similar values for L*, a* and WI_D, but b* was higher for the polycrystalline than for the monocrystalline brackets. These results may be explained by the structural characteristics of the brackets, since the polycarbonate types are composed of a polymeric matrix reinforced with glass fibers that produce less lightness and more yellowing, as well as a more irregular porous surface. Ceramic brackets are smoother because of the aluminum oxide in their composition. Moreover, both ceramic types are lighter than the polycarbonate, with monocrystalline brackets being even lighter and more translucent than polycrystalline brackets because they consist of a larger size of ceramic grains and contain fewer impurities[32].

After staining, L* and WI_D decreased significantly for all brackets, while b* and a* increased significantly. Thus, the first null hypothesis (H01) was rejected, as all the parameters evaluated underwent statistically significant changes. These results corroborated those found by Borges et al.[33] who reported change in the color of esthetic brackets exposed to cigarette smoke. In smokers, the oral cavity is exposed to cigarette smoke, which consists of toxic substances such as carbon monoxide, ammonia, nickel, arsenic, tar, lead and cadmium[34]. The components present in cigarette smoke impregnate tooth surfaces and materials in the oral cavity, and consequently, yellow, red/brown and black pigments can be incorporated into these materials[18], explaining the decrease in lightness (L*) and "whiteness" WI_D), and the increase in values on the b* axis (greater yellowing of the brackets). Due to their high water absorption capacity (considering that they were immersed in artificial saliva before and during the staining simulation protocols) and greater surface irregularities (Fig. 1), polycarbonate brackets were more susceptible to staining than ceramic brackets[7,8]. Furthermore, changes in the surface of polycarbonate and polycrystalline ceramic brackets were observed, considering that originally, there were differences between them since the polycarbonate type is made of a polymer, and the polycrystalline type is made of alumina oxide. This may explain the greater deposition of cigarette smoke components on polycarbonate brackets[18]. Polycarbonate brackets change color when immersed in vitro in coloring solutions such as red wine, coffee and tea[10], and staining may increase over time. Among the ceramic brackets, polycrystalline alumina brackets (composed of aluminum oxide crystals fused at high temperatures and produced by means of a less complex industrial process[3,4]) have rougher, more porous surfaces than monocrystalline ceramic brackets[4]. This agrees with the microscopy images of the present study, in which the monocrystalline ceramic bracket did not exhibit perceptible changes in surface texture, even after cleaning (Fig. 1). Nevertheless, the parameters L* and WI_D showed that polycrystalline ceramic brackets had the highest lightness and whiteness after staining, although their surface was rougher than the monocrystalline type. Polycrystalline ceramic brackets yellowed less (lower b* values), even with the deposition of smoke pigments. This could be explained by the initial differences (baseline) between the brackets with regard to these parameters.

Smokers need more reinforcement of the cleaning methods than do non-smokers to reverse the extrinsic staining of brackets and teeth. Nicotine, which is present in high concentration in tobacco leaves, can produce salts with acids that are generally soluble in water and can be absorbed by brackets and adhesive materials[14]. Cleaning with sodium bicarbonate jet is quick and practical, but prolonged use can increase bracket surface roughness[35,36]. After the cleaning procedures, all brackets showed a significant increase in L* and WI_D, and a significant decrease in a* and b*, enabling us to state that as an immediate result, these procedures promoted the removal of pigments, especially those on the surface. For all brackets, bicarbonate jet cleaning led to L* values that were statistically similar to baseline, and significantly higher than those achieved with the Robinson brush. For polycarbonate brackets, the bicarbonate jet also achieved significantly higher a* and WI_D values and significantly lower b* values than did the Robinson brush. The pressure of the jet and the impact of the sodium bicarbonate particles against the structure of the bracket provided more effective dispersion and penetration into inaccessible regions, with greater power of abrasion and stain removal. However, depending on bracket material, degradation of the sandblasted surface was observed in the scanning electron microscopy images, which was more severe on the polycarbonate bracket. Thus, even though bicarbonate jet cleaning minimizes or removes surface staining, it can considerably increase surface degradation of polycarbonate brackets, and even lead to less color stability over time. The second null hypothesis is therefore rejected.

For polycarbonate brackets, after the use of airborne particle abrasion, a considerable loss of part of the polymeric matrix was observed, triggered by the force of the jet when it reached the surface, generating a significant increase in water sorption and, possibly, greater instability of color throughout the course of treatment. For polycrystalline ceramics, there were cracks on the surface between the molten grains of the crystal structure. When airborne abrasion is performed with another type of particle (such as aluminum oxide), ceramics begin to show greater retention of cements and a larger number of surface irregularities[37].

After bicarbonate jet cleaning, the change in color determined by ΔE_{ab} and ΔE_{00} was significantly greater in polycarbonate brackets than in monocrystalline ceramic brackets, followed by the polycrystalline type (Table 3), which were less stained.

Perez et al.[30] proposed a “whiteness” index (WI_D), also based on CIEL*a*b* coordinates, with the aim of avoiding the subjectivity of the visual factor in measuring color. Its advantage is that it provides a very simple analysis: higher values indicate whiter samples and lower values (including negative) indicate darker samples.

In the current study, after bicarbonate jet cleaning, ΔWI_D was higher for the polycarbonate than for the polycrystalline ceramic brackets. With the Robinson brush, ΔWI_D was higher for monocrystalline ceramic than for polycarbonate brackets. For the polycarbonate brackets, ΔWI_D was significantly higher with the bicarbonate jet than with the Robinson brush. The results suggest that polycarbonate brackets are more sensitive to cigarette smoke, since their color changed more by staining in comparison to the ceramics. Among the ceramics, the monocrystalline were the most resistant, in terms both of staining and the deleterious effects on the surface considering the cleaning methods used to remove stains, since their smoother, more regular surfaces were maintained.

In view of the findings presented, we suggest that ceramic brackets may be a better alternative for smoking patients due to their greater resistance to staining and better tolerance of the effects of both cleaning methods.

CONFLICT INTERESTS

The authors declare no potential conflicts of interest regarding the research, authorship, and/or publication of this article.

FUNDING

None.

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