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Efeito da escovagem na rugosidade superficial de duas resinas compostas: estudo piloto

Effect of toothbrushing on the surface roughness of two composite resins: a pilot study

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Effect of toothbrushing on the surface roughness of two restorative composites: a pilot study

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ABSTRACT

Objective: The purpose of the present pilot study was to evaluate the influence of toothbrushing on the surface roughness of two resin-based composites (RBCs), Synergy D6 and Brilliant EverGlow™ (Coltène, Whaledent, Altstätten, Switzerland).

Materials and Methods: Twenty disk-shaped composite specimens (diameter 8.9 mm/ height 2.8 mm, n=10 per RBC) were made. One side of each specimen was finished and polished with SwissFlex system (Coltène, Whaledent, Altstätten, Switzerland). The specimens were subjected to a toothbrushing simulation process with an electric toothbrush (Oral-B® Expert, Weybridge, UK) under a 1:1 slurry (dentifrice/distilled water) for 18 minutes and a load of 120 grams. Surface roughness (Sa and Sq values-μm) was measured using a non-contact 3D optical profiler (S NEOX 3D, Sensofar). Statistical analysis results were analysed with non-parametric Mann-Whitney and Wilcoxon tests (α=0.05).

Results: There were no statistically significant differences, concerning surface roughness, between both RBCs evaluated or between brushed or non-brushed zones, independently of the composite resin.

Conclusions: Within the limitations and conditions of the present study, toothbrushing did not increase the roughness of the two RBCs.

Keywords: Surface roughness, simulated toothbrushing, resin-based composites.

INTRODUCTION

Material properties and technical approaches are two essential factors that have developed together over time in order to allow for a better clinical performance of composite resin restorations. Resin-based composite (RBC) restorations, gather a wide fraction of dentist's routine practice because it is the most aesthetic restorative material applied in direct restoration[1,2]. Some of these materials are able to mimic the surface smoothness, colour, translucency and gloss appearance of dental tissues, thereby creating imperceptible restorations[3]. However, aesthetic failures frequently account for an increasing in roughness, surface staining, colour mismatch or anatomical form loss of the restorations implying a progressive clinical unacceptability[4].

Resin-based composite can be distinguished by differences in formulation tailored to their particular requirements as restoratives, sealants, cements, provisional materials, among others[5]. Resin composites are materials usually composed of a polymeric matrix of dimethacrylate monomers (Bis-GMA, TEGDMA or UDMA), inorganic filler particles (silica allotropes and synthetic glasses) coated with a methyl methacrylate-functional silane coupling agent to bond them to the organic matrix, and a photoinitiator system[3,6]. Two general classifications are used to categorize RBCs according to various characteristics: based on the filler type, filler distribution, average particle size of filler or on the manipulation characteristics of the filled monomer paste[7].

The classification of composites according to particle size is the most frequently used since this parameter affects the physical and mechanical properties, the depth of polymerization, the polymerization shrinkage, the degree of polishing and finally aesthetics of composites. Thus the percentage of filler content and the average particle size embedded in a particular composite are the primary determinants of the properties and handling characteristics of the composite resin[7]. Three widely used resin composites categories have been proposed considering filler size and distribution: microfilled, microhybrid, and nanocomposite (nanofill or nanohybrid resin composite)[8,9].

More recently, several adjustments in filler characteristics such as the introduction of nano and submicron-sized particles have been proposed in order to provide a material with high polishing properties combined with gloss retention. It is a general belief that smaller filler particles protect the softer resin phase from wear and reduce surface alterations resulting from loss of particles. The size of the fillers is usually ascribed to have a significant impact on composites surface properties, such as smoothness and gloss[10–12]. In the same way, appearance and surface luster are often related to clinical performance of restorations, especially in anterior teeth. There is no clinical evidence, however, that nanofill or submicron restoratives show better performance compared to microhybrids regarding restorations aesthetic and surface qualities[10].

Despite manufacturers' efforts in developing and marketing new materials, the question still remains whether clinicians should consider using nanofill or submicron composites over traditional microhybrids. This question cannot be indisputably answered based on the scarce clinical evidence[10]. However, published *in vitro* studies have shown that the roughness of microfilled and nanofilled RBCs is less than that of hybrid RBCs[3,8,13–15]. On the other hand, different studies have shown that all composite materials undergo clinical degradation due to mechanical and/or chemical interaction with the oral environment. The RBC surfaces are constantly exposed to erosive substances presented in food and/or drinks. Furthermore, toothbrushing with toothpastes with a certain abrasiveness plays an important role in the changes of surface roughness observed with restorative materials[3,4,16]. Thus it is possible that a synergistic effect of abrasion and erosion phenomena will roughen all RBC materials over time. The result of this surface roughening can be a decrease in gloss and an increase in color changes, both affecting the aesthetic appearance of the restorations[3].

The surface roughness has been recognized as a parameter of high clinical relevance because it has a major impact at increased plaque deposition, gingival inflammation, loss of surface gloss and increased extrinsic staining, especially in Class V restorations[3,8]. *In vivo* studies that evaluated the threshold surface roughness for bacterial plaque retention showed that a mean roughness of above 0.2μm was related to a substantial increase in bacterial retention[8,16,17]. Moreover, a smooth surface adds to the patient's comfort, as differences in surface roughness of 0.3μm can be easily detected by the tip of the patient's tongue[16,18].

Previous studies have reported that, besides material composition, also finishing and polishing procedures might influence composite surface quality. Therefore, in adhesive restorations, it is important to determine the best finishing/polishing technique to obtain the best results[9,14]. On the other hand, the ability to polish composites depends on size, shape, hardness and quantity of filler particles[18–23]. Previous studies have shown that resin composites with smaller particle sizes promote higher gloss and lower surface roughness after polishing with several polishing systems[13,14,24]. Thus, the structure of the resin composite and the characteristics of the particles have a direct impact on the surface smoothness and the susceptibility to extrinsic staining[14].

In vitro evaluation of surface changes in restorations by simulated toothbrushing might be a surrogate parameter to assess the ability of a material to maintain its gloss and smoothness and prevent staining of the material. Nevertheless, studies with regard to in vitro/in vivo comparisons are missing[16]. Surface roughness and wear tests after simulated toothbrushing have been indicated to assess the mechanical features of restorative materials[3,4,8,20,25].

The aim of the present study is to measure the surface roughness of two resin composites, before and after brushing with toothpaste slurry in a device for simulated toothbrushing as a function of a predefined brushing time and load.

The null hypothesis is that there is no difference on surface roughness assessments after simulated toothbrushing between resin composites.

MATERIALS AND METHODS

RBCs sample preparation

Two different experimental RBCs were tested in this study (Table1); ten specimens of each material, **Brilliant EverGlow** (Coltène, Whaledent, Altstätten) and Synergy D6 Composite (Coltène, Whaledent, Altstätten, Switzerland) respectively, were prepared using a cylindrical polyethylene mould, measuring 8,9 mm in diameter and 2,8 mm height. Each RBC was placed directly into the mould and a constant pressure with a glass slide was applied to extrude the material excess and reduce voids inside the material. All specimens were light-cured with a LED light-curing unit (SPEC 3, Coltène, Altstätten, Switzerland) using an irradiance of 1600mW/cm^2 for 40s on each side. The specimens were removed from the moulds and the excess was cut off with an Enhance point (Dentsply, DeTrey Konstanz, Germany). The samples were carefully identified and were then stored in distilled water for 24h. The top surfaces of the disks were sequentially wet polished with SwissFlex system (Coltène, Whaledent, Altstätten, Switzerland) using an increasing grain size disk sequence of #70μm, #50μm, #30μm and #5μm. Polishing was performed using a slow-speed handpiece running at 10'0000 rpm. New disks were used to polish each specimen. After polishing, all specimens were cleaned in water to remove any debris left, were identified and dried with a soft paper. All finishing and polishing procedures were applied on one side of the specimens, with light pressure, in a single direction and all these procedures were carried out by the same operator. All specimens were evaluated individually in a stereomicroscope (Nikon® SMZ 1500, Tokyo, Japan) and some of them were excluded for not meeting the quality criteria, due to defects in polishing and presentation of bubbles. Six specimens were excluded.

Experimental design

The specimens of RBCs were divided into 2 groups: group I (n=7) with Brilliant EverGlow™ and group II (n=8) with Synergy D6 Composite.

For simulated toothbrushing, all specimens (n=15) were fixed with wax in a plastic container with a sample holder. A slurry of toothpaste was prepared by mixing the Protection Caries toothpaste (Elgydium®, Pierre Fabre Oral Care, France; relative abrasiveness RDA-49,34 +- 3.53) with saliva diluted in a 1:1 weight ratio (3,53g of toothpaste and 35 ml of distilled water). Each specimen was embedded with previously mixed slurry ensuring a total coverage of the surface.

The toothbrush was performed in an electric toothbrushing device (Oral-B® Expert, Weybridge, UK) with a toothbrush head (Oral-B® Precision Clean, Weybridge, UK), which employed a circular motion technique. A holder was developed to make sure that in every brushing cycle the toothbrush stayed in the same position and brushing affected only half of each specimen, leaving the other half non-brushed (Fig.1). The load was ensured by placing a 120g weight over the arm of the toothbrush. A brushing time was defined for each sample of 18 minutes.

The slurry was replaced for every new specimen and an individual toothbrush head was used for each group of composite resin.

Roughness measurement

Before simulated toothbrushing, the roughness (Sa and Sq- values in μm) of two randomly chosen specimens from each group was previously measured. Then, after simulated toothbrushing, the roughness of all specimens was measured at two independent zones; (Z1) where the specimen was not brushed and (Z2) where the specimen was brushed. Roughness was analysed using a non-contact 3D optical profiler (S neox® 3D, Sensofar, Stuttgart, Germany) using the brightfield at a 50x magnification. The S neox® 3D uses a high-resolution CCD sensor of up to 1360x1024 pixels in combination with high-resolution displays of 2560x1440. Its four LED light sources inside its optical core improves lateral resolution and optical coherence length. Additionally, the red, green and blue LEDs are pulsed to acquire real colour high images and contrast colour-coded depth information in real time.

The surface roughness results were given in Sa (μm) and Sq (μm), they are height parameters (Figure 2). Sa is a 3D parameter expanded from the roughness (2D) parameter Ra. It expresses the average of the absolute values of Z (x,y) in the measured area.

Sq is a 3D parameter expanded from the roughness (2D) parameter Rq. It expresses the root mean squared of Z (x,y) in the measured area. It is equivalent to the average mean squared of the measured region on the three-dimensional display diagram when valleys have been changed to high peaks by squaring.

Statistical analysis

Statistical analysis was processed with the IBM SPSS *Statistics* 20.0 (SPSS Inc, Chicago, IL, USA) software system using the Mann-Whitney test for intergroup comparisons and Wilcoxon test for intragroup pairwise comparisons. Significance level was set to α=0.05 for all analyses.

Table.1- Resin composites evaluated in the study.

Resin-based composite	Matrix	Resin Type	Filter	Filler Weight (%)
Brilliant EverGlow™ Coltène, Whaledent, Altstätten, Switzerland	Bis-GMA TEGDMA Bis-EMA	Nanohybrid	Prepolymerized filler silica Colloidal nano-silica Barium glass	79
SinergyD6 Universal Enamel Coltène, Whaledent, Altstätten, Switzerland	UDMA TEGMA Bis-GMA	Nanohybrid	Methacrylate Barium glass Silanized amorphous silica Hydrophobic silica	80

Abbreviations: Bis-GMA: bis-phenol A diglycidylmethacrylate; TEGDMA: triethylene glycol dimethacrylate; Bis-EMA: bisphenol A polyetheylene diether dimethacrylate, UDMA: urethane dimethacrylate.

Figure. 1 - Diagram of brushing apparatus. A) Electric toothbrushing device B) Weight c) Holder D) Specimen E) Toothbrush head Z1) where the sample was not brushed Z2) where the specimen was brushed.

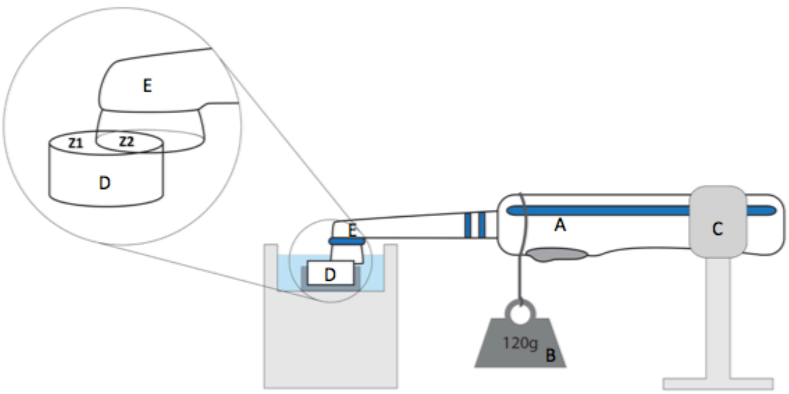
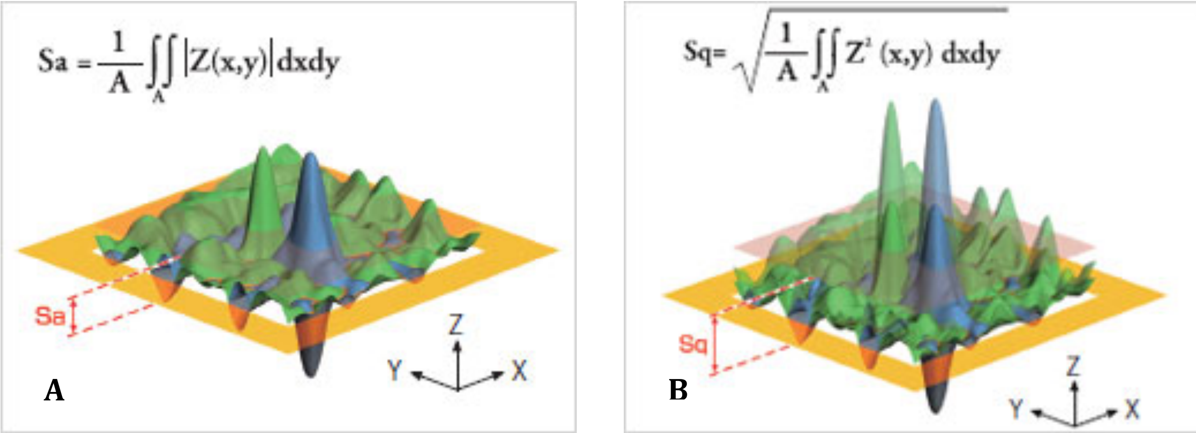


Figure. 2 – **A**) Arithmetic mean height (Sa); **B**) Root mean squared height (Sq).
Source: http://www.olympus-ims.com/en/knowledge/metrology/roughness/3d_parameter/



RESULTS

The surface roughness results are given in Sa (μm) and Sp (μm) and are presented in Table 2. The results showed no statistically significant differences concerning surface roughness between both RBCs evaluated or between brushed or non-brushed zones independently of the composite resin tested.

In group I the Z2 values (Sa and Sq) were greater than Z1 (Sa and Sq); except for s specimen 1.3 where the values were the same.

In group II the Z2 values (Sa an Sq) were greater than Z1 (Sa and Sq), for the specimen 2.2, 2.3,2.4. However, for the specimen 2.1, 2.5, 2.6, Z1 values (Sa and Sq) were greater than Z2 (Sa and Sq).

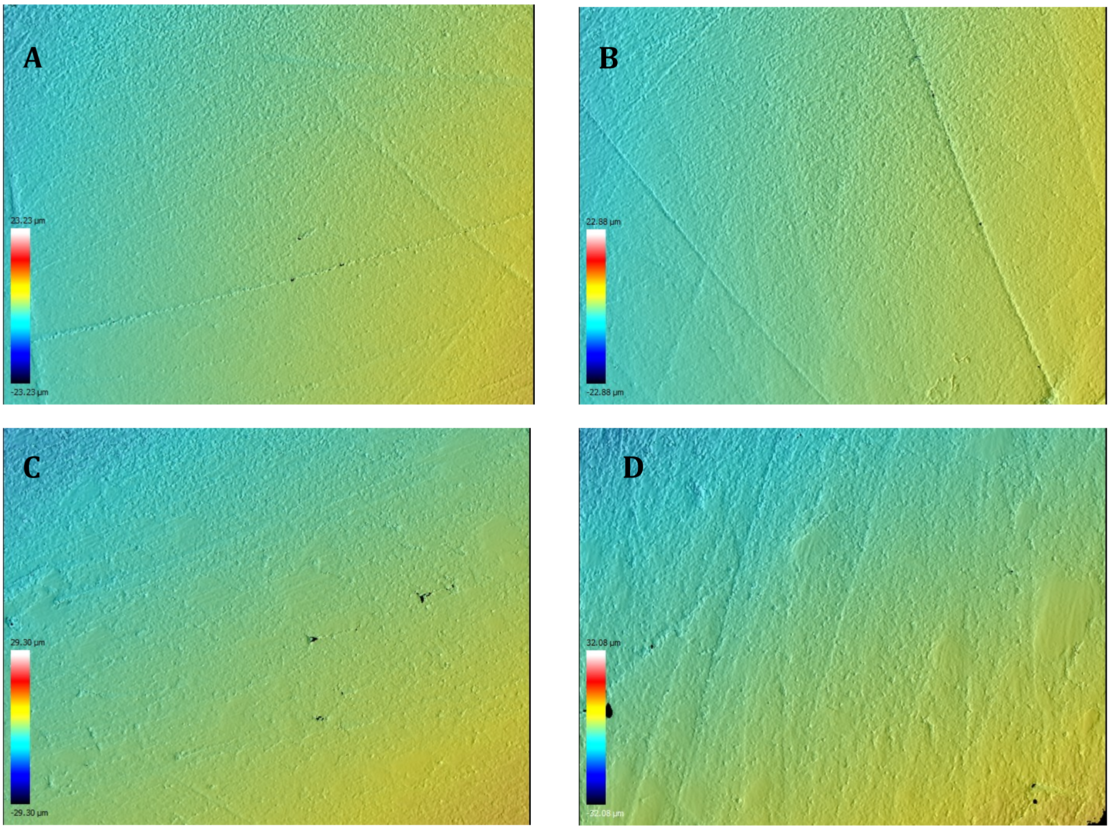
The average and standard deviation values, for Z1 and Z2 (Sa and Sq) were higher in group II.

Two topographic images of each composite without (Z1) or with (Z2) simulated toothbrushing are shown in Fig.3.

Table 2 – Surface roughness (Sa and Sq values-μ) of two distinct zones: without (Z1) and with (Z2) toothbrushing. Individual values, mean and standard deviation (SD) are expressed in micrometres. Intergroup comparison was performed with Mann-Whitney test. The comparison within each group between brushing and non-brushing zones was performed with Wilcoxon test. α= 0.05.

	Sample	Sa Z1	Sa Z2	Sa Z2-Z1	Wilcoxon p-value	Sq Z1	Sq Z2	Sq Z2-Z1	Wilcoxon p-value
GI Brilliant EverGlow™	1.1	3.09	3.42	0.33	0.144	3.61	4.02	0.41	0.144
	1.2	1.89	2.31	0.42		2.30	2.78	0.50	
	1.3	2.49	2.49	0.00		2.90	2.90	-0.04	
	1.4	1.08	1.68	0.60		1.27	1.97	0.70	
Mean ± SD		2.14± 0.86	2.47± 0.72	0.34± 0.25		2.52± 0.99	2.91± 0.84	0.39± 0.31	
GII Synergy D6	2.1	0.94	0.88	-0.06	0.917	1.20	1.00	-0.09	0.917
	2.2	3.00	3.33	0.34		3.66	4.10	0.35	
	2.3	5.17	5.29	0.12		6.11	6.25	0.13	
	2.4	2.59	2.67	0.08		3.14	3.01	0.06	
	2.5	6.61	5.33	-1.28		7.8	6.5	-1.3	
	2.6	0.60	0.50	-0.10		0.71	0.58	-0.12	
Mean ± SD		3.15± 2.36	3.00± 3.00	0.15± 0.15		3.76± 3.75	3.59± 3.59	0.17± 0.17	
Mann-Whitney (p-value)		0.762	0.762	0.114		0.610	0.762	0.067	

Fig.3 - S NEOX 3D images (50x) of samples without toothbrushing (Z1; first column) and after toothbrushing (Z2; second column). Group I (**A**,**B**) specimen 1.3, Group II (**C**,**D**) specimen 2.2.



DISCUSSION

The increased importance of dental aesthetics on an individual professional and social life demands direct restorative materials to be able to replace and mimic the features of dental tissues lost by caries or trauma. This means that, in addition to providing improved mechanical properties, the restorations built-up with composite resins should simulate aesthetic characteristics, such as surface smoothness, colour, translucency, gloss and, primarily, maintain stability over time.

The clinical relevance of roughness can be seen from two aspects. First, this property is strongly related to bacterial colonization in surfaces located in the oral environment. Moreover, an increased surface roughness, reduces the possibility of dislodgment of the oral biofilm, which is a periodontal health concern[25,26]. Secondly, an increasing in roughness can induce changes in colour, translucency and gloss of RBCs, which is an aesthetic concern[3,13,27]. Surface roughness refers to the finer irregularities of the surface texture that usually result from the action of the production process or the characteristics of the material[28]. A clinical study showed that an Ra-value of 0,2μm is the critical threshold value for bacterial retention[8,16,1717,29]. In addition another study reported that a surface roughness 0.3μm can be detected by a patient's tongue[16,18]. In the oral cavity, the surfaces of restorative materials are exposed to a variety of factors, which may alter the quality of the surface. Among other factors, oral hygiene procedures play a significant role. The daily use of prophylactic home procedures may have side effects, such as the roughening of the surface of restorative materials and thereby enhancing bacterial growth and retention of stain.

Concerning surface roughness, evaluation of the Ra value is the most frequently used parameter for comparison purposes. Ra value corresponds to the arithmetic mean of the departure of the profile from a mean line derived from the top and bottom of the undulations on the trace. However, previous studies have disclosed that one problem with the use of the Ra-value is that it represents a two-dimensional parameter and it only gives information on the roughness height and no information at all on the profile of the surface[16,30–32]. To provide this information there is a need to create an image of the surface topography. Non-contact 3D optical profiler (S NEOX 3D, Sensofar) provides a definite characterization of the surface, in three-dimensions. The measurements were made with Sa-values, which is a 3D parameter expanded from the roughness (2D) parameter Ra. Stable results can be obtained with this commonly used parameter because the influence of a single injury on the measurement value becomes extremely small[33].

The aim of the present study was to evaluate the influence of brushing on the surface roughness of two RBC. The 120g used load is comparable to the mean load measured in clinical studies[3,16,34–37] .The technical specification of ISO on wear testing by toothbrushing defines a useful force between 50g and 250g for the experimental setup[16]. During toothbrushing, the toothpaste is quickly diluted by saliva and in vitro studies simulate this effect by diluting the toothpaste with distilled water. However, the special properties of saliva, which contains specific proteins and ions that may diminish the roughening effect of the toothbrush, cannot be simulated[16].

In the current experimental protocol, a total of 2160 strokes were applied within 18 minutes, which may correspond to the amount of toothbrushing that is carried out over a period of 54 days. This number was based on an estimation that a tooth is brushed for 10s in each daily tooth brushing of 2 min. Considering that an individual brushes the teeth twice a day, this means that each tooth will be submitted, on average, to 40 strokes daily (2 strokes per second/280 strokes in a week)[3,38,39]. However, we can speculate that the time of brushing was not sufficient to detect differences. Other studies used more prolonged periods of 48 minutes or 10 hours[13,16]. This parameter might have influenced the results, since these same studies have higher roughness values when the samples are subjected to higher brushing times.

Different studies using 2D evaluation methods, found an increase roughness of nanohybrid resin, after simulated brushing[3,4,13,16,29,38], with Ra-values in the order of 0.13, 0.09 μm[29,38].

After simulated toothbrushing, the roughness of all specimens was measured at two independent zones (Z1) where the sample was not brushed and (Z2) where the specimen was brushed. The results showed no statistically significant differences concerning surface roughness between both RBCs evaluated or between brushed or non-brushed zones independently of the composite resin. Nevertheless, when final roughness was analysed, distinct performances were observed before simulated toothbrush testing. A very high value of roughness should be noted after polishing surfaces, compared to other studies[3,8,14,40]. A study using 3D evaluation method presented roughness values of the resin after polishing, Sa-values 0.10μm [40]. Surface roughness, associated with improper finishing and polishing, can cause increased wear rates and plaque accumulation, which compromise the clinical performance of the restoration[19,24,41,42]. A poor polishing technique, the reduced polishing time[14,28,43] and the force applied during polishing[28,43], are possible methodological errors that can explain the presence of surface irregularities in the polished area (Z1). Thus one possible way to optimize the use of this methodology would be improve and standardize the roughness values for maximums of 0.10μm (values below the critical limit for bacterial adhesion – 0.20 μm) and use a polishing machine as reported in other studies[16,29,38,44].

Consequently, the null hypothesis tested, which stated that there is no difference on surface roughness assessments after simulated toothbrushing between resin composites, was not rejected.

CONCLUSION

Within the limitations and conditions of the present study, tootbrushing did not increase composite surface roughness. The results showed no statistically significant differences concerning surface roughness between both RBCs evaluated or between brushed or non-brushed zones independently of the composite resin.

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