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Original Research Article

Effect of two surface sealant agents on surface roughness of a nano-hybrid resin composite

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Abstract

The objective of this investigation was to assess the influence of two surface sealant agents on surface roughness of the nano-hybrid resin composite. Thirty cylindrical specimens were prepared from a nano-hybrid resin composite (Grandio) after covering with Mylar matrix strip with no finishing or polishing. The specimens were randomly allocated into 3 groups/10 each: Group 1/control/Mylar strip/no surface treatment; group 2 surface sealant (Biscover LV) was applied, and group 3 surface sealant (G-Coat Plus) was applied. The surface roughness (Ra) was determined with a stylus profilometer and the topography of representative samples of the control and experimental specimens were evaluated by scanning electron microscopy (SEM). Group 1/control showed the lowest Ra (M±SD) 0.053±0.021. While Ra of group 2 (Biscover LV) and group 3 (G-Coat Plus) were 0.369±0.040 and 0.381±0.047 respectively. There was no statistically significant difference of surface roughness when Biscover LV and G-Coat Plus **surface sealants were applied (*p*>0.05). SEM examination of the surface of all groups showed comparable surface topography. The surface roughness of the nano-hybrid resin composite tested in this study showed lowest Ra value when Mylar strip was used. No significant difference of surface roughness was found when the two surface sealant agents were applied.**

Keywords: Composite Glaze, Nano-Hybrid Resin Composite, Surface Roughness, Surface Sealants

INTRODUCTION

The surface roughness is a microstructural phenomenon of the material created by physical processes which modify their surfaces (Ergücü and Türkün, 2007). The surface roughness of different restorative materials governs the quality, anatomic form, color and performance of materials in the oral cavity (Kawai and Urano, 2001; Rodrigues-Junior et al., 2014). Roughness could also worsen buildup of plaque, speed water diffusion into the bulk of the material and its potential degradation, and diminish longevity and esthetics of the restorations (Kawai and Urano, 2001; Voltarelli et al., 2010). Experimental data demonstrated that high surface roughness of restorative materials is correlated to presence of the biofilm on its surface (Bollen et al., 1997). The surface roughness also influences the biofilm formation and maturation on restorative materials and a more complex biofilm can be formed on a rougher substrate rapidly (Rimondini et al., 1997; Eick et al., 2004). In addition, the smooth surface is likely having a better wear in the oral cavity (Voltarelli et al., 2010). Even after accomplishing appropriate finishing/polishing of the restorative materials, the surface exhibits microcracks as well as microdefects, creating a rough surface (Takeuchi et al., 2003; Uctasli et al., 2007; Lopes et al., 2012).

Surface sealants has been introduced in an attempt to overcome the presence of microdefects and microcracks on the restorative materials. The so-called surface penetrating sealant should be able to fill, by capillary action, the structural microdefects and microfissures that are created during placement of the restorative materials to improve their clinical longevity (Dickinson et al., 1990; Dickinson and Leinfelder 1993; Ergücü and Türkün 2007). This approach is assumed to form a better regular, uniform smooth surface (Takeuchi et al., 2003; Bertrand et al., 2000). Strategies were attempted to develop a sealant/glaze without forming an oxygen-inhibited layer after curing (Suh, 2003). The effects of dental erosion caused by acidic solutions on the surface of restorative dental materials could be minimized by the application of a surface sealant (Briso et al., 2011).

Different types of resin composite are commonly used because of their higher esthetic properties and ease of use (Ferracane, 2011). A review article highlighted and focused on the strengths and deficits of the resin composites, their clinical uses, and differences between their types including microfilled, packable, hybrid, nano-hybrid, silorane-based, ormocer-based, and flowable composites (Ilie and Hickel, 2011). To preserve or improve the properties of direct restorative materials, the application of surface sealants is being recommended to increase the durability of restorations (Lee and Powers, 2007). However, the application of surface sealants to improve the quality of resin composites is still controversial (Cilli et al., 2009; Lopes et al., 2012). As far as the authors are aware, little information is known regarding the surface roughness of nano-hybrid resin composites after application of the surface sealants. Examining the properties of the surface sealants may assist in identifying their nature and the long-term durability when it is applied. Therefore, the objective of this investigation was to assess the effect of two surface sealant agents on surface roughness of the nano-hybrid resin composite. The tested null hypothesis was that there are no differences between surface roughness of the nano-hybrid resin composite with or without the application the surface sealants.

MATERIALS AND METHODS

This study was approved by the Ethical Committee of Human Studies, College of Dentistry Research Center, King Saud University. Thirty cylindrical specimens (8 mm diameter, 2mm thickness) were prepared from a universal light-cured 87% filled nano-hybrid composite (Grandio, VOCO GmbH, Cuxhaven, Germany) according to the manufacturer’s instructions and the specimens were built according to the ISO 404910 for evaluating surface roughness (ISO, 2000). The material was expressed into the Teflon molds and to ensure a uniform flat surface, a standard glass microscope slide (Shandon™ Polysine Slides, Thermo Scientific, Kalamazoo, MI, USA) was placed on top of Mylar matrix strip (Dental Mylar Strips, Dent America Inc., City of Industry, CA, USA) and stabilized with a C-clamp. Each specimen was light cured for 20 seconds using a LED curing light (Elipar S10, 3M ESPE, Seefeld, Germany). The bottom of the cylindrical specimen was also light cured for 20 seconds and marked to identify the bottom surface, so only the top surface was measured for surface roughness, no further finishing or polishing was carried out. Specimens were stored in distilled water in closed containers for 24 hours at 37°C and 100% relative humidity.

Specimens were randomly allocated into three groups (n=10). The power sample size was 0.81 and level of significant σ=0.05 with estimated standard deviation =0.9, the sample size should be at least 9 in each group. Groups were divided into one control and two experimental groups where surface sealant agents were applied according to the instructions of the manufacturer. Group 1, control/Mylar strip/no surface treatment; group 2, Biscover LV (BisCover LV, Bisco Inc., Schaumburg, IL, USA) which is composed of dipentaerythritol penta-acrylate esters and ethanol was applied; and group 3, G-Coat Plus (GC America Inc. Alsip, IL, USA) which is formulated with adhesive monomer and nanofillers was applied. For the two experimental groups, each surface-sealant was applied in one direction with a soft brush in a thin, even layer without any agitation to avoid the formation of air bubble. Twenty seconds after application, the specimens coated with BisCover LV were polymerized for 30 seconds. While the specimens coated with G-Coat Plus were polymerized for 20 seconds. All specimens were Thermo cycled between 5°C and 55°C with a dwell time of 30 seconds and a transfer time of 5 seconds for 1500 cycles (Thermocycler THE-1100, SD Mechatronik GMBH, Feldkirchen-Westerham, Germany).

The surface roughness (Ra; the arithmetic mean of the sum of roughness profile values) in micrometers were determined with a stylus profilometer (Hommelwerke GmbH, Schwenningen, Germany). The surface roughness of the top surface of each specimen was measured using a 5µm radius and multiple line scans employing a 0.25mm cut-off length and 1.25mm total scan length traversed at 0.25mm/s with a downward force of 4mN. Four line scans, two in horizontal and two perpendicular directions, were made per specimen surface and were averaged.

Representative samples, one specimen from each group was selected for qualitative SEM (JEOL JSM-636OLV, Tokyo, Japan) examination. Each specimen

Table 1. Descriptive statistics of surface roughness {Sa = Arithmetic mean height} for the control and experimental groups.

Groups	N	Minimum	Maximum	Mean	Std. Deviation
Group 1	9	0.03	0.09	0.051	0.021
Group 2	9	0.31	0.42	0.369	0.040
Group 3	9	0.32	0.44	0.381	0.047

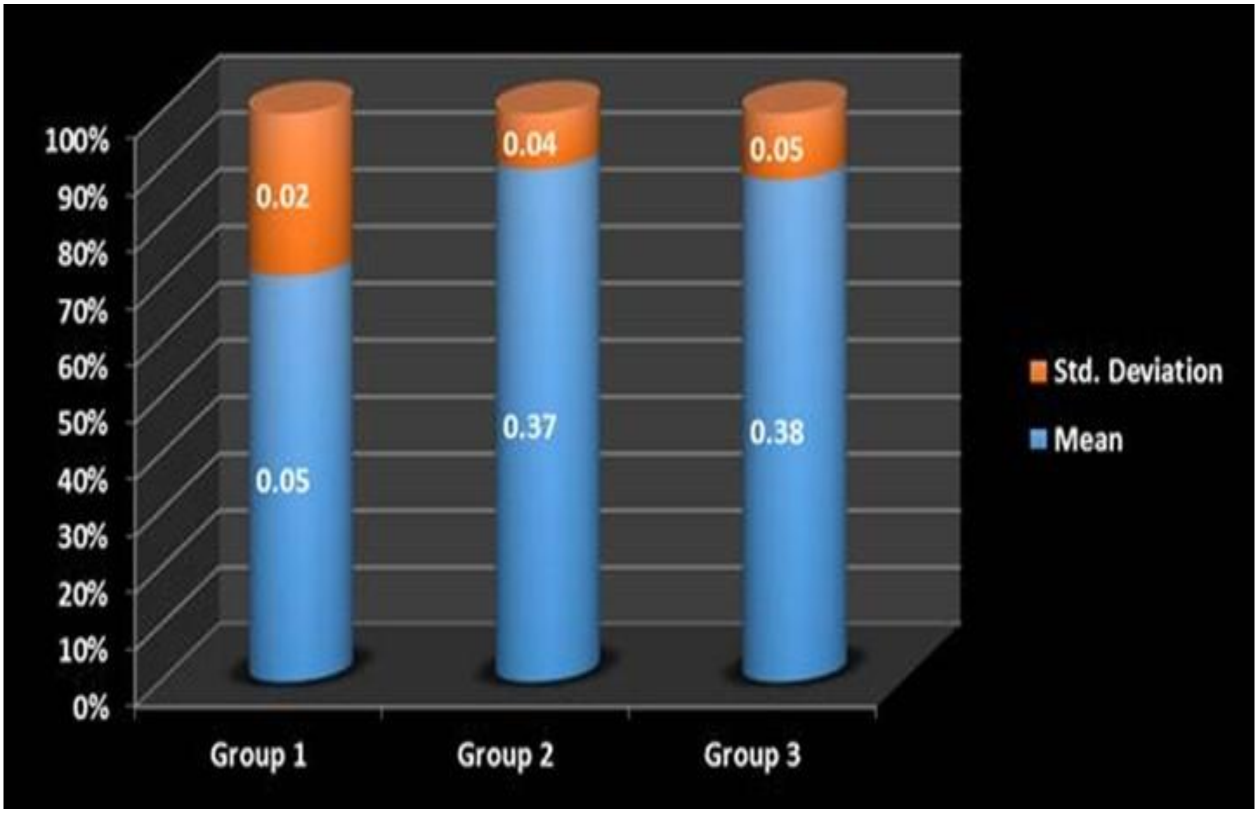

Figure 1. The mean and Std. Deviation of the surface roughness (Ra) for the control and experimental groups.

was dried for 24 hours at 37°C, gold sputter-coated and had the top surface evaluated at an accelerating voltage of 10 kV using low magnification (200×). Then a representative image at the center regions of each specimen was taken at 1000×. Surface topography of the experimental specimens was assessed and results were compared with the control group.

Data were analyzed using two-way ANOVA and Post Hoc Tukey's HSD (honest significant difference) test. All statistical analyses were established with a significance level of $p<0.05$. The statistical analysis was performed with SPSS Version 16.0 (SPSS Inc. Released 2007. SPSS for Windows, Chicago, SPSS Inc., Ill).

RESULTS

Table 1 show the descriptive statistics of surface roughness (Ra) for each group. Group 1/control/Mylar strip/no surface treatment showed the lowest surface roughness (Mean±Std. Deviation) 0.051±0.021. The surface roughness of group 2 (Biscover LV) was 0.369±0.040 and for group 3 (G-Coat Plus) was 0.381±0.047. Figure 1 shows the mean and Std. Deviation of the surface roughness (Ra) for each group. There was no statistically significant difference of surface roughness when Biscover LV and G-Coat Plus surface sealants were applied ($p>0.05$).

SEM examination of the surface of all groups showed comparable surface topography (Figure 1-3) (Figures 1-4). The application of the surface sealant agents did not show different surface topography compared to control group (Mylar strip/no surface application of surface sealant agent).

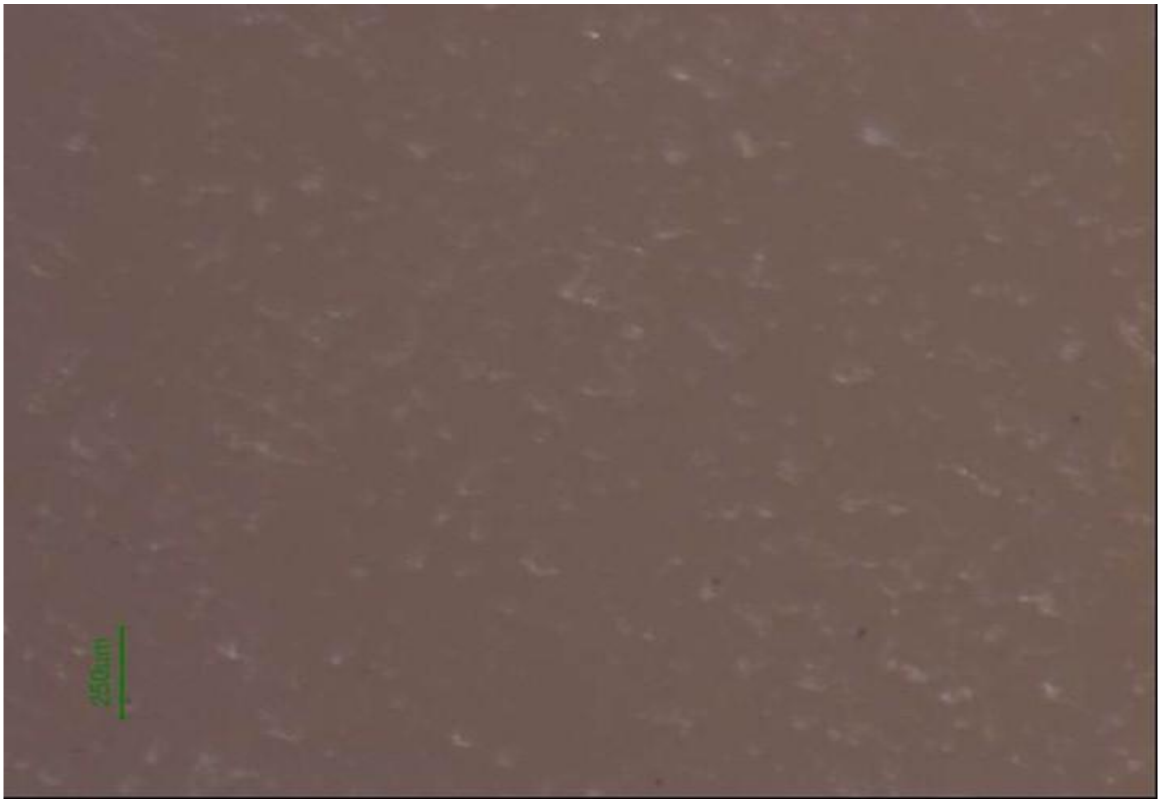

Figure 2. Scanning electron micrograph of the surface of group 1 (control/Mylar strip/no surface treatment) (×1000 magnification).

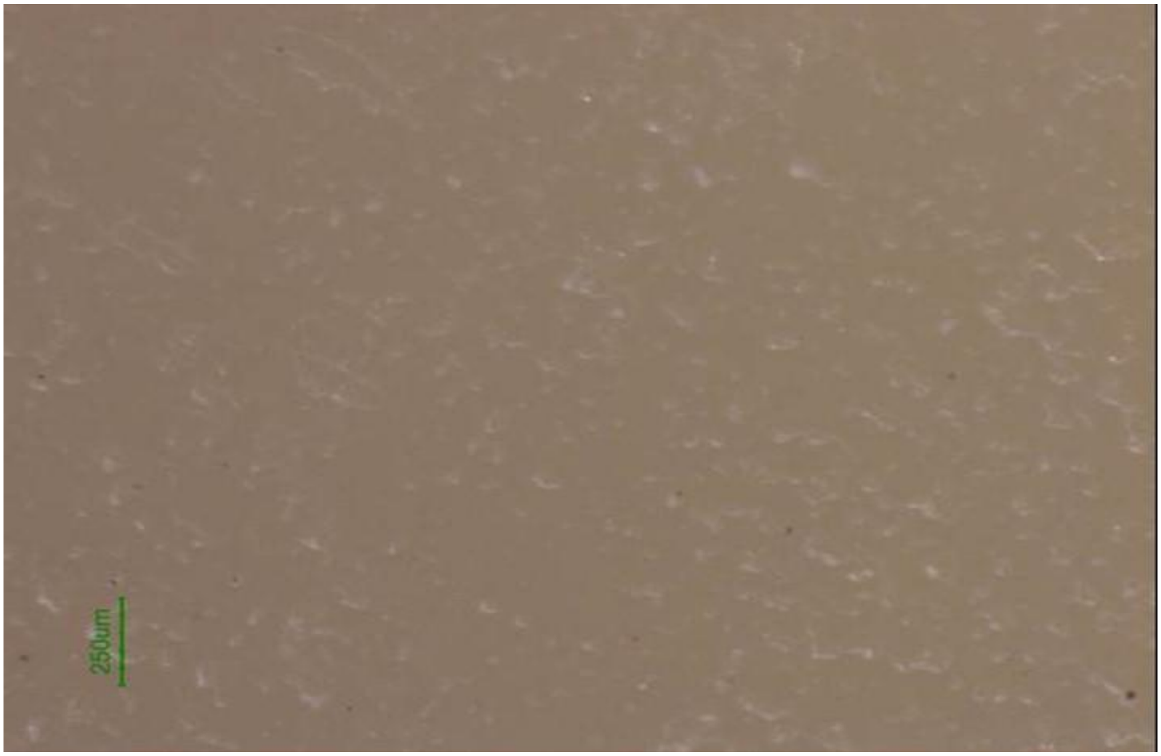

Figure 3. Scanning electron micrograph of the surface of group 2 where surface sealant (Biscover LV) was applied (×1000 magnification).

Figure 4. Scanning electron micrograph of the surface of group 3 where surface sealant (G-Coat Plus) was applied (×1000 magnification).

DISCUSSION

The tested null hypothesis in the present study was rejected as there was no difference between surface roughness of the nano-hybrid resin composite with and without application the surface sealant agents. The findings of the present study revealed that application of surface sealant did not promote smoother surfaces for the two tested materials. This is in agreement with another study which reported that surface sealants were unsuccessful in improving the surface roughness of nanofiller resin composite (Lopes et al., 2012). In contrast, another study evaluated the effectiveness of the surface sealant application on the surface roughness after finishing and polishing procedures of tested composites showed that their use considerably improved the smoothness of all tested resin composites surfaces (Attar, 2007; Bonato et al., 2016). Also, a recent study evaluated the influence of sealant agents on the roughness of nano-hybrid resin composites concluded that most of the tested materials developed smoother surfaces (Dede et al., 2016). A study concluded that the ability of sealant to cover the defects on the resin composite was evident, but not to achieve a regular surface which reduced the microhardness of the surface (Bertrand et al., 2000). The thermocycling and greater thickness of the sealants may be contributing factors to the difference in the results of different studies. A study indicated that the thickness of the non-filled sealant layer presented considerable variation (0-70μm), when analyzed under SEM and it was practically impossible to obtain a uniform macroscopic layer (Bertrand et al., 2000). In the present study, all surface sealants were non-filled. Also, thermocycling performed in the present study may expand and contracts the sealant layer. The differences in temperature during thermocycling could also lead to formations of microcrack and the elimination of nonadherent surface particles (Lima and Soares, 2011).

The surface roughness (Ra) higher than 0.2μm or more would result in accumulation of bacterial plaque, generating periodontal pathologies and carious lesions (Takeuchi et al., 2003; Bollen et al., 1997). Results of the present study demonstrated that all surface roughness values of the control and experimental groups were more than 0.2μm. There is no agreement about reference data on the minimum limit of roughness below which the bacteria would not adhere (Mei et al., 2011) but the most commonly mentioned limit of surface roughness (Ra) is below 0.2μm for adherence of dental biofilm (Bollen et al., 1997; Mei et al., 2011; Antonson et al., 2011). Maybe it is most accurate to say, the mentioned limit depends on the bacteria species. It is important to emphasize that rough surfaces favor bacterial adhesion and biofilm formation on the teeth and restorations, which can further cause secondary caries, as well as gingival and periodontal diseases (Mei et al., 2011; Bollen et al., 1997; Antonson et al., 2011). It is essential when comparing the surface roughness data of different studies to consider their variations and to take with thoughtfulness their results due to differences in methods and settings of surface analysis as well as the tested materials.

In this study, even though no statistically significant difference between the two tested sealants when applied to a nano-hybrid resin composite, the use of surface sealant agents resulted in higher Ra values compared to the control. The nano-hybrid resin composite is a submicron hybrid resin composite, filled with nanometer size particles, from which some are dispersed and others create nanoclusters, as secondarily formed fillers (Mitra et al., 2003). The size of these nanoclusters can range from about 0.6 to10µm (Mitra et al., 2003). Most surface sealants are formed by the same dimethacrylate based material used in resin composites, and they have no reinforcing fillers (Valentini et al., 2012). Water diffusion may influence the sealant similar to it is effect on resin composites. The sealant agents may result in weak retention to the underlying material, low resistance to abrasion, and poor surface quality due to uneven spreading which relay on viscosity (Bertrand et al., 2000; Sarac et al., 2006). It was reported that the nano-hybrid resin composite materials after sealant (BisCover) application lowered Ra than those of microhybrid and hybrid resin composites which may be due to the ability of the sealant to plug the micro fissures and micro defects by capillary action also to the smaller size of the filler particles and high density of nano-hybrid resin composites which result in smoother surfaces (Sarac et al., 2006). To fulfill its performance, surface sealants should have good wettability, low contact angle with the restoration surface, low viscosity, and good capacity of penetrating the existing micro defects (D’Alpino et al., 2006). For this reason, the presence of components such as low molecular weight monomers have been described as essential (D’Alpino et al., 2006). It is assumed that a surface sealant, consisting of BisGMA modified by low molecular weight monomers such as TEGDMA and THFMA, could control the characteristics of viscosity and wettability (Dickinson et al., 1990). The wear resistance of composite resins can be enhanced by the use of surface sealants, as long as it is annually applied (Dickinson et al., 1990; Dickinson and Leinfelder 1993). An *in vivo* study reported that after one year, wear values of sealed restorations equivalent to half of those found in non-sealed restorations (Dickinson et al., 1990; Dickinson and Leinfelder 1993). The goal is to produce restorations with smooth surfaces without irregularities which result in improved esthetics and minimal plaque accumulation (Maliderou et al., 2006; Hamouda, 2011).

In the present investigation; the specimens that were cured against a Mylar strip and no further finishing or polishing showed the lowest surface roughness. Mylar strips and celluloid crowns are usually applied as matrices for shaping restorative materials which more likely require no further surface finishing (Bollen et al., 1997). Using polyester strips against resin composite was suggested to produce the best smooth surface (Bollen et al., 1997) which justified its application in the present study. Our results were supported by another study, which reported significantly higher surface roughness for polished resin composite compared to the one polymerized against Mylar strips (Carlen et al., 2001). Many studies reported that the consequence of using different polishing methods on surface roughness would not reproduce the surface smoothness initially created by a Mylar strip (Ozgünaltay et al., 2003; de Oliveira et al., 2011). However, other studies observed this phenomenon on some resin composite materials, whereas the others showed no significant differences (de Oliveira et al., 2011; Ionescu et al. 2012).

As measurement of surface roughness determined by measurement method, the research protocol for roughness is vital (Karan and Toroglu, 2008). The assessment of roughness using SEM is subjective and descriptive as well as unreliable for quantitative analysis (Winchester, 1991). A contact profilometer with a stylus that moves in line is used for the quantitative investigation of roughness and may induce misconception due to holes on the surface (Tholt de et al., 2006). Other instruments are available such as non-contact optical interferometers and atomic force microscopes (AFM). In this study, contact profilometer was used to measure surface roughness.

The results of this investigation should consider the limitations of the study, including its *in vitro* setting. *In vitro* studies lack reproduction of oral environment, such as saliva, oral mastication and antagonist occlusion, and other factors that can affect the surface roughness of the dental materials. Nevertheless, *in vitro* studies can provide isolated data of some variables with no interference from other factors. Further *in vitro* and *in vivo* studies are required to improve the knowledge of the mechanical behavior of the composite resins with surface sealant application. Thermocycling was performed in this study to simulate some aspects of the oral environment. Another limitation of this study, is the difficulty in standardization of the thickness of the non-filled sealant layer which has been reported to present considerable variation (0-70µm) (Bertrand et al., 2000).

CONCLUSION

Under the experimental conditions and within the limitations of this *in vitro* study, the following conclusions were drawn: All surface roughness values of the control and experimental groups were higher than the plaque accumulation threshold of 0.2μm. The surface roughness of the nano-hybrid resin composite tested in this study showed lowest Ra value when Mylar strip was used with no further finishing or polishing. No significant difference of surface roughness was found between the two surface sealants were applied.

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Conflict of Interest

The authors declare that they have no conflict of interest to declare or financial and non-financial competing interests.

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