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Effect of Surface Sealants and Polishing Time on Composite Surface Roughness and Microhardness

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Clinical Relevance

Application of surface sealants do not improve the surface smoothness and microhardness of the composite resin.

SUMMARY

The objective of this study was to evaluate the effect of surface sealants and polishing delay time on a nanohybrid resin composite roughness and microhardness. Eighty disc specimens were made with a nanohybrid resin (Esthet-X HD, Dentsply). The specimens were divided into two groups (n=40) according to polishing time: immediate, after 10 minutes; delayed, after 48 hours. Each group was subdivided into four groups (n=10), according to the surface treatment: CG, control–rubber points (Jiffy Polishers, Ultradent); PP, rubber points + surface sealant (PermaSeal, Ultradent); PF, rubber points + surface sealant (Fortify, Bisco); PB, rubber points + surface sealant (BisCover, Bisco). Surface roughness (R_a) and microhardness (50 g/15 seconds) were measured. Surface morphology was analyzed by scanning electron microscopy and atomic force microscopy. The data were analyzed statistically using one-way analysis of variance and the Games-Howell *post hoc* test (α=0.05). PermaSeal roughness (G2) in the delayed polishing group was significantly higher (*p*=0.00) than that of the other groups. No difference was observed among the groups between immediate and delayed polishing (*p*=1.00), except for PermaSeal (*p*=0.00). Moreover, PermaSeal showed the lowest microhardness values (*p*=0.00) for immediate polishing. Microhardness was higher at delayed polishing for all the surface treatments (*p*=0.00) except Fortify (*p*=0.73). Surface smoothness similar to polishing with rubber points was achieved when surface sealants were used, except for PermaSeal surface sealant, which

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resulted in a less smooth resin composite surface. However, surface sealant application did not significantly improve composite resin microhardness.

INTRODUCTION

The finalization of a composite resin restoration on either anterior or posterior teeth implies applying finishing and polishing steps.[1] This procedure is essential to maintaining marginal integrity,[2] esthetics,[3] longevity of the restorations,[4] oral health,[5,6] comfort of the patient,[2,7,8] and reduced pigmentation and wear.[9] Therefore, negligence during execution of the restoration may result in exposure of restoration margins, leading to microleakage,[10,11] caries recurrence, greater susceptibility to surface staining,[1] decreased wear resistance of the material,[12] and greater accumulation of plaque, leading to gingival irritation[13] and thus contributing to greater patient discomfort.[14,15]

The technique of finishing and polishing a restoration seeks to maintain a proper anatomy by removing small excesses and thus obtain a smooth surface that provides adequate light reflection.[2,16-18] These procedures can be achieved with rubber points, diamond burs, sandpaper discs and strips, and polishing pastes[2,19-22] and usually consist of three to four steps.[23-27] Restorations carried out carefully achieve a result that requires minimal finishing and that obtains smooth and contiguous edges of the tooth structure.[2] For a restoration to be imperceptible, the surface should be similar to enamel in terms of brightness and texture. These characteristics are directly related to the surface roughness of the restorative material.[28-32]

In addition, the mechanical properties of the composite, such as microhardness and flexural strength, are essential for the material to resist masticatory forces and have greater longevity. Microhardness is directly related to the depth of cure of the restorative material.[33,34] The lower the microhardness of a resin, the more susceptible the material is to forming grooves and surface defects, which can lower the resistance and cause premature failure of the restoration.[35-38]

To this end, surface sealants were developed to improve the final appearance of the restoration.[39] These sealants consist of fluid resins with little or no filler, which are applied to the surface of composite resins or glass ionomers after the finishing and polishing step.[40-42] Their application fills irregularities, making the restoration smoother and brighter and promoting improved marginal sealing and consequent reduced microleakage.[41,43-45] Surface sealant may be applied on all composite restorations, including temporary acrylic resin restorations.[39,46]

Another important issue is the optimal time for performing the polishing of composite restorations. There is still controversy in the literature. It is known that immediate polishing can compromise the initial marginal sealing of the restoration; however, marginal sealing may become better with higher hygroscopic expansion of the material in contact with the oral fluid.[10] This probably compensates for damage caused by immediate polishing.[5,11] In addition, some authors have shown that higher surface smoothness, higher microhardness,[23] and lowest microleakage[5] can be achieved when the polishing is performed immediately after photoactivation.

Therefore, this study aimed at determining the effect of three different surface sealants and polishing delay time on the surface roughness and microhardness of a nanohybrid resin. The null hypothesis tested was that the application of the sealing surface 1) would not alter the surface roughness of the composite, 2) would not alter the composite microhardness, and 3) the polishing period would not influence the composite surface roughness or microhardness.

METHODS AND MATERIALS

One polishing system and three different surface sealants for resin composite were used in this study. The polishing composite system consisted of rubber polishers for abrasive composite polishing (Jiffy Composite Adjusters and Polishers, Ultradent, South Jordan, UT, USA). The polishers are flame-shaped and available in three grain sizes. The surface sealants evaluated were PermaSeal (Ultradent), Fortify (Bisco Inc, Schaumburg, IL, USA), and BisCover (Bisco Inc). A nanohybrid composite was used (Esthet-X HD, Dentsply Caulk, Milford, DE, USA). The composition of the materials used is described according to the manufacturer's information (Table 1). Light-emitting-diode-based photocuring (Translux Blue, Heraeus Kulzer, Hanau, Germany) was used with a light intensity of 876 mW/cm^2.

A total of 80 composite discs (Esthet-X HD, Dentsply), 12 mm in diameter and 2.5 mm in height, were fabricated in a custom metallic matrix. The specimens were made by inserting two increments of composite into a metal matrix. A glass slide (1.1 mm) and polyester strip were positioned at both ends of

Table 1: *Materials and instruments used.*

Commercial Name	Composition	Application Mode	Manufacturer
Jiffy Polishers	Bowls, discs, or abrasive rubber butts, impregnated with silicon carbide particles and aluminum oxide	In descending order of abrasiveness, rinsing between the point of change	Ultradent Inc
PermaSeal	Bisphenol A glycidyl ether dimethacrylate, triethylene glycol dimethacrylate, initiators	Initial polishing, 37% phosphoric acid application for 20 seconds, wash, dry, spread the product on the surface, soft air jets, and polymerization for 20 seconds	Ultradent Inc
Fortify	Urethane dimethacrylate, bisphenol A dimethacrylate, ethoxylated	Initial polishing, 37% phosphoric acid application for 20 seconds, wash, dry, apply the product using rubbing movements, soft jets of air, and polymerize for 10 seconds	Bisco Inc
BisCover	Bisphenol A ethoxylate dimethacrylate, acrylate urethane ester, polyethylene glycol acrylate	Polishing, 37% phosphoric acid application for 15 seconds, wash, dry, apply the product in one direction, once, without rubbing, wait 15 seconds, and polymerize for 30 seconds	Bisco Inc
Esthet-X HD	Bisphenol A glycidyl methacrylate (Bis-GMA), bisphenol A ethoxylate (Bis-EMA), and triethylene glycol dimethacrylate (TEGDMA), camphorquinone, photoinitiator, stabilizer, pigments and glass fluoroborosilicate barium; particles from 0.04 to 2.5 μm, with a mean of 0.6-0.8 μm	Increments up to 2 mm and light cure for 20 seconds, finishing with diamond butts and polishing with cups, discs, or candle flames	Dentsply

the matrix and pressed digitally to promote the flow of excess material and to obtain a flat surface. The curing was performed according to the manufacturer's instructions, and the specimens were kept dry and at room temperature. In addition, the surface of all specimens was polished with a metal device (DP-10, Panambra, São Paulo, SP, Brazil), using SiC #1200 sandpaper under constant irrigation for 10 seconds, to ultimately obtain a flat stable surface.

The specimens were randomly divided into two groups (n=40), according to the time elapsing from preparation to polishing: immediate polishing (10 minutes after preparation of specimens) or delayed polishing (48 hours after preparation of the specimens). Each group was subdivided into four groups (n=10), according to the surface treatment used: CG, control group with polishing with abrasive sequential rubber points of decreasing grain (Jiffy polishers, Ultradent); PP, rubber points + surface sealant (PermaSeal, Ultradent); PF, rubber points + surface sealant (Fortify, Bisco Inc); PB, rubber points + surface sealant (BisCover, Bisco Inc). The group consisting only of polishing with rubber points was used as the control for both immediate and delayed polishing periods. The specimens in the delayed polishing group were stored in distilled water at 37°C for 48 hours before applying the surface treatment.

A new polishing instrument was used after polishing three specimens for all groups. The polishing time for each instrument was standardized at 30 seconds; the pressure on the surface of the composite was applied intermittently and determined by the operator. After each application of the polishing instrument, the surface of the specimens was cleaned with an air/water spray for 15 seconds. Surface sealants were applied to the surface of the specimens according to the manufacturers' recommendations, which advocate prior polishing. The surface roughness was measured for all 10 specimens of each group, using a Portable Digital Surface Roughness Tester (PR-100, Instrutherm, São Paulo, SP, Brazil), according to the Japan Industrial Standard (B 0601, 1994), to obtain the arithmetic average roughness parameter (R_a). Three consecutive measurements were made at different regions of each specimen, turning the specimen 90° for each measurement. The device was operated with a 0.8-mm cutoff, a 0.1-mm/s read speed, and a 4-mm measuring path. The mean values obtained were subjected to statistical analysis. The Vickers microhardness (VHN) was measured on all 10 specimens of each group, using a microdurometer (HMV 2 version 1.23, Shimadzu, Japan). Four indentations were performed on each sample, with a 50 gm load for 15 seconds, measured according to each quadrant of the specimen. The average individual microhardness value for each specimen was used for statistical analysis.

The analysis of surface morphology was performed on one specimen for each surface treatment, only for

Table 2: *Description and comparison of R_a and VHN of the evaluated groups*

Surface Treatment	Polishing Time Point	Roughness	Microhardness
Polishing (control)	Immediate	0.34 (0.10)A,B	52.30 (2.87)b,c
	Delayed	0.33 (0.06)A,B	69.75 (4.57)d
PermaSeal	Immediate	0.30 (0.05)A	33.01 (7.83)a
	Delayed	0.61 (0.08)C	57.03 (9.46)b,c
Fortify	Immediate	0.38 (0.10)A,B	49.39 (3.14)b
	Delayed	0.40 (0.12)A,B	53.88 (6.12)b,c
BisCover	Immediate	0.42 (0.05)B	49.15 (5.44)b
	Delayed	0.31 (0.08)A,B	58.59 (6.65)c

Similar capital (Ra) and lowercase letter (VHN) at the same column are not statistically significant (p>0.05).

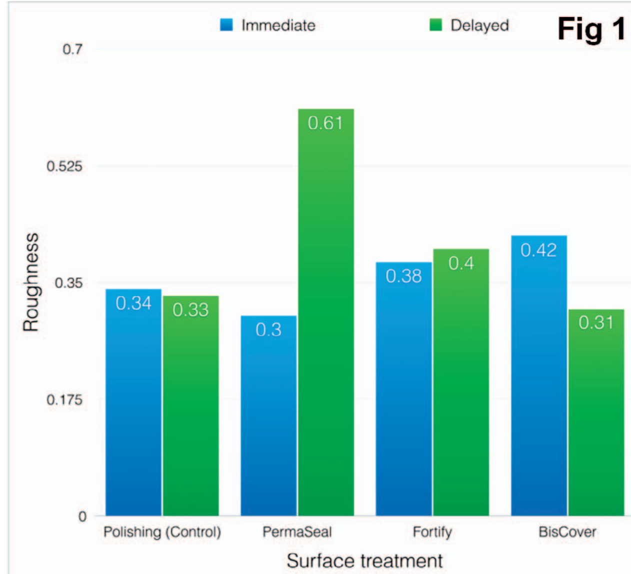
the delayed polishing period, by scanning electron microscopy (SEM) and atomic force microscopy (AFM).[47] SEM observation was enabled by coating each sample with gold-palladium alloy, and the morphologic examination was performed with 500× magnification. For AFM analysis, the specimens were dried and observed under the microscope to obtain images relating to a surface sample area of 15 µm.

The R_a and VHN data were analyzed by one-way analysis of variance (ANOVA) and *post hoc* Games-Howell. All analyses were conducted at a significance level of 5% ($p \leq 0.05$), using SPSS statistical software (version 20.0 for Mac, SPSS Inc, Armonk, North Castle, New York, USA).

RESULTS

ANOVA showed statistically significant differences between groups with regard to R_a. The PermaSeal R_a values for delayed polishing were significantly higher compared with all the other groups ($p=0.00$). There was no difference between immediate and delayed polishing for all the groups ($p=1.00$), except PermaSeal ($p=0.00$; Table 2; Figure 1).

Regarding the VHN test, ANOVA showed statistically significant differences between groups. The PermaSeal group showed significantly lower values for immediate polishing, a result statistically different from the other groups ($p=0.00$). The highest microhardness values were obtained when only polishing points (control) and delayed polishing were performed, a result statistically different from the other groups ($p=0.00$). Moreover, the microhardness was lower at immediate polishing for all the surface treatments ($p=0.00$) except Fortify, which showed no



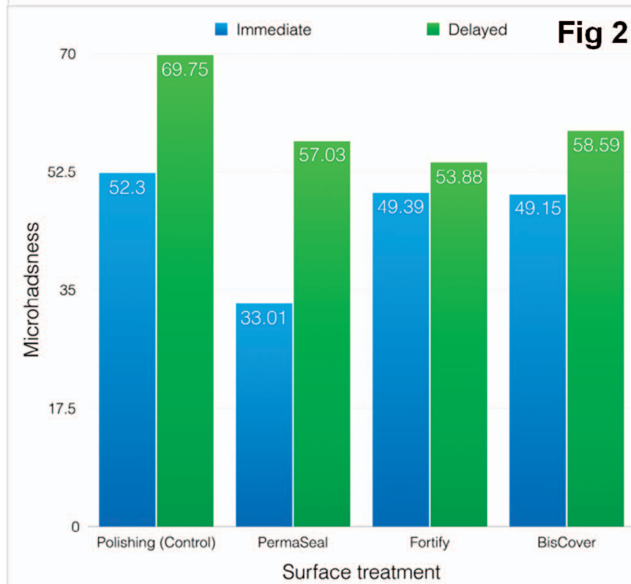


Figure 1. *Graphical representation in the form of vertical bars of the arithmetic average R_a of the evaluated groups.*
Figure 2. *Graphical representation in the form of vertical bars of the arithmetic averages of VHN of the evaluated groups.*

difference between immediate and delayed polishing ($p=0.73$; Table 2; Figure 2).

In the surface morphology analysis by SEM, ripples/waves were observed on the surface of PermaSeal (Figure 3B) and Fortify (Figure 3C), but more frequently on the surface of PermaSeal. BisCover and Polishing points (control) had fewer surface irregularities. Observing the surface morphology using AFM, the most irregular surfaces were observed for Fortify (Figure 4C) and BisCover (Figure 4D).

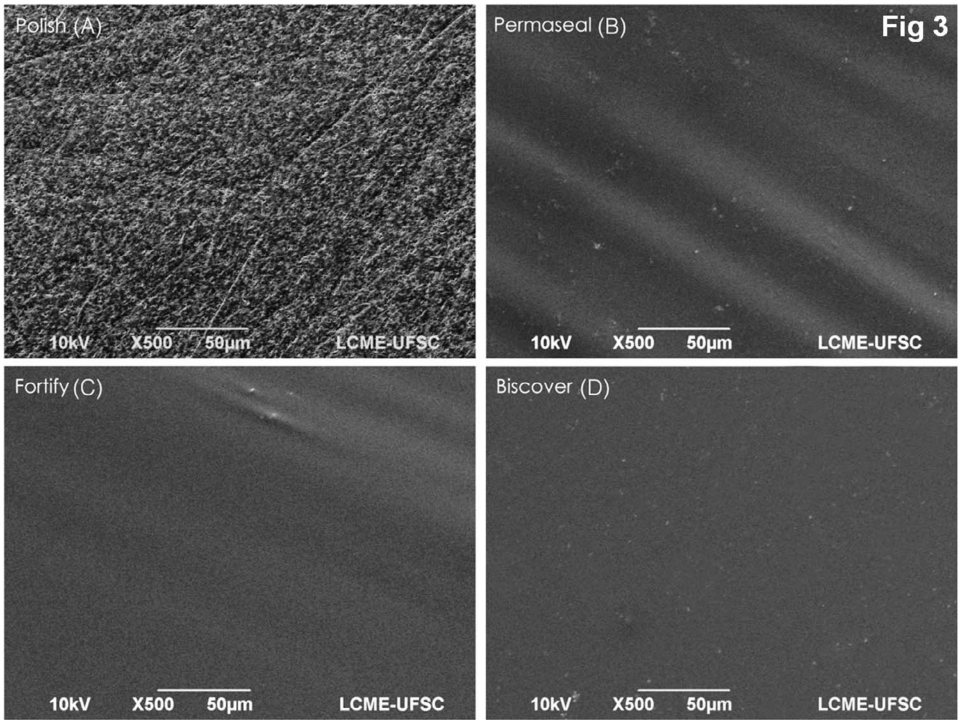


Figure 3. *SEM observation of delayed polishing and application of sealants (500× magnification): A, polish; B, Permaseal; C, Fortify; D, Biscover.*

DISCUSSION

According to the results of this study, the null hypotheses were partially rejected, because there was some difference among the sealants tested in relation to surface roughness, microhardness, and polishing time.

In this study, the control group showed no statistical difference between immediate and delayed polishing regarding surface roughness, similar to previous studies.[21,22] However, microhardness was higher for delayed polishing for this same group, which is in line with other studies that showed increased microhardness for delayed polishing.[24,33] Despite the controversial results in regard to time point, there is consensus among the studies that the influence of immediate or delayed polishing on the physical and mechanical properties of the composite

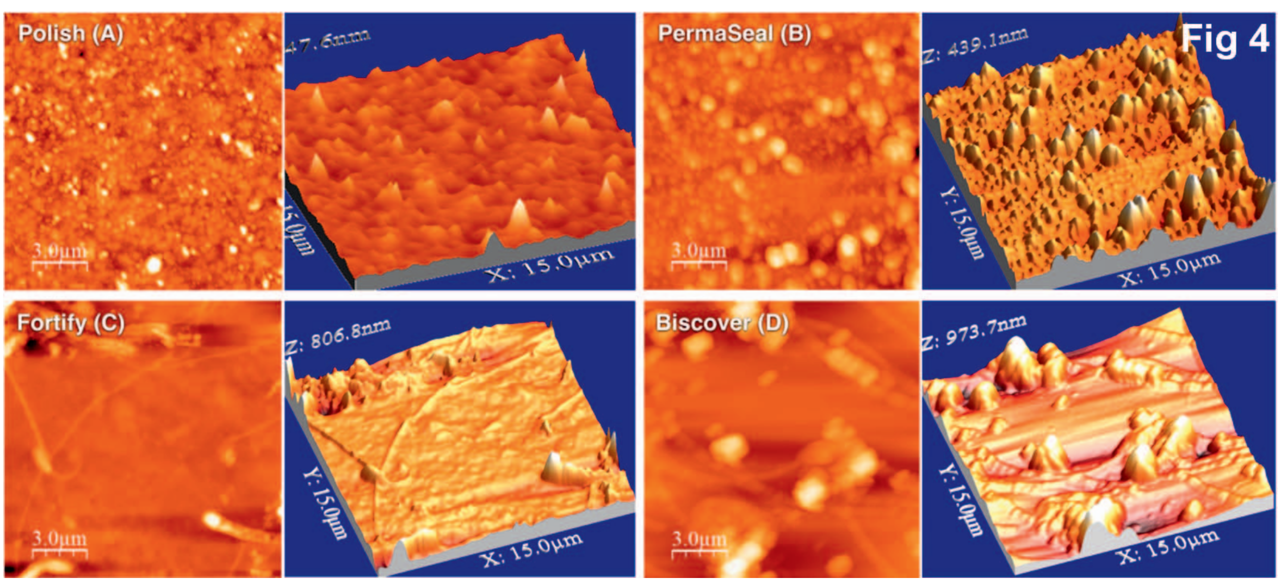


Figure 4. *AFM images of delayed polishing and application of sealants (3.0-µm magnification): A, polish; B, Permaseal; C, Fortify; D, Biscover.*

is materials and time dependent.[23,24,33] Nonetheless, there are limitations to comparing the results of previous studies with this study, due to variations in the materials and methods used.

Some similar studies demonstrate that the application of sealants results in lower roughness values (R_a) compared with when only polishing is performed.[25,39] These results differ from those found in this study, in which there were no significant roughness-related differences between polishing and application of surface sealants. This difference between the studies can be attributed to the fact that, in this study, the sealants were applied to prepolished composite, unlike the studies cited.

Despite the use of the same technique of finishing and polishing, different composites have different patterns of surface smoothness.[23,26] This occurs because, during the procedure, the organic matrix wears away more easily than the filler particles, which remain exposed on the surface and are more prone to becoming detached from the material.[23,26,27] The loss of these particles results in surface defects in the material, making it more irregular,[23] as seen in Figures 3A and 4A. Because the sealants are highly fluid[40,41] and the materials are applied in a thin layer on the composite, the sealants probably penetrated the surface defects of the composite resin, thus maintaining the microtopography of the previously existing surface. This probable occurrence may explain the statistical similarity of most sealants polished only with rubber points.

In this study, when delayed polishing was performed and PermaSeal was used, a rougher surface was obtained, differing from the other groups, where the intragroup results were similar. When PermaSeal is rubbed vigorously on the surface of the composite with the applicator tip provided by the manufacturer (Black FX Micro Tip), a higher incorporation of air bubbles can occur in the sealant.[42] The presence of bubbles and application of air jets prior to curing can create surface irregularities, which can be seen in Figure 3B. The presence of these factors may have contributed to increasing the roughness observed in this group, which differed from the others at the same polishing time point. The same surface topography can be observed in Fortify, but with lower intensity (Figure 3C). This material is also applied vigorously to the surface of the composite resin and requires an air jet prior to curing. In addition, the two SEM images taken for Fortify differ from the images obtained for BisCover (Figure 3D), which is applied in a single layer without friction and without the application of an air jet. The SEM images differed from the AFM images, probably because the AFM image provided a view of a nanometric area of the sample[47] and was therefore not representative of the whole surface morphology.

The surface roughness obtained in all the groups was higher than the surface roughness limit for the adhesion of bacteria, which is 0.2 μm.[8] This situation may promote the accumulation of plaque, which predisposes the restorations to decay and/or causes gum inflammation. However, with the exception of PermaSeal at the delayed polishing point, the values in the other groups were less than 0.5 μm, which corresponds to the threshold of human perception of composite resin restoration roughness.[6]

It was observed that delayed polishing resulted in a surface with greater microhardness compared with immediate polishing, even with the application of the sealant, as also reported in other studies.[18,24] That is because the monomers continue to be converted into polymers after the initial polymerization, resulting in increased microhardness with the passage of time.[33]

It should be stressed that PermaSeal had the lowest microhardness value for the immediate polishing period, statistically different from the other groups. Similar results were observed in another study, in which PermaSeal had the lowest microhardness values after 10-minute polymerization, compared with BisCover.[40] However, after delayed polishing, PermaSeal had greater microhardness, statistically similar to that of the other sealants. Thus, it can be assumed that immediate polishing impairs microhardness more when PermaSeal is used.

Despite the limitations of this *in vitro* study, sealants can be considered a viable alternative to increase the surface smoothness of composite resin. This being the case, further clinical research is needed to endorse the results of the present study.

CONCLUSIONS

Despite the limitations of this study, the following conclusions were made: 1) it is possible to obtain surface roughness similar to polishing with rubber points when surface sealants are used, except in the case of PermaSeal; 2) application of a surface sealant does not significantly improve the microhardness of the composite resin; and 3) the microhardness values were higher for the delayed polishing period, except for Fortify. In contrast, the polishing delay time did not influence the surface roughness, regardless of the surface treatment applied.

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Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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