INTRODUCTION

The surface quality of resin composite restorations is one of the most important factors determining their clinical success in the oral cavity. The natural gloss and final esthetic of the restoration, abrasivity and wear kinetics\(^1\); improved mechanical properties\(^2\); and tactile perception and comfort of the patient\(^9\) are highly associated with surface properties. Moreover, smooth surfaces and margins reduce the risk of biofilm adhesion and maturation, recurrent caries, gingival irritation\(^{48}\) and staining\(^9\).

The smoothest possible surface is obtained when the resin composite polymerizes against a Mylar matrix without subsequent finishing or polishing\(^{10,11}\); however, such a surface has a resin-rich layer, poor mechanical properties, is susceptible to increased wear and discoloration and should be eliminated\(^{2,9}\). In addition, in clinical situations, most restorations need to be adjusted to their final shape. Thus, finishing and polishing of restorations are crucial.

Commercially available finishing and polishing systems have a wide variety of abrasives, such as silicon carbide, aluminum oxide, diamond and silicon dioxide, which are impregnated in rubber and aluminum oxide or diamond silica-coated abrasive discs that use one, two or multiple application steps\(^{12}\). In several \textit{in vitro} studies, multi-step aluminum-oxide discs exhibited the smoothest surfaces\(^{13-16}\); however, due to their geometry, the anatomically contoured surfaces of composite restorations are difficult to polish\(^{23}\). In contrast, one- and two-step polishing systems that use elastomeric or rubberized polishers in various shapes, sizes and dimensions come into direct contact with the restoration surface and complement the access limitations of the aluminum-oxide discs. Two-step polishing systems that use diamond abrasive-impregnated polishers appear to be particularly effective in achieving high surface smoothness similar to\(^{2,17}\) or better than that achieved by the multi-step aluminum-oxide-coated abrasive disc systems\(^{18}\). Thus, the success of the one-step polishing systems was found to be closely related to the initial finishing regimen\(^{18}\).

The composition of resin composites has evolved significantly since the materials were first introduced to dentistry more than 50 years ago\(^{19}\). Modification of filler concepts, reduction of the filler particle size and increase in filler loading seem to be the most significant changes\(^{20}\). Apart from traditional hybrid and micro-hybrid composites, nano-fill and nano-hybrid composites represent the state of the art in terms of filler formulation\(^{19}\). Regarding surface roughness after polishing, nano-hybrids may not perform like nano-filled composites\(^{17,21}\), but their performance is similar to or slightly better than that of micro-hybrids\(^{21}\). To our knowledge, there is no comparison in the literature of surface roughness among the micro-hybrid, nano-hybrid and supra-nanofilled composites polished with two-step polishing systems. Therefore, the purpose of this \textit{in vitro} study was to investigate the surface roughness and the morphology of two supra-nanofilled (Estelite Omega, Estelite \textit{Σ} Quick), two micro-hybrid (Esthet.X HD, G-aenial) and three nano-hybrid (Clearfil Majesty Posterior, Charisma Diamond, Beautifil II) resin composites polished with aluminum-oxide/diamond-abrasive-impregnated (Enhance/PoGo) and diamond-abrasive-impregnated (Venus Supra) two-step polishing systems. The null hypotheses of this study
are 1) there would be no significant differences in the surface roughness among the two polishing systems for each composite; and 2) there would be no significant difference in the surface roughness among the different types of composites for each polishing system.

MATERIALS AND METHODS

Seven commercially available resin composites, chosen for their different types of filler particles: two supra-nanofilled [Estelite Omega (EO; Tokuyama Dental Co, Tokyo, Japan), Estelite ∑ Quick (EQ; Tokuyama Dental Co, Tokyo, Japan)], two micro-hybrid [Esthet.X HD (EHD; Dentsply Caulk, Milford, DE, USA), G-aenial (GAE; GC Dental Products Corp., Aichi, Japan)] and three nano-hybrid [Clearfil Majesty Posterior (CMP; Kuraray Medical Co, Tokyo, Japan), Charisma Diamond (CD; Heraeus Kulzer, Hanau, Germany), Beatiful II (BII; Shofu Co, Kyoto, Japan)] and aluminum oxide/diamond-abrasive-impregnated (Enhance/PoGo; Dentsply Caulk, Milford, DE, USA) and diamond-abrasive-impregnated (Venus Supra; Heraeus Kulzer, Hanau, Germany) two-step polishing systems were used in this study. The properties of the resin composites and the composition of the two-step polishing systems and their application modes are listed in Tables 1 and 2. A total of 210 composite discs (shade A2), 30 from each resin composite, 5-mm in diameter and 2-mm-thick were prepared. Each material was inserted into a cylindrical metal mold and pressed between two opposing Mylar matrices, which were then covered with a glass slide 1 mm thick to extrude excess material and to produce a smooth, flat surface. The specimens were then polymerized through the glass slide using a halogen curing unit (Optilux 501, Kerr, CA, USA) according to the manufacturer’s instructions with a light intensity...
of 500 mW/cm². Following storage in distilled water for 24 h at 37°C, the specimens in each composite group were randomly divided into three subgroups (n=10); 1) Mylar matrix group (control), 2) Enhance/PoGo group, and 3) Venus Supra group.

The Mylar matrix group received no polishing treatment. In the Enhance/PoGo group, the specimens were first wet-polished for 20 s with Enhance at a low speed (10,000 rpm), thoroughly rinsed with water for 10 s to remove debris and then air-dried for 5 s. Then, the specimens were wet-polished with PoGo at 10,000 rpm for 40 s, rinsed for 10 s and air-dried for 5 s. In the Venus Supra group, the specimens were wet-polished with a pre-polisher for 20 s at low speed (7,500 rpm), thoroughly rinsed with water for 10 s and then high-gloss polished for 40 s at low speed (7,500 rpm). The same protocol was repeated for rinsing and drying.

Disc-shaped polishers were preferred with both finishing treatments because they come into direct contact with the surfaces of the specimens. Each polisher was used only once, with the same low-speed hand silicon carbide (SiC) paper for 30 s.

Pre-roughening treatments because they come into direct contact with the surfaces of the specimens. Each polisher was standardized using a polishing machine (Buehler, Hanau, Germany) at a rotation speed of 400 rpm, and constant moving action was applied under water coolant to prevent heat build-up. A new SiC paper was used for each specimen and discarded after each application. All specimen preparation, finishing and polishing procedures were performed by the same operator. The surface roughness of the specimens was evaluated with a profilometer (Perthometer M1 Mahr, Göttingen, Germany). For each specimen, five measurements at different locations and in different directions, with a cut-off length of 0.25 mm, a tracing length of 0.8 mm and a stylus speed of 0.1 mm/s, were recorded, and the roughness value (Ra; µm) was calculated as the average of these five readings. The second operator, who was blind to the polishing systems, as well as to the type of composite, performed all of the roughness evaluations. During the experimental period, the surface-roughness tester was periodically calibrated (Mahr GmbH, Göttingen, Germany).

### Statistical analysis

The effect of polishing systems on the surface roughness in each composite group was statistically analyzed using one-way ANOVA, followed by Tukey’s test. The comparison of the composites in terms of different polishing systems was performed by two-way ANOVA and a post-hoc Bonferroni test at a significance level of p<0.05 (SPSS, 20.0; Chicago, IL, USA).

**Scanning electron (SEM) and atomic force (AFM) microscopy**

For surface characterization, two representative specimens from each group with Ra values close to the mean values were selected. One specimen was coated with gold and examined under a commercial atomic force microscope (Veeco metrology Group Inc., Santa Barbara, CA, USA), using the contact mode. Cantilevers with a constant spring of 0.1 N/m and Nanoprobe SPM Tips, OTR 8-35 type were used. Deflection and height-mode images were obtained simultaneously with a resolution of 512×512 pixels. Images were acquired in 10×10-µm sizes and analyzed with specific software (Nanoscope v616r1, Veeco Metrology Inc., Santa Barbara, CA, USA and WSxM 4.0 Develop 11.1, Nanotec Electronica S.L, Trea Cantas, Spain).

### RESULTS

Mean surface-roughness values (Ra; µm), standard deviations (±SD), and statistical analysis of the control and polished resin composites are shown in Table 3.

In each composite group, the smoothest surfaces were obtained in the Mylar matrix group (control), whereas both polishing systems created significantly rougher surfaces than their corresponding control groups (p<0.05). However, when the Mylar matrix groups were compared, no significant differences were found among the composites (p>0.05).

Results of the two-way ANOVA indicated that the composite (p<0.0001), the polishing system (p<0.0001), and the interaction between them were statistically significant (p<0.0001). Regarding the Enhance/PoGo polishing system, significantly smoother surfaces (p<0.05) were obtained with the supra-nanofilled composites EO, EQ and the micro-hybrid composite EHD, which were not significantly different from each
Table 3  Mean surface roughness values (Ra, µm), standard deviations (±SD) and statistical analysis of the control and polished supra-nanofilled, micro-hybrid and nano-hybrid composites

| Materials             | Control      | Two-step Polishing Systems |
|-----------------------|--------------|----------------------------|
|                       | Mylar Matrix | Enhance/PoGo               | Venus Supra               |
| Estelite Omega (EO)   | 0.027±(0.003) | 0.063±(0.010)             | 0.078±(0.009)             |
| Esthetix Quick (EQ)   | 0.025±(0.003) | 0.060±(0.004)             | 0.074±(0.004)             |
| G-aenial (GAE)        | 0.023±(0.002) | 0.060±(0.004)             | 0.102±(0.022)             |
| Clearfil Majesty Posterior (CMP) | 0.027±(0.003) | 0.085±(0.011)             | 0.078±(0.013)             |
| Charisma Diamond (CD) | 0.035±(0.003) | 0.120±(0.010)             | 0.147±(0.024)             |
| Beautifil II (BII)    | 0.039±(0.004) | 0.109±(0.009)             | 0.112±(0.01)              |

Different superscript letters in each column and different capital letters in each row indicate significant differences at p<0.05.

Other (p>0.05). With this polishing system, the nano-hybrids CMP and BII exhibited significantly the highest Ra values (p<0.05), which did not significantly differ from each other (p>0.05). In addition, the nano-hybrid CD and the micro-hybrid GAE exhibited intermediate Ra values that were significantly different from both the smoothest and roughest composites (p<0.05).

With the Venus Supra polishing system, the supra-nanofilled composites EO, EQ and the micro-hybrid composite GAE showed significantly lower Ra values than any other composites, (p<0.05), and the difference between them was not significant (p>0.05). There were no significant differences between the Ra values of the nano-hybrids CMP and BII (p>0.05), which exhibited the roughest surfaces of all of the composites tested (p<0.001). The surface roughnesses of the micro-hybrid EHD and the nano-hybrid CD were significantly different from those of the roughest and smoothest composites (p<0.05), but no significant difference was observed between them (p>0.05).

Except for the micro-hybrid composite GAE (p=0.332) and the nano-hybrid composites CD (p=0.616) and B II (p=0.411), the differences in surface roughness between the Enhance/PoGo and Venus Supra polishing systems in each composite group were significant, showing smoother surfaces for the Enhance/PoGo polishing system (p<0.05).

Atomic force microscopy (AFM) observations
The Mylar matrix (control) groups showed uniform surfaces, with some matrix imperfections (Figs. 2a, 4a, 6a, 8a, 10a, 12a, 14a). A small number of air voids were evident on supra-nanofilled composites EO and EQ (Figs. 2a and 4a respectively) and the micro-hybrid composites CMP, CD and BII control groups (Figs. 10a, 12a and 14a, respectively) which were not evident on SEM. For all composites, polished specimens generally presented a more irregular topography than their control groups.

The Enhance/PoGo polishing system created slight uniform irregularities on the supra-nano-filled composites EO and EQ (Figs. 2b and 4b, respectively) and the micro-hybrid composite EHD (Fig. 6b). On the other hand, the Venus Supra polishing system created several narrow scratch lines on EO (Fig. 2c), undulating surface topography on EQ (Fig. 4c) and deep scratch lines on EHD (Fig. 6c). The micro-hybrid composite GAE exhibited deep and superficial scratch lines on AFM with the Enhance/PoGo (Fig. 8b) and...
Venus Supra (Fig. 8c) polishing systems, which were not evident on SEM. Regarding the nano-hybrid composite CMP, both polishing systems revealed resin abrasion between the fillers, along with deep voids that represent debonded fillers (Figs. 10b and 10c). Undulating surface topography on CD was observed with both of the polishing systems (Figs. 12b and 12c); however, debonded fillers were evident only after polishing with Venus Supra (Fig. 12c). Irregular surface topography due to the protrusion of fillers was observed on BII with Enhance/
PoGo (Fig. 14b), whereas deep voids representing debonded fillers were evident after polishing with Venus Supra (Fig. 14c).

DISCUSSION

Surface roughness is the most frequently used parameter in assessing the surface quality of different restorative materials. Due to the limitations of the
quantitative measurement methods, the results are often verified qualitatively with scanning electron microscopy (SEM) to demonstrate shape and contour changes that may not be shown by the profilometer. However, SEM also has limitations in defining the surface topography because it does not allow for visualization of the three-dimensional surface texture. Therefore, atomic force microscopy (AFM) has recently been employed in dental-materials research to provide three-dimensional detailed topographical images of
The fabrication, shape and dimension of the specimens, inter-individual differences between various operators\textsuperscript{26}, polishing time, applied force, rotation speed of the handpiece and water spray can significantly affect the results\textsuperscript{22}. Pre-roughening with diamond burs results in a non-homogeneous surface texture\textsuperscript{22} and creates different surface roughnesses on different materials\textsuperscript{22,27}. Therefore, in this study, pre-roughening was standardized using a polishing machine with 320-grit SIC paper that generated roughness similar to that created with a 30/40-μm diamond bur, which represents clinical contouring and finishing\textsuperscript{22}. With both polishing systems, according to the manufacturer’s instructions, the finishing step was accomplished in 20 s and the polishing step was completed in 40 s. To eliminate inter-individual differences in manual polishing that could substantially affect the results, all of the finishing and polishing procedures were performed by the same operator. All of the roughness evaluations were performed by a second operator who was blind both to the materials and to the polishing systems.

Several studies have demonstrated that the smoothest composite surfaces were achieved with the Mylar matrix; however, clinicians seldom leave composite restorations unfinished and unpolished, which would significantly increase the surface roughness\textsuperscript{10,11}. These findings are in agreement with the results of this study. Both of the two-step polishing systems created higher Ra values than for those same composites with the Mylar matrix-finished surfaces; however, the Mylar matrix-created surfaces are less characteristic of the bulk material used, and the surface roughness is mostly related to the Mylar itself\textsuperscript{28}. Comparison of the Mylar matrix groups among the tested composites supports the hypothesis, showing no significant differences between the composites (\(p>0.05\)). Consistent with the qualitative results, SEM observations also revealed homogeneous surface textures, with some matrix imperfections and a resin-rich layer (Figs. 1a, 3a, 5a, 7a, 9a, 11a, 13a), whereas AFM detected a low surface profile (Figs. 2a, 4a, 6a, 8a, 10a, 12a, 14a) for all tested composites.

Based on the results, the first null hypothesis that there would be no significant differences in surface roughness between two two-step polishing systems for each composite was accepted only for the micro-hybrid GAE (\(p=0.332\)) and the nano-hybrids CD (\(p=0.616\)) and B II (\(p=0.411\)). Regarding supra-nanofilled composites EO and EQ, micro-hybrid EHD and the nano-hybrid CMP, the differences between the Enhance/PoGo and Venus Supra polishing systems in each composite group were significant, showing smoother surfaces for Enhance/PoGo (\(p<0.05\)). PoGo is a one-step polishing system and can be used without any finishing treatment; however, according to the manufacturer, finishing can be accomplished with Al\textsubscript{2}O\textsubscript{3}-abrasive-impregnated Enhance and polishing can be performed with diamond-impregnated PoGo. For that reason, in this study, Enhance/PoGo was classified as a two-step
polishing system. On the other hand, Venus Supra is a two-step polishing system that consists of a diamond-impregnated pre-polisher and a diamond-impregnated high-gloss polisher. The efficiency of finishing/polishing systems is related to the type of abrasive material, particle size, hardness, shape of the abrasive and the speed and pressure used during application. Therefore, for both of the two-step polishing systems, disc-shaped polishers were preferred because they come into direct contact with the specimens. During application, the time was fixed at 20 s for the first step and 40 s for the second step, whereas the rotation speed was set according to the manufacturer's instructions. As the second step of the two-step polishing systems (PoGo and Venus Supra high gloss polisher) involves diamond-impregnated polishers with nearly the same grit size (7 µm and 4–8 µm, respectively), the differences in Ra values could be explained either by the quantity of abrasives used in the instrument or by the type of abrasive material used for the finishing. Enhance contains an Al₂O₃ abrasive (40 µm), and the Venus Supra pre-polisher is diamond-impregnated (40 µm). The hardness of the Al₂O₃ abrasive is significantly higher than that of most of the filler particles used in resin composites. This difference may lead to equal abrasion of the filler particles with the resin matrix, leaving a smooth surface. On the other hand, diamond is harder than Al₂O₃; therefore, it may cause deeper scratches on the composite’s surfaces, resulting in higher roughness. This result is consistent with the SEM and AFM observations of the supra-nanofilled composites EO (Figs. 1b and 2b) and EQ (Figs. 3b and 4b) and the micro-hybrid composite EHD (Figs. 5b and 6b), on which Enhance/PoGo created a smoother surface topography than Venus Supra. Similarly, Endo et al. and Jung et al. described detrimental surface alteration effect of relatively large diamond particles in finishing instruments on resin composites.

In addition to the finishing and polishing treatments, the surface roughness of the composites is also influenced by several material factors, such as the type, shape, size and distribution of the inorganic fillers. The surface roughness has been decreased by decreasing the filler size and increasing the filler content. Use of a finer filler size results in less interparticle spacing, more protection of the softer resin matrix and less filler plucking; however, during polishing, it is still difficult to avoid the occurrence of irregularities at the interface between the filler particles and the resin because they have different levels of hardness. According to the results of this study, the second null hypothesis, that there would be no significant differences in surface roughness among the different types of composite for each polishing system, was rejected. With both polishing systems, the supra-nanofilled composites EO and EQ presented the lowest Ra values, whereas the nano-hybrids CMP, CD and BII showed significantly higher values (p<0.05). The Ra data after polishing correlated well with the mean filler size of these materials. The mean filler size of EO and EQ (0.2 µm) was the lowest among the tested materials, which may explain why it yielded the lowest Ra values; nano-hybrid composites with larger filler sizes, e.g., CMP (0.02–1.5 µm), CD (0.6 µm) and BII (0.8 µm) yielded higher Ra values. Another possible explanation for the smoothness of the surfaces achieved with supra-nanofilled composites can be the spherical shape of their fillers. Composites filled with this type of filler have resulted in lower roughness and higher gloss values than nano-hybrid composites filled with irregularly shaped fillers that are similar to the tested nano-hybrid composites (CMP, CD, BII) that contain irregular glass fillers. The differences in surface morphology after polishing between the supra-nanofilled composites and nano-hybrid composites were clearly observed on SEM and AFM. EO and EQ showed smooth surfaces on SEM and lower surface profile on AFM after using Enhance/PoGo (Figs. 1b–2b and 3b–4b, respectively) and presented narrow scratch lines after using Venus Supra (Figs. 1c–2c and 3c–4c, respectively). On the other hand, resin matrix abrasion, filler protrusions and some filler debonding were the characteristic features of the nano-hybrid composites CMP (Figs. 9b, c–10b, c), CD (Figs. 11b, c–12b, c) and BII (Figs. 13b, c–14b, c) with both of the polishing systems. Consistent with the present data, Ergücü et al. and Endo et al. showed higher Ra values and rougher surfaces, that are characterized with protrusion and debonding of fillers, for the nano-hybrids compared to a nano-filled composite.

When the tested nano-hybrids were compared, CMP, CD and BII exhibited similar Ra values with Enhance/PoGo. Similarly, Jung et al. indicated no significant differences between nano-hybrids after polishing with Enhance/PoGo. In contrast, CMP and BII yielded significantly higher Ra values than CD with Venus Supra. Although CMP, CD and BII all contain irregular glass fillers, they differ from each other in terms of other types of fillers, filler loading and type of resin matrix (Table 1). CMP includes glass ceramics and alumina nanofiller and has the highest filler loading (82% vol; 92% wt) among the tested composites. Higher filler content is expected to protect the resin matrix from excessive abrasion, resulting in smoother surfaces; however, fillers that are much harder than the resin matrix may cause prominent matrix abrasion during polishing, which was also observed with the other nano-hybrids. The abrasion of the softer resin matrix may result in a lack of support of the fillers, leading to further filler debonding and roughening of the surface. As shown in SEM and AFM, debonding of the inorganic filler particles was more prominent with CMP (Figs. 9c and 10c) than with CD (Figs. 11c and 12c), which corresponded well to its high surface roughness with Venus Supra. On the other hand, BII comprises surface-reaction-type pre-reacted glass-ionomer filler, with a relatively large mean filler size (0.8 µm) compared to the smaller mean filler size of CD (0.6 µm). The greater Ra values of BII corresponded to the larger fillers that were exposed after polishing with Venus Supra and, consequently, yielded a rougher surface profile (Fig. 14c) than CD (Fig. 12c).
In general, it is difficult to distinguish nano-hybrids from micro-hybrids because nano-hybrids also contain a range of filler sizes. In this study, the micro-hybrid GAE yielded significantly lower Ra values than the nano-hybrids CMP, CD and BII with both of the polishing systems, whereas the micro-hybrid EHD exhibited significantly smoother surfaces than the nano-hybrids only with Enhance/PoGo. In contrast to the nano-hybrids, the micro-hybrids EHD and GAE did not present any filler protrusion or filler debonding on SEM and AFM (Figs. 5b, 6b and 7b, 8b, c). The non-uniform abrasion of the resin matrix and the fillers of the nano-hybrids may explain the difference in roughness between the micro-hybrid and nano-hybrid composites. These results are in accordance with those of Gönülöl and Yılmaz; nano-hybrids exhibited similar or rougher surfaces compared to a micro-hybrid composite using seven different polishing systems.

GAE revealed similar Ra values for both of the polishing systems. Neither resin removal nor filler debonding was observed in SEM and AFM (Figs. 7b, 7c and 8b, 8c, respectively). On the other hand, EHD exhibited significantly rougher surfaces with Venus Supra than with the Enhance/PoGo polishing system, consistent with the observations from the SEM (Figs. 5b and 5c, respectively) and AFM (Figs. 6b and 6c, respectively). The differences in Ra values between these two micro-hybrids were also significant for each polishing system (Table 3). GAE and EHD have almost the same filler loading (62% Vol; 76% Wt and 60% Vol; 77% Wt, respectively). Their differences in roughness can be attributed to the type and size of the inorganic fillers and the type and ultimate degree of cure of the resin matrix. The lower hardness of UDMA-based resins compared to Bis-GMA-based resins has been attributed to differences in their degree of polymerization, molecular rigidity and final strength. Therefore, the incorporation of 2 types of pre-polymerized fillers with relatively lower hardness than the glass fillers and UDMA as a major component of the resin matrix may account for the similar abrasion of the fillers with the resin matrix in GAE.

With both polishing systems, the supra-nanofilled composites EO and EQ behaved similarly to or slightly better than the micro-hybrids EHD and GAE. Micro-hybrids might have been expected to show higher Ra values because of their larger filler sizes (EHD 0.6 µm; GAE 16–17 µm, 16 nm, 850 nm) than the supra-nanofilled composites (0.2 µm). In addition, the smaller, the specific surface areas of spherical fillers require less resin matrix to wet them and thus allow for higher filler loading in EO and EQ than EHD and GAE; however, comparison between these two groups showed no material and polishing system dependent effect.

AFM can provide three-dimensional data on surface topography which cannot be visualized by SEM. Thus, in this study, air voids in control groups of EO, EQ CMP, CD, BII and polishing scratches on GAE were detected on AFM. These features were not visible in the SEM images. The differences between SEM and AFM techniques suggest that AFM can offer more detailed definition of surface topography.

Based on studies using mechanical profilometry devices, the critical threshold Ra value for the simultaneous increase in plaque accumulation is 0.2 µm, whereas a surface roughness of 0.25–0.5 µm can be detected by the patient’s tongue. According to the results, the mean surface roughness achieved with the Enhance/PoGo and Venus Supra polishing systems on the supra-nanofilled, micro-hybrid and nano-hybrid composites were below the clinically acceptable threshold value and were highly satisfactory; however, under the dynamic conditions of the oral environment, an increase in surface roughness is expected. Therefore, further evaluation of the impact of aging on surface roughness is necessary.

CONCLUSION

Under the limitations of this in vitro study, the following may be concluded:

1. Supra-nano spherical filled composites polished with two-step polishing systems created smoother surfaces than nano-hybrid composites and performed similarly to or slightly better than the micro-hybrids.
2. The surface roughness of micro-hybrid and nano-hybrid composites seems to be dependent on materials and polishing systems.
3. An aluminum oxide/diamond-abrasive-impregnated two-step polishing system created smoother surfaces than the diamond-abrasive-impregnated two-step polishing system on supra-nano spherical filled composites.

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REFERENCES

1) Shimane T, Endo K, Zheng JH, Yanagi T, Ohno H. Wear of opposing teeth by posterior composite resins —Evaluation of newly developed wear test methods. Dent Mater J 2010; 29: 713-720.
2) Gordan VV, Patel SB, Barrett AA, Shen C. Effect of surface finishing and storage media on bi-axial flexure strength and microhardness of resin-based composite. Oper Dent 2003; 28: 560-567.
3) Jones CS, Billington RW, Pearson GJ. The influence of surface roughness of oral hard materials to the threshold surface roughness for bacterial plaque retention: a review of the literature. Dent Mater 1997; 13: 258-269.
4) Brambilla E, Cagetti MG, Gagliani M, Fadini L, Garcia-Godoy F, Strohmenger L. Influence of different adhesive restorative materials on mutans streptococci colonization. Am J Dent 2005; 18:173-176.
5) Ono M, Nikaido T, Ikeda M, Imai S, Hanada N, Tagami J, Matin K. Surface properties of resin composites materials relative to biofilm formation. Dent Mater J 2007; 26: 613-
7) McConnell MD, Liu Y, Nowak AP, Pilch S, Masters JG, Composto RJ. Bacterial plaque retention on oral hard materials: effect of surface roughness, surface composition and physisorbed polycarboxylate. J Biomed Mater Res A 2010; 92: 1518-1527.

8) Quirynen M, Bollen CM. The influence of surface roughness and surface-free energy on supra- and subgingival plaque formation in man. A review of the literature. J Clin Periodontol 1995; 22: 1-14.

9) Ergüçü Z, Türkün LS, Aladağ A. Color stability of nanocomposites polished with one-step systems. Oper Dent 2008; 33: 413-420.

10) Ergüçü Z, Türkün LS. Surface roughness of novel resin composites polished with one-step systems. Oper Dent 2007; 32: 185-192.

11) Janus J, Fauxpoint G, Arntz Y, Pelletier H, Etienne O. Surface roughness and morphology of three nanocomposites after two different polishing treatments by a multitechnique approach. Dent Mater 2010; 26: 416-425.

12) Jefferies SR. Abrasive finishing and polishing in restorative dentistry: a state-of-the-art. Dent Clin North Am 2007; 51: 379-397.

13) Antonson SA, Yanca RI, Klinic E, Antonson DE, Hardigan PC. Comparison of different finishing/polishing systems on surface roughness and gloss of resin composites. J Dent 2011; 198: e9-e17.

14) Lu H, Lee YK, Oguri M, Powers JM. Properties of a dental resin composite with a spherical inorganic filler. Oper Dent 2006; 31: 734-740.

15) Sarac D, Sarac SY, Kulunk S, Ural C, Kulunk T. The effect of polishing techniques on the surface roughness and color change of composite resins. J Prostheth Dent 2006; 96: 33-40.

16) Gönülol N, Yılmaz F. The effects of finishing and polishing techniques on surface roughness and color stability of nanocomposites. J Dent 2012; 40S: e64-e70.

17) Endo T, Finger WJ, Kanemura H, Kotousov A, Swain MV. On the design of dental resin composites. J Dent Mater 2010; 26: 416-425.

18) Jung M, Otte A, Klimke J. Is surface roughness of resin composites affected by operator's performance. Am J Dent 2009; 21: 3-6.

19) Bota AC, Duarte S Jr, Filho PIP, Gheno MM. Effect of polishing on surface roughness of composite resins as elucidated by atomic force microscopy. Microsc Microanal 2008; 14: 380-386.

20) Turkun LS, Turkun M. The effect of one-step polishing system on the surface roughness of three esthetic resin composite materials. Oper Dent 2004; 29: 203-211.

21) Chung KH. Effects of polishing and finishing procedures on the surface texture of resin composites. Dent Mater 1994; 10: 325-330.

22) Edelhoff U, Yildiz E, Uren MM, Ozsoy AO, Toksoy Topcu F. Effects of polishing systems on the surface roughness of tooth-colored materials. J Dent Sci 2013; 8: 160-169.

23) Baseren M. Surface roughness of nanofill and nanohybrid composite resin and ormocer-based tooth-colored restorative materials after several finishing and polishing procedures. J Biomat Mater 2004; 19: 121-134.

24) Ereifej NS, Oweis YG, Eliades G. The effect of polishing technique on 3-D surface roughness and gloss of dental restorative resin composites. Oper Dent 2013; 38: E1-E12.

25) Hosoya Y, Shinraishi T, Odatsu T, Nagafuji J, Kotaku M, Miyazaki M, Powers JM. Effects of polishing on surface roughness, gloss, and color of resin composites. J Oral Sci 2011; 53: 283-291.

26) Lefever D, Perakis N, Roig M, Krejci I, Ardu S. The effect of toothbrushing on surface roughness of resin composites. Am J Dent 2012; 25: 54-58.

27) Mitra SB, Wu D, Holmes BN. An application of nanotechnology in advanced dental materials. J Am Dent Assoc 2003; 134: 1382-1390.

28) Sekiya K, Okamoto A, Fukushima M, Iwaku M. In vivo wear pattern of experimental composite resins based on different resin monomers. Dent Mater 1993; 1: 12-14.

29) Takahashi H, Finger WJ, Endo T, Kanemura M, Koostatha N, Komatsu M, Balkenhol M. Comparative evaluation of mechanical characteristics of nanofiller containing resin composites. Am J Dent 2011; 24: 264-270.