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Original Article

Surface roughness and gloss of polished nanofilled and nanohybrid resin composites

Lu Zhang, Peng Yu*, Xiao-Yan Wang

Department of Cariology and Endodontology, Peking University School and Hospital of Stomatology & National Clinical Research Center for Oral Diseases & National Engineering Laboratory for Digital and Material Technology of Stomatology, Beijing Key Laboratory of Digital Stomatology, Beijing, China

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Background/purpose: There is limited literature on the polishability of new launched nanofilled and nanohybrid. The aim of this study is to evaluate the polishability of nanofilled and nanohybrid composites by measuring surface roughness and gloss values and explore the surface qualities of composite before and after polishing in vitro.
Materials and methods: One nanofilled resin composite, two nanohybrid resin composites and one microhybrid resin composite were selected. All specimens were light cured against celluloid matrix strips. Then surface roughness(Ra) and gloss(GU) values were tested as negative control. Specimens were roughened with a 600-grit silicon carbide paper for 30 s to serve as positive control and then polished with Sof-Lex polishing disk system. Mean Ra and GU values of each step were measured with a profilometer and a small-area glossmeter. The surface qualities were observed by scanning electron microscope.
Results: Ra values of polished surfaces were significantly higher than negative control and lower than positive control($P < 0.05$). All materials showed no significant difference on Ra values after polishing($P > 0.05$). GU values of polished surfaces were significantly lower than negative control and higher than positive control($P < 0.05$). After polishing the microhybrid resin composite showed lower GU values than nanofilled and nanohybrid resin composite groups. The SEM images showed surface textures and irregularities were corresponded to the results of surface roughness and gloss.
Conclusion: No significant differences were noted on surface roughness among nanofilled, nanohybrid, and microhybrid composites after polishing with Sof-Lex disc system. Microhybrid composite presented lower gloss values than nanofilled and nanohybrid resin composites.

* Corresponding author. Department of Cariology and Endodontology, Peking University School and Hospital of Stomatology, No.22, Zhongguancun South Avenue, Haidian District, Beijing, 100081, China. Fax: +86 010 82195385.
E-mail address: yupeng_pkuss@126.com (P. Yu).

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Introduction

Surface qualities are considered as essential factors for long-term success of resin composite restorations. Rough surfaces cause unsatisfied esthetic appearance and plaque accumulation,[1] which could lead to failure of the restorations. It has been proved that surface qualities could be affected by the composition of restorative materials, the instruments used as well as operator's performance during finishing and polishing procedures.[2-4]

Resin-based composite is one of the most commonly used direct restorative materials, which mainly consists of resin matrix and filler particles. Filler particles significantly influence the outcome of finishing and polishing.[5] Generally, resin-based composites with smaller filler size exhibit smoother surfaces after proper finishing and polishing.[6] As polishing could be microscopically regarded as grinding process, fillers with greater size may lose the retention of resin matrix and subsequently fall off, leaving more pits and dents on the surfaces. Therefore, optimal surface smoothness could be hardly achieved.

Recently the introduction of nano-sized filler particles perfectly solves this issue because they could be removed equally along with the resin matrix.[2] Nanofilled and nanohybrid are two types of resin composites containing nanofillers in the market. Nanofilled composites contain none but nano-fillers and nano-clusters,[7] while nanohybrid composites contain both nano-fillers and hybrid fillers.[8] No definitive conclusion was drawn that significant difference on polishability between nanofilled and nanohybrid resin composite.

It has shown that the smoothest surfaces of resin composite were obtained after being light-cured against matrix strip. Furthermore, several studies showed aluminum abrasive polishing disc produced better results for most types of resin-based composites compared with other polishing instruments,[9,10] even though its application has been limited to labial and proximal surfaces of anterior teeth.[11] Nevertheless, no consistent protocol was concluded for the use of abrasive disc.

The purpose of this study was to evaluate the surface roughness and gloss values of these two variant nanocomposites before and after polishing with aluminum abrasive discs, as well as to further explore the influence of nano-filler particles on the qualities of polished surfaces. The null hypotheses were as follows: there was no difference in a) surface roughness and b) gloss values of all tested resin composite materials.

Materials and methods

Materials used in this study contained a nanofilled resin composite Filtek Z350 XT (3M ESPE, St. Paul, MN, USA), two nanohyrid resin composites Harmonize (Kerr, Orange, CA, USA) and Tetric N-Ceram (Ivoclar Vivadent AG, Schaan, Liechtenstein) and a conventional microhybrid resin composite Filtek Z250 (3M ESPE). Detailed information was listed in Table 1. The polishing system used was Sof-Lex disc system (3M ESPE) as described in Table 2.

Surface roughness measurement

The mean surface roughness (Ra) of each specimen was measured using a surface profilometer (Surftest SJ-401, Mitutoyo, Kanagawa, Japan) with a stress force of 0.75 mN, standard cutoff of 1.0 mm, transverse length of 0.8 mm, amplitude height of 2.5 μm, and stylus speed of 0.5 mm/s. Two measurements of Ra were performed at cross directions for each specimen, and the numerical average of these values was reported.

Gloss measurement

Gloss was measured using a small-area glossmeter (Novo-Curve, Rhopoint Instrumentation, East Sussex, UK), with a square measurement area of 2×2 mm and 60° geometry. Gloss measurements were expressed in gloss units (GU). A custom-made, 10-mm-thick, black polytetrafluoroethylene mold was placed over the specimen during measurements to enable accurate specimen positioning and eliminate the influence of the overhead light.

Specimen preparation

Each resin-based composite material was placed into a custom-made Teflon mould (8 mm diameter × 2 mm thickness). Then two glass plates covered with celluloid matrix strips were placed on both sides of the Teflon mould. All specimens were light cured for 40 s totally, each side for 20 s respectively with Bluephase light-cure unit (Ivoclar-Vivadent AG). Thirteen specimens were prepared for each group: Group HM (Harmonize); Group FT3 (Filtek Z350 XT); Group TN (Tetric N-Ceram); Group FT2 (Filtek Z250). Specimens were discarded if any visible voids were examined on the surfaces.

Ten specimens of each group were tested for surface roughness and gloss values as negative control. The top surface of each sample was roughened with a 600-grit silicon carbide paper for 30 s to serve as positive control. The specimens were then stored in distilled water at 37 °C for 24 h. The specimens of each group were tested for surface roughness and gloss values as positive control.

Three specimens of each group were prepared for SEM examination.

Finishing and polishing procedures

Ten specimens of each experimental group were polished with Sof-Lex disks (three-step system):

Step 1 (medium grit): The medium (dark orange) disc was applied for 20 s, rinsed and dried with air/water syringe for a total of 10 s.

Step 2 (fine grit): The fine (light orange) disc was applied for 20 s, rinsed and dried with air/water syringe for a total of 6 s.

Step 3 (superfine grit): The superfine (yellow disc) was applied for 20 s, rinsed and dried with air/water syringe for a total of 6 s.

Table 1 Information of resin-based composites used in the study.

Material	Abbreviation	Classification	Composition	Filler Ratio(wt%/vol%)	Manufacture
Harmonize	HM	Nanohybrid	**Resin:** BisGMA, BisEMA, TEGDMA **Filler:** nano-scale spherical silica and zirconia particles, barium glass particles	81/64.5	Kerr
Filtek Z350 XT	FT3	Nanofilled	**Resin:** BisGMA, UDMA, TEGDMA, PEGDMA, BisEMA6 **Filler:** non-agglomerated/non-aggregated silica filler and zirconia filler, and aggregated zirconia/silica cluster filler	78.5/63.3	3M ESPE
Tetric N-Ceram	TN	Nanohybrid	**Resin:** Dimethacrylates **Filler:** barium glass, prepolymer, ytterbium trifluoride, and mixed oxide	75-77/53-55	Ivoclar Vivadent
Filtek Z250	FT2	Microhybrid	**Resin:** BisGMA, UDMA, BisEMA **Filler:** oxide, zircon/silica	82/60	3M ESPE

Table 2 Polishing systems used in the study.

Polishing system	Approximate Average Particle Size	Manufacture
Sof-Lex-SL Red (aluminum oxide)	60 μm (electrostatically coated)	3M ESPE
Sof-Lex-SL Medium orange (aluminum oxide)	30 μm (electrostatically coated)	3M ESPE
Sof-Lex-SL Light orange (aluminum oxide)	30 μm (slurry coated)	3M ESPE
Sof-Lex-SL Yellow (aluminum oxide)	3 μm	3M ESPE

All specimen preparation, finishing, and polishing procedures were performed by a single operator to reduce variability. Specimens were held in a custom-made silicone mould (Nagy Impression Material, Aidite, Qinhuangdao, China), and the polishing discs were applied with light hand pressure. For each specimen, polishing discs were discarded after each finishing or polishing step. The specimens were thoroughly rinsed with distilled water and air-dried before starting the next finishing or polishing step. All specimens were cleaned in water in an ultrasonic bath (BioSonic UC100, Coltene Whaledent AG, Altstatten, Switzerland) for 30 min to remove all impurities deposited on their surfaces.

Scanning electron microscope (SEM) analysis

The additional 3 specimens from each group were prepared for scanning electron microscope (SEM) analysis to represent as negative control, positive control and Sof-Lex group. The specimens were sputter coated with gold and observed with a scanning electron microscope (EVO 18; Zeiss, Wetzlar, Germany).

Statistical analysis

Statistical analysis was carried out using SPSS version 25.0 (IBM SPSS Inc, Chicago, IL, USA). Ra and GU were subjected to one-way repeated measures analysis of variance and LSD test at a significance level of 0.05. Both Ra and GU data were found to be normally distributed and homogeneity of variance.

Results

Surface roughness

Surface roughness of all materials generally increased after roughening with silicon carbide paper and decreased after polishing with Sof-Lex disc system. Ra values of polished surfaces were significantly greater than those polymerized against matrix strip. In matrix strip group, FT3 showed lower Ra values than TN. After roughened with silicon carbide paper, FT2 showed lower Ra values than HM. All materials showed no significant difference on Ra values after polished with Sof-Lex disc system (see Table 3).

Gloss value

Gloss values of all materials generally decreased after roughened with silicon carbide paper and then increased after polished with Sof-Lex disc systems. GU values of polished surfaces were significantly lower than those polymerized against matrix strip. In the matrix strip group, FT3 showed the greatest GU value while TN showed the lowest GU value. After roughening with silicon carbide paper, FT2 group showed lower GU values than HM group. After polished with Sof-Lex disc system, FT2 group showed lower GU values than other groups. HM, FT3 and TN groups exhibited no significant statistical differences (see Table 4).

Table 3 Surface roughness Ra values of resin-based composites (μm).

Material	Matrix strip	Sandpaper	Sof-Lex
HM	0.091 ± 0.012^{ABa}	1.016 ± 0.124^{Ab}	0.227 ± 0.048^{Ac}
FT3	0.087 ± 0.012^{Aa}	0.932 ± 0.072^{ABb}	0.269 ± 0.059^{Ac}
TN	0.100 ± 0.015^{Ba}	0.949 ± 0.111^{ABb}	0.225 ± 0.065^{Ac}
FT2	0.092 ± 0.008^{ABa}	0.856 ± 0.099^{Bb}	0.269 ± 0.065^{Ac}

*Different uppercase letters in each column and different lowercase letters in each row indicate significant differences by the same surface treatments and within the same materials, respectively ($P < 0.05$). HM (Harmonize), FT3 (Filtek Z350 XT), TN (Tetric N-Ceram), FT2 (Filtek Z250).

Table 4 Gloss values of resin-based composites.

Material	Matrix strip	Sandpaper	Sof-Lex
HM	95.9 ± 1.3^{Aa}	9.8 ± 0.6^{Ab}	54.2 ± 6.3^{Ac}
FT3	99.9 ± 1.2^{Ba}	9.2 ± 0.4^{ABb}	51.0 ± 5.0^{Ac}
TN	92.8 ± 1.5^{Ca}	9.7 ± 0.7^{ABb}	53.3 ± 6.7^{Ac}
FT2	98.0 ± 3.0^{Da}	9.2 ± 0.7^{Bb}	44.1 ± 5.7^{Bc}

*Different uppercase letters in each column and different lowercase letters in each row indicate significant differences by the same surface treatments and within the same materials, respectively ($P < 0.05$). HM (Harmonize), FT3 (Filtek Z350 XT), TN (Tetric N-Ceram), FT2 (Filtek Z250).

Scanning electron microscope (SEM) analysis

SEM images of all materials were presented in Fig. 1. The images revealed that surface textures and irregularities were corresponded to the results of surface roughness and gloss. After being light-cured against matrix strip, all materials presented smooth surfaces without scratches or defects. Moreover, the regular structures of resin-based composite were revealed. For HM group, nanoparticles were dispersed between larger fillers (Fig. 1A). For FT3 groups, the so-called nanocluster of varying sizes could be observed (Fig. 1D). For TN group, irregularly shaped fillers less than 1 μm were evenly distributed in the resin matrix (Fig. 1G). For FT2 group, fillers were irregular shape but larger than TN group (Fig. 1J).

After roughening with silicon carbide papers, deep ploughs and grooves were clearly visible and the surface textures were similar among all materials (Fig. 1 B, E, H, K). The regular structures of resin-based composites were completely concealed by the surface irregularities.

After polished with Sof-Lex discs system, surfaces of all materials were flattened and majority of the defects were eliminated. For HM, TN and FT2, only a few scattered scratches on the surfaces were detectable and the basic structures of materials were reemerged (Fig. 1C, I, L). For FT3, only several circular pits could be observed while no obvious scratches were discernible (Fig. 1 F).

Discussion

This study examined the surface roughness and gloss of nanohybrid, nanofilled and microhybrid resin composite materials before and after polishing. Based on the results, hypothesis a) was accepted, whereas hypothesis b) was rejected.

Ra value is the main parameter to describe the surface roughness of a flattened surface. Surfaces with a Ra value larger than 0.2 μm are considered clinically unacceptable because it had higher risks of enhancing bacterial adhesion,[12] increasing possibilities of dental caries and periodontal diseases. Gloss value is another parameter to examine the smoothness of surfaces and is characterized by the amount of light reflected by a surface at the same angle of the incident light.[13] However, no acceptable value had been decided clinically. It has been discovered that human enamel had a gloss value of 53, which could be considered as critical value to a certain extent.[14]

In the present study, surfaces against matrix strip exhibited both lowest roughness and highest gloss values in all groups, which was corresponded to previous studies.[15,16] FT3 presented the smoothest surfaces among all types of materials, which was contributed to its unique nanofilled type of fillers. This was because resin-based composites with smaller filler sizes could present glossier surfaces on account of their lower degree of diffuse reflection.[17] However, this superficial layer had less fillers than resin matrix and was easily worn out. Besides, the excess material of the surface was usually removed during finishing and polishing procedures, which led to various degrees of rough surfaces depending on materials, polishing instruments as well as operators. For all materials, it was more practical to compare the differences of surface roughness right after finishing and polishing procedures.

After finishing and polishing, all materials presented no significant differences on surface roughness. Despite of different filler sizes, no solid evidence showed types of resin composite could influence the polishing outcomes. This result was in accordance with Kaizer's review, which demonstrated no evidence to support the choice of nanofilled/nanohybrid over microhybrid composites on better surface qualities.[18] FT3, the nanofilled resin composite used in this study, contains not only nano-scaled silica/zirconia fillers but also nanoclusters. Those agglomerated nano particles could possibly fell off due to lacking retention of resin matrix during finishing and polishing, which could be proven by the obvious circular depressions on the SEM images of FT3. This could also explain the similarities of both nanofilled and nanohybrid composites on the results of surface roughness. Unexpectedly, microhybrid resin composite FT2 showed no difference on surface roughness compared with other materials. Barakah and Taher speculated that surface roughness was a matter of hardness of filler system with polishing abrasives, regardless of filler sizes.[19] Considering the same zirconia/silica fillers type as FT3, the results seemed reasonable. Similar conclusions were also drawn on several studies.[20,21]

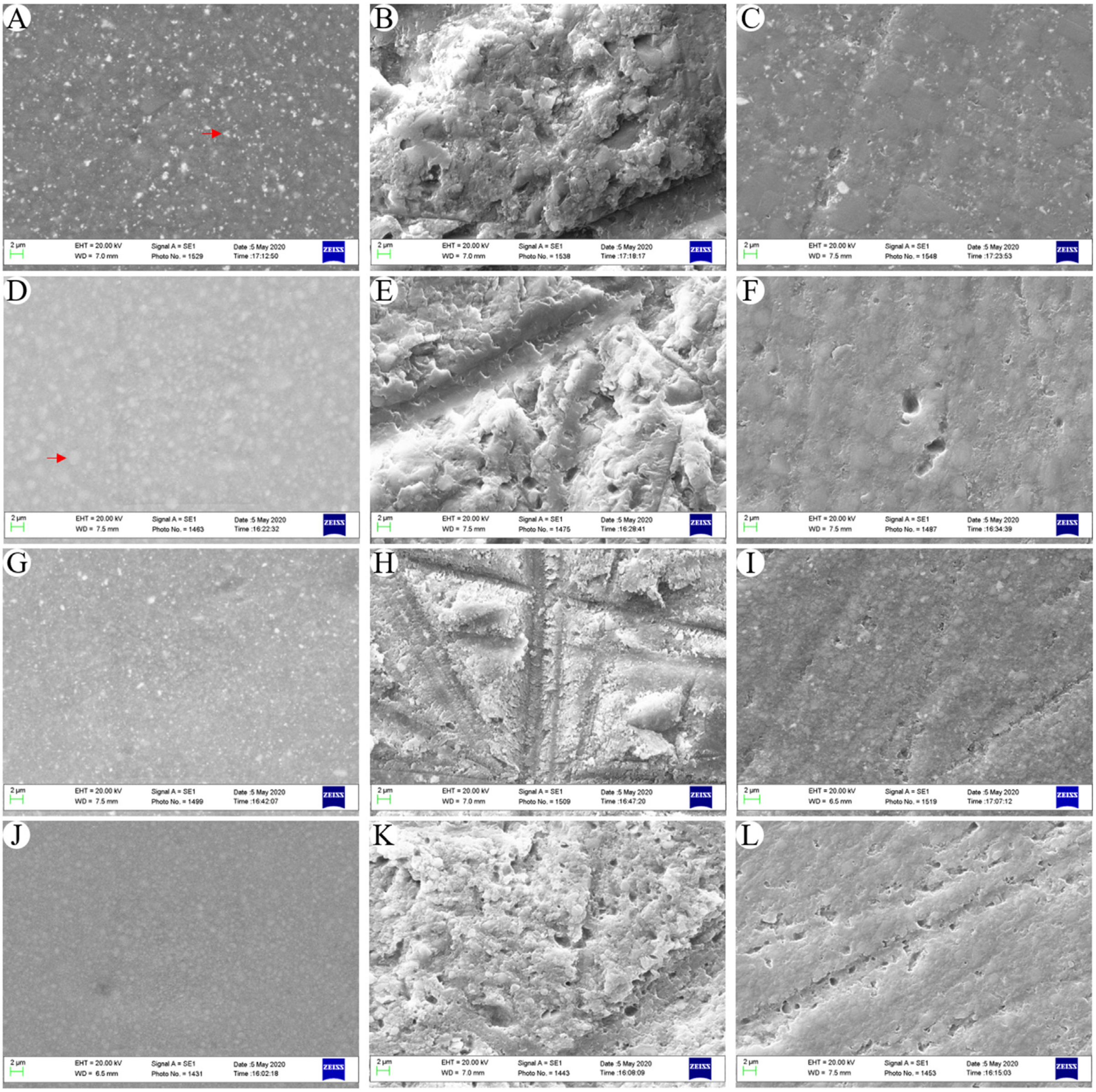

Figure 1 SEM images of all the groups. (A) HM-matrix strip group (red arrow indicates dispersed nanoparticles); (B) HM-sandpaper group; (C) HM-Sof-Lex group; (D) FT3-matrix strip group (red arrow indicates nanocluster); (E) FT3-sandpaper group; (F) FT3-Sof-Lex group; (G) TN-matrix strip group; (H) TN-sandpaper group; (I) TN-Sof-Lex group; (J) FT2-matrix strip group; (K) FT2-sandpaper group; (L) FT2-Sof-Lex group.

It is noteworthy that surface roughness of all materials failed to achieve the critical value of 0.2 μm after polishing with Sof-Lex systems. Even though most of the literatures have shown that alumina abrasive disc system presented the lowest surface roughness than any other systems,[22–24] the polishing outcomes were also influenced by other related factors. It has been proved that polishing time was key factors to influence polishing outcomes. For resin-based composite, Jones et al. recommended 25 s per step for Super-snap, which was another widely-used aluminum polishing disc system.[25] In the present study, each polishing disc was only applied for 20 s according to the recommendations of manufacturers. This could explain why roughness of all materials was higher than clinical standard. As the mylar matrix of Sof-Lex disc was less flexible than super-snap disc, the polishing time of those two systems need to be further studied even though both of them were composed of aluminum abrasive particles with similar sizes.

As for gloss value, HM, TN and FT3 group were able to reach the clinical standard of 53 after polishing, while FT2 group wasn't. In studies of Silikas et al. and da Costa et al., FT2 presented similar gloss values with nanofilled/nanohybrid composite materials using Sof-Lex disc system.[26,27] However, the numerical gloss values evidently exceeded the critical values. This could also be attributed to the way of using Sof-Lex polishing systems, which need to be further, explored. Chiang et al. stated that gloss values were strongly correlated with the subjective interpretation of surface texture rather than fillers composition of resin composites.[5] SEM images showed that fillers of FT2 bulged outwards and were evidently larger than other materials, which might lead to more surface light diffusion of incident light. Moreover, from the point of plastic industry, gloss is affected by filler size distribution, refractive index of fillers, viscosity and refractive index of resin matrix. That might be another reason for its lower gloss values.[28]

Under the limitation of the present study, it could be concluded that no significant differences were noted on surface roughness among nanofilled, nanohybrid, and microhybrid composite after finishing and polishing with Sof-Lex disc system. Microhybrid composite presented lower gloss values than nanofilled and nanohybrid resin composite.

Declaration of Competing Interest

The authors deny any conflicts of interest related to the present study.

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