

Effects of Delayed Finishing/Polishing on Surface Roughness, Hardness and Gloss of Tooth-Coloured Restorative Materials

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ABSTRACT

Objectives: The aim of this study was to investigate the effect of delayed finishing/polishing on the surface roughness, hardness and gloss of tooth-coloured restorative materials.

Methods: Four different tooth-coloured restoratives: a flowable resin composite- Tetric Flow, a hybrid resin composite- Venus, a nanohybrid resin composite- Grandio, and a polyacid modified resin composite- Dyract Extra were used. 30 specimens were made for each material and randomly assigned into three groups. The first group was finished/polished immediately and the second group was finished/polished after 24 hours. The remaining 10 specimens served as control. The surface roughness of each sample was recorded using a laser profilometer. Gloss measurements were performed using a small-area glossmeter. Vickers microhardness measurements were performed from three locations on each specimen surface under 100g load and 10s dwell time. Data for surface roughness and hardness were analyzed by Kruskal Wallis test and data for gloss were subjected to one-way ANOVA and Tukey test ($P < .05$).

Results: The smoothest surfaces were obtained under Mylar strip for all materials. While there were no significant differences in surface roughness of immediate and delayed finished/polished Dyract Extra samples, immediately finished/polished Venus and Grandio samples showed significantly higher roughness than the delayed polished samples ($P < .05$). In Tetric Flow samples, immediately finishing/polishing provided smoother surface than delayed finishing/polishing ($P < .05$). The highest gloss values were recorded under Mylar strip for all materials. While delayed finishing/polishing resulted in a significantly higher gloss compared to immediate finishing/polishing in Venus samples ($P < .05$), no differences were observed between delayed or immediate finishing/polishing for the other materials ($P > .05$). The lowest hardness values were found under Mylar strip. Delayed finishing/polishing significantly increased the hardness of all materials.

Conclusions: The effect of delayed finishing/polishing on surface roughness, gloss and hardness appears to be material dependent. (Eur J Dent 2010;4:50-56)

Key words: Hardness; Roughness; Gloss; Tooth-coloured restorative materials; Finishing; Polishing.

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INTRODUCTION

The smoothness of restorative material's surfaces has a great importance in the success and clinical longevity of the restorations.¹⁻³ It is known that materials with rough surfaces enhance bacterial adhesion and decrease stain resistance.⁴⁻⁶ Especially restorations in close contact to gingival tissues require surface smoothness for optimal gingival health as well.⁷ Surface gloss is another factor playing an important role on the appearance of tooth-coloured restorative resins.⁸ Gloss is a desirable characteristic for restorative materials to mimic the appearance of the enamel.^{9,10} A smooth and glossy surface is generally obtained under a Mylar strip without subsequent finishing or polishing, but unfortunately intra-oral finishing is always required.¹¹ Moreover, such a surface has a higher resin content and will reduce the wear resistance of the restoration over time. Therefore, finishing and polishing of tooth-coloured restorative materials after placement are inevitable procedures that will improve esthetics, early wear resistance, color stability and marginal integrity.^{1,2,5}

Hardness that might be defined as the resistance of a material to indentation is an important mechanical property that predicts the degree of cure of restorative materials.^{12,13} Hardness has also been used to predict the wear resistance of a material and its ability to abrade or be abraded by opposing dental structures or materials.¹⁴ Restorations that are not properly polymerized may result with a softer surface that will retain the scratches created by the finishing procedures. These scratches can compromise the fatigue strength of the restoration and lead to premature failures.¹⁵

Proper finishing and polishing should establish a smooth, glossy surface texture with optimum restoration contour facilitating the removal of plaque.¹⁶⁻¹⁸ The timing of the finishing/polishing procedure might have an effect on the physical properties of the restorative materials, and might increase the risk of premature failures. Although several authors have proposed a 24-hour delay before the completion of finishing procedures,^{19,20} most clinicians perform finishing/polishing procedures immediately after restoration placement.

The effect of different finishing/polishing systems on surface hardness and roughness of com-

posite resins has been widely reported in the literature.²¹⁻²³ However, the effect of delaying finishing/polishing procedures is less investigated.

The aim of this study was to investigate the effect of delayed finishing/polishing on the surface hardness, roughness and gloss of different groups of tooth-coloured restorative materials.

MATERIALS AND METHODS

Four different tooth-coloured restorative materials were used in the study: a flowable resin composite- Tetric Flow (Ivoclar Vivadent AG, Schaan, Liechtenstein); a hybrid resin composite- Venus (Heraus Kulzer, Dormagen, Germany); a nanohybrid resin composite- Grandio (Voco, Cuxhaven, Germany) and a polyacid modified resin composite- Dyract Extra (Dentsply Caulk, Milford, DE, USA) (Table 1). All materials were of A2 shades. A teflon mold (10-mm in diameter and 2-mm thick) was used to prepare 30 specimens from each of the restorative materials. To prepare each specimen, the mold was placed on a Mylar strip covered glass slide and the uncured resin composites were placed in the molds. Another Mylar strip was then placed over the mold and the material was compressed with a glass slide, thus extruding the excess resin composite and forming a flat surface. The samples were polymerized from the top of the mold with a tungsten halogen light (Hilux, Benlioglu, Ankara, Turkey) according to the manufacturer's recommended polymerization times. The intensity of the curing light was 550 mW/cm², as verified with a hand-held radiometer (Curing Radiometer Model 100, Demetron/Kerr, Danbury, CT, USA). A control group of 10 specimens of each material received no finishing and polishing procedures after being cured under Mylar strip. The remaining 20 specimens from each restorative material were randomly divided into two groups (n=10/group) according to the finishing/polishing time. Ten specimens from each restorative material were finished and polished immediately after the polymerization; the other 10 were finished and polished 24 hours later.

Finishing was performed with 30 µm diamond finishing burs (Diatech, Diatech Dental AC, Heerbrugg, Switzerland) with a high-speed hand-piece at 40,000 rpm under three-way water-cooling. The application time was limited to 10 seconds. A new finishing bur was used for every five samples.

Medium to super-fine aluminum oxide discs (Sof-Lex, 3M, St. Paul, MN, USA) were used for polishing. The aluminum oxide discs were discarded after each use. Each disc was used in a circular motion with light pressure for 20 seconds with a slow-speed hand piece (NSK Ti-Max Electric Handpiece, Japan). The rpm was set to 5,000. To control the variability, one investigator, blinded to which material was being processed, performed all the finishing and polishing procedures in a randomized order. All groups were stored in saline for two weeks at 37°C before analyses.^{24,25}

Measurement of surface roughness

The surface roughness of each specimen was recorded using a laser profilometer (MicroXAM Interferometric Surface Profiler, Dublin, Ireland) by a second operator who was also blind to the restorative materials and finishing/polishing procedures.

The average surface roughness (Ra, μm) was measured using MapVue AE software, Version 1.20. Three tracings at different locations on each specimen were recorded. Profilometer results were analyzed taking the Ra value into consideration.

Measurement of gloss

Gloss measurements, expressed in gloss units (GU) were performed using a small-area glossmeter (Nova-Curve, Rhopoint Instrumentation, East Sussex, UK), with a square measurement area of 2x2 mm and 600 geometry. Environment influence was eliminated using a custom-made 10-mm thick black polytetrafluoroethylene mold with the specimen size hole in its center, which has been placed on the top of the specimens during measurements. Three measurements were performed for each specimen.

Measurement of surface hardness

Microhardness measurements were performed using a Vicker's indenter attached to a microhardness tester (Microhardness Testers HMV-2, Shimadzu Corporation, Kyota, Japan). The indentation load was 100 g with a 10 seconds dwell time. Three indentations were taken from each specimen that were equally spaced over a circle and not closer than 1 mm adjacent indentations or the margin of the specimen. The average hardness was calculated for each specimen.

Table 1. Restorative materials and compositions (Bis-GMA= Bisphenol-glycidyl methacrylate; Bis-GA= Bisphenol-glycidyl acrylate; UDMA= urethane dimethacrylate; TEGDMA= triethylene glycol dimethacrylate).

| Restorative Material and Batch Number | Type | Composition | Filler Volume % | Average Filler Particle Size (μm) |
|---|-----------------------------------|---|-----------------|---|
| Tetric Flow Ivoclar/Vivadent, Schaan, Liechtenstein # J01757 | Flowable resin composite | Bis-GMA, UDMA, TEGDMA | 39.7 | 0.04-3.0 |
| Venus Heraeus Kulzer, Dormagen, Germany # 010101 | Hybrid resin composite | Bis-GMA, TEGDMA | 61 | 0.04-0.7 |
| Grandio Voco, Cuxhaven, Germany # 441042 | Nanohybrid resin composite | Bis-GMA, dimethacrylate, UDMA, TEGDMA | 65.6 | Glass ceramic(microfiller) 1 μm , SiO ₂ (nanofiller), 20-60nm |
| Dyract Extra Dentsply Caulk, Milford, DE, USA # 066001434 | Polyacid-modified composite resin | UDMA, carboxilic acid modified dimethacrylate resin, TEGDMA, BHT, Strontium- alimino-sodium-fluoro silicate glass, stronsium fluoride | 50 | 0.8 μm inorganic strontium fluoride glass particles |

Statistical analysis

Means and standard deviations were calculated for surface roughness, gloss and surface hardness. Data were analyzed by Kruskal-Wallis test for surface roughness and hardness. Data for gloss was analyzed by one-way ANOVA and Tukey test. All statistical analysis was conducted at a significance level of $P < .05$.

RESULTS

The mean Ra values for the four restorative materials at baseline, after immediate finishing/polishing and delayed finishing/polishing are displayed in Table 2. For all materials, the smoothest surfaces were obtained under Mylar strip (control). There was no statistical difference in surface roughness values of immediate and delayed finished/polished Dyract Extra samples ($P > .05$). While immediately finished/polished Venus and Grandio samples showed significantly higher roughness values than delayed polishing, immediately finishing/polishing caused smoother surface in Tetric Flow samples ($P < .05$).

The highest gloss values were recorded under Mylar strip for all materials (Table 3). Delayed fin-

ishing/polishing resulted in a significantly higher gloss compared to immediate finishing/polishing in Venus samples ($P < .05$). No difference in gloss measurements was observed between delayed or immediate finishing/polishing for the rest of all materials evaluated ($P > .05$).

Table 4 presents Vickers hardness values of the baseline, immediate and delayed finished/polished specimens. The lowest hardness values were recorded for all restorative materials under Mylar strip. The highest hardness values were reached when finishing/polishing was delayed ($P < .05$).

DISCUSSION

The concern about the possible detrimental effects of immediate finishing/polishing procedures on restorative materials has inspired this study. In the present study, finishing and polishing were completed immediately after curing of the restorative materials, because this is a common method in most clinical situations. It has been stated that finishing can be performed immediately after a light-cured resin composite material that has been polymerized, or 5 minutes after the initial harden-

Table 2. Means and standard deviations of surface roughness (Ra, μm) for each restorative material.

| Restorative materials | Mylar | Immediate Finishing/Polishing | Delayed Finishing/Polishing |
|-----------------------|---------------|-------------------------------|-----------------------------|
| Tetric Flow | 0.013 (0.01) | 0.140 (0.02) | 0.195 (0.05) |
| Venus | 0.022 (0.006) | 0.144 (0.012) | 0.127 (0.014) |
| Grandio | 0.032 (0.011) | 0.440 (0.306) | 0.345 (0.052). |
| Dyract Extra | 0.050 (0.006) | 0.167 (0.015)* | 0.179 (0.046)* |

* indicates no statistically significant difference within each row ($P > .05$).

Table 3. Average gloss values (GU) and standard deviations for each restorative material.

| Restorative materials | Mylar | Immediate Finishing/Polishing | Delayed Finishing/Polishing |
|-----------------------|----------------------------|-------------------------------|-----------------------------|
| Tetric Flow | 85.40 (10.78) ^a | 23.88 (5.53) ^b | 28.05 (12.10) ^b |
| Venus | 82.26 (6.53) ^a | 26.46 (6.79) ^c | 33.7 (8.14) ^d |
| Grandio | 82.54 (8.18) ^a | 8.32 (0.61) ^e | 11.73 (2.76) ^e |
| Dyract Extra | 82.40 (6.41) ^a | 15.53 (4.04) ^f | 20.96 (11.21) ^f |

Within material groups, same superscript letters indicates no statistically significant difference ($P > .05$).

Table 4. Mean surface hardness and standard deviations for each restorative material.

| Restorative materials | Mylar | Immediate Finishing/Polishing | Delayed Finishing/Polishing |
|-----------------------|---------------------------|-------------------------------|-----------------------------|
| Tetric Flow | 36.50 (2.32) ^a | 46.66 (5.07) ^b | 51.36 (4.10) ^c |
| Venus | 54.90 (2.3) ^d | 65.39 (6.1) ^e | 84.4 (11.2) ^f |
| Grandio | 89.35 (11.6) ^g | 252.78 (13.3) ^h | 280.85 (11.0) ⁱ |
| Dyract Extra | 46.03 (2.7) ^j | 61.81 (2.3) ^k | 72.07 (4.1) ^l |

Within material groups, different superscript letters indicates statistically significant difference ($P < .05$).

ing of a self-cured material.^{11,26} On the other hand, several studies have concluded that microleakage is reduced if polishing of the margins is delayed because of the hydropscopic expansion of the material that reduces the contraction gaps.^{19,27}

The surface roughness of a restoration is important for patient's comfort, esthetics, plaque retention and staining.⁴⁻⁶ The size and composition of the filler particles of the restoratives determine the material's ability to be finished and polished, thus the smoothness of the restoration.^{28,29} As expected, the smoothest surface was obtained under Mylar strip. During finishing/polishing, the matrix supporting inorganic filler particles might wear away leaving irregularities projecting from the surface. This study showed that immediately finishing/polishing significantly increased the roughness of Venus and Grandio samples but not of Tetric Flow samples. This phenomenon can be explained by the difference in filler content per volume of Tetric Flow resin composite. It might also be partially contributed to the lower degree of polymerization and viscosity of the UDMA monomer in the Tetric Flow material.³⁰ The different finishing/polishing times had no effect on the roughness of the polyacid modified resin composite tested compared to the resin composites investigated. A possible explanation for this finding may be the difference in the filler content and matrix composition of the different materials.

The critical threshold surface roughness for bacterial adhesion is 0.2 μm .⁴ Only Grandio samples showed surface roughness values greater than 0.2 μm after immediate finishing/polishing. After delayed finishing/polishing, Grandio specimens' roughness values were above this critical threshold. This finding was unexpected since Grandio is a nanohybrid composite that contains silicium dioxide particles of 20-50 nm. However, this material also contains 1 μm glass ceramic particles that might have been left protruding from the surface after the finishing and polishing procedures. Jung et al²³ evaluated the surface texture of four nanohybrid and one hybrid composite after finishing, and found that except for one nanocomposite, all materials were smoother than the hybrid composite tested. In another study evaluating the effect of different polishing systems on the surface roughness and the gloss of various resin composites, the microfill (Durafill), nanofill (Filtek

Supreme), and microhybrid (Esthet-X) resin composites showed smoother and glossier surfaces than the minifill hybrids (Z100 and Z250) tested.⁹ Silikas et al³¹ compared the surface properties of microhybrid and nanohybrid composites and found no difference in surface roughness of these materials. However, the system used for finishing and polishing also should be taken into account. The types of finishing polishing systems and abrasives might have influenced the roughness and gloss of the materials. On the other hand, we only tested one nano hybrid resin composite. This result could not be extrapolated to all nanohybrid composites. Moreover, many studies concluded that the effectiveness of polishing systems is material dependent.^{32,33} Our aim was to investigate the effect of finishing/polishing time on different restorative materials, not to compare the different polishing methods.

Yap et al³⁴ compared the effects of immediate and delayed finishing/polishing procedures on the surface roughness and hardness of tooth-coloured restoratives. Contrary to our findings, they reported that delayed finishing/polishing of polyacid-modified composite resins resulted in a smoother surface. They attributed this result to the maturity of the restorative material at the time of finishing/polishing. They also reported that the surface roughness of resin composites was generally not influenced by the finishing/polishing time.

In the present study, we found that delayed finishing/polishing significantly increased the hardness of the tested materials. Our results are also corroborated by another investigation which also proved that delayed finishing/polishing of resin composites generally resulted in a surface of similar or even harder than that obtained with immediate finishing/polishing.³⁴ On the other hand, Venturini et al²⁵ reported that immediate polishing did not produce a negative influence on the surface roughness, hardness and microleakage of a microfilled (Filtek A110) and a hybrid (Filtek Z250) resin composite compared to delayed polishing. In a recent study, contrary to our findings, the specimens with delayed polishing showed lower hardness results compared to specimens that were polished immediately.³⁵ The authors attributed this result to the loss of surface properties after polymerization using a delayed polishing proce-

dures. They also recommended immediate polishing since this procedure reduces the number of clinical sessions and the wellness of the patients.

It might be expected that smoother surfaces would demonstrate higher gloss values. Lu et al⁵ stated that the gloss was directly influenced by the surface roughness. On the other hand, Lee et al³⁶ found that the gloss was not only influenced by the surface roughness but also by other factors such as the difference in refractive indices of the resin matrix and the fillers. In the present study, similar to the roughness findings, the highest gloss was obtained under Mylar strip polymerized samples. Although, except for Dyract Extra, finishing/polishing time has changed the roughness of the tested materials, significant differences in gloss values were only observed in Venus samples. Therefore, it might be concluded that the composition of the material rather than the roughness might have an effect on the gloss. Heintze et al³⁷ also stated that the gloss was material dependent.

Mechanical profilometers that provide limited two-dimensional informations are generally employed to measure surface roughness for in vitro investigations.^{9,10,18,21,22} The main disadvantage of a mechanical profilometer is that the stylus can not detect irregularities that are smaller than its own diameter. In the present study, a 3-D laser surface profilometer was chosen to evaluate the surface roughness, which provides non-contact, rapid, quantitative surface measurements, thus there is no deterioration of the sample.³⁸ Additionally, the 3-D laser profilometer uses a beam of light that sweeps the sample surface detecting even angstrom level variations more precisely.³⁸

CONCLUSIONS

Under the limitations of this in vitro study, it might be concluded that:

- For all the restorative materials tested, the smoothest surfaces and highest gloss values were obtained under a Mylar strip and without any finishing/polishing procedure.
- The effect of delayed finishing/polishing on the surface roughness and the gloss of the resin composites tested was material dependent.
- The surface hardness of the resin composites tested increased when finishing and polishing procedures were delayed.

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