THE EFFECT OF FINISHING AND POLISHING SYSTEMS ON SURFACE ROUGHNESS, MICROHARDNESS AND MICROLEAKAGE OF A NANOHYBRID COMPOSITE

Ece EDEN[1], Dilsah COGULU[2], Thomas ATTIN[3]*

1. Prof. Dr., DDS, PhD, Ege University School of Dentistry Department of Pedodontics, Izmir-Turkey
2. Assoc. Prof. Dr., DDS, PhD, Ege University School of Dentistry Department of Pedodontics, Izmir-Turkey
3. Prof.Dr. DDS, PhD Zurich University Clinic for Preventive Dentistry, Periodontology and Cariology, Zurich-Switzerland

Abstract

The aim of this study is to examine the effect of different finishing and polishing systems on the surface roughness, microhardness and microleakage of a nano-hybrid composite.

The effect of four different finishing and polishing systems (Mylar-strip, Diamond finishing bur, Sof-lex disc, PoGo) were evaluated on a nanohybrid composite (Ceram-X mono, Denstply). The surface roughness was measured by profilometer, microhardness was measured by Vicker's microhardness tester. For microleakage evaluation, class V cavities (3x4x2 mm) were prepared at cemento-enamel junction of 60 third molars. Teeth were thermocycled 500 times (5-55^{o}C) and immersed in 0.5% basic-fuchsin for 24-hours and evaluated. The two-way ANOVA and Posthoc tests were used for surface roughness, One-way-variance-analysis and Posthoc tests were used for microhardness and microleakage was analyzed by Kruskal-Wallis and Mann-Whitney-U tests.

Measured surface roughness scores listed according to the techniques as; PoGo<Mylar-strip=Sof-lex<Diamond bur (p=0.000), microhardness scores as; Mylar-strip=diamond bur<Sof-Lex<PoGo (p=0.010), microleakage scores as; PoGo<diamond bur=Mylar-strip<Sof-Lex (p=0.004). PoGo was found as the most successful group regarding the investigated properties. Conclusions: The findings revealed that finishing and polishing techniques have a significant effect on the surface roughness, surface hardness and marginal sealing ability of composite restorations.

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Introduction

Resin composites are one of the most investigated materials in dentistry today. Patients and clinicians prefer these materials because of their esthetic appearance, adequate strength, moderate cost compared to ceramics and adhesion to tooth structure.[1-4]

Surface roughness, microhardness and microleakage are critical factors that influence the clinical behavior of the dental restorations. The factors significantly affecting the microhardness values of restorative materials include the filler volume fraction, composition resin type, and polymerization degree.[5] A reduced polymerization is associated with a higher affinity to intrinsic discoloration due to colorants under clinical conditions. It might be assumed that due to surface changes caused by polishing, these properties of composites are affected by finishing and polishing procedures.[6,7] Surface roughness which is closely related to the organic matrix, inorganic filler composition of the material, and finishing and polishing procedures can influence dental biofilm retention, resulting in superficial staining, gingival inflammation and secondary caries, thus affecting the clinical performance of the restorations. Studies on surface roughness have shown that there was a substantial increase in bacteria retention above a threshold of 0.2 µm.[1-4] One of the major

***Corresponding author:**
Assoc. Prof. Dr. Dilsah COGULU
Ege University School of Dentistry
Department of Pedodontics
35100 Bornova-Izmir, Turkey

e-mail: dilsah.cogulu@ege.edu.tr

shortcoming of composite restorations is the polymerization contraction during setting that results in microleakage.[8] This phenomenon involves the infiltration of oral fluids, bacteria, toxins, soluble ions and molecules into the interface between the prepared cavity walls and the restoration.[9] A truly adhesive restoration reduces marginal contraction gaps and thus microleakage, and reduces marginal staining and caries recurrence. Finishing and polishing procedures may produce microleakage because of thermal effects.[6,7]

It has been shown that appropriate finishing/polishing procedures play an important role in improving the esthetics and longevity of the dental restorations.[10-13] Finishing is defined as the gross contouring or reduction of a restoration to obtain ideal anatomy. Polishing refers to the reduction of roughness and scratches created by finishing instruments.[14] A variety of instruments are commonly used for finishing and polishing resin restorations including carbide burs, diamonds, abrasive-impregnated rubber cups and points, abrasive discs, abrasive strips, and polishing pastes.[11,15-18] It is important to determine which finishing and polishing system offers the best results for adhesive restorations.[13] However, there is no consensus on which material and technique provides the smoothest surfaces for resin composites.

The purpose of this *in vitro* study was to determine the effect of different finishing and polishing systems on the surface roughness, microhardness and microleakage of a nanohybrid composite resin.

Materials and Methods

Cylindirical specimens (5 mm in diameter and 2 mm in height) were prepared for each group for surface roughness and microhardness evaluations. A nanohybrid composite resin (CeramX mono, Dentsply, DeTrey, Konstanz, Germany) was inserted in the metallic matrix and covered with clear strip and pushed with a glass plate. The specimen was then light cured following the manufacturer's instructions using a halogen light system (Optilux 501, Kerr Corp, Orange, CA). The power output density used was 620 mW/cm^2. The specimens were submitted to different finishing and polishing systems and procedures according to the manufacturer's instructions.

Group 1: Mylar strip (Hawe-Neos Dental, Bioggio, Switzerland): no procedure after curing

Group 2: Diamond finishing bur (the cured surface of the specimens with the mylar strip were finished using 10 strokes diamond bur #4219FF - KG Sorensen, Barueri, SP, Brazil)

Group 3: Procedures in Group 2 followed by medium, fine and super-fine aluminum oxide-impregnated discs (Sof-lex, 3M ESPE Dental Products, St. Paul, MN, USA) under dry conditions with light hand pressure for 30 seconds) of without water cooling.

Group 4: Procedures in Group 2 followed by diamond impregnated cured urethane dimethacrylate resin polishing devices (PoGo, Dentsply DeTrey, Konstanz, Germany) under dry conditions with light hand pressure using a planar motion for 30 seconds at 15,000 rpm using a slow-speed hand piece.

In order to reduce the technique variability, only one operator performed these procedures.

Surface roughness evaluation

Surface roughness (Ra) was measured with a profilometer (Surfcorder SE 1200, Kosaka Laboratory Co, Chiyoba-Ku, Tokyo, Japan) in 15 specimens. The Ra-value is the arithmetic mean line calculated by the analyzer. Three traces were recorded for each specimen on different locations. The roughness value was recorded as the average of these three readings. A calibration block was used periodically to check the performance of the profilometer. The mean Ra values were determined with a cut-off value of 0.8 mm, a transverse length of 0.8 mm, and a stylus speed of 0.1 mm/seconds near the center of each specimen.

Microhardness evaluation

Microhardness measurements on cured surfaces of the specimens were determined by Vicker's Hardness Testing Machine (Micromet 5114; Buehler, Lake Bluff, ILL, USA). The Vicker's surface microhardness test method consisted of indenting the test material with a diamond tip, in the form of a right pyramid with a square base and Vicker's microhardness readings were undertaken using a load of 50 g for 20 s. Three indentations were recorded from each specimen that were equally spaced over a circle and not closer than 1 mm to adjacent indentations or the margin of the specimen, and the microhardness value was obtained as the average of these readings.

Microleakage evaluation

Sixty freshly extracted mandibular third molar teeth were selected for the study. The teeth were cleaned with a scaler and stored in distilled water at 4°C. Class V cavities (mesio-distal width of 3 mm, occluso-gingival length of 4 mm, and a depth of 2 mm) were prepared on the buccal surfaces of teeth at the cemento-enamel junction. The cavity on each tooth was restored with Xeno V (Dentsply, DeTrey, Konstanz, Germany) adhesive system and a resin composite; CeramX mono (Dentsply, DeTrey, Konstanz, Germany) according to the manufacturer's instructions. The teeth were stored in distilled water at all times and were not permitted to dehydrate under any circumstances. Immediately after polymerization, all restorations were divided into four subgroups (n=15).

The specimens then were submitted to 500 thermocycles with 30 s baths at temperature of 5°C and 55°C and a dwell time of 10 s in a resting bath at 24°C. The apex of each tooth was sealed with composite resin and two coats of nail varnish were applied leaving 1 mm around the margins of the finished restorations. The restorations were then stored in 0.5% basic fucsin dye for 24 h at 37°C. After removal from the dye solution, the teeth were washed and sectioned longitudinally through the center of the restorations in a bucco/lingual plane with a diamond saw (Isomet, Buehler, Ltd, LakeBluff, IL, USA).

Marginal leakage, as indicated by the depth of dye penetration at the margins, was evaluated under stereomicroscope (Olympus, Tokyo, Japan) at x40 magnification. For each restoration, the section with greater leakage was selected for scoring. The evaluations were carried out blindly by an evaluator who was not aware of the groups. The following scale was used to assess the extent of dye penetration at the tooth-restoration interface:

0: no evidence of dye penetration
1: dye penetration to less than half of the cavity depth
2: dye penetration to the full cavity depth
3: dye penetration to the axial wall and beyond.[19]

Statistical analysis

The surface roughness was analyzed by two way ANOVA and Posthoc Dunnett T3 tests, microhardness was analyzed by One-way-variance-analysis and Posthoc Dunnett T3 test and microleakage was analyzed by Kruskal-Wallis and Mann-Whitney-U-tests.

Results

Surface roughness evaluation

Table I shows the average surface roughness (Ra) for each polishing technique. There was a statistically significant interaction in finishing and polishing techniques on surface roughness (p<0.05). The smoothest surface was observed in PoGo group.

Measured surface roughness scores are listed in ascending order according to the techniques as; PoGo<Mylar strip=Sof-lex<diamond finishing bur (p=0.000).

Groups	(Ra)
Diamond finishing bur	0.99 ± 0.18^A
Sof-lex disc	0.31 ± 0.61^B
Mylar Strip	0.28 ± 0.10^B
PoGo	0.10 ± 0.30^C

Groups indicated with same letters in the Posthoc test grouping are not statistically significantly different

Table I. The average surface roughness values (mean ± standard deviation) in the tested groups (Ra)

Microhardness evaluation

The average microhardness scores for each finishing and polishing techniques are shown in Table II. A statistically significant difference between these techniques was observed (p<0.05). The group with the significantly highest microhardness was PoGo.

Measured microhardness scores are listed in ascending order according to the techniques as; Mylar strip=diamond finishing bur<Sof-lex<PoGo (p=0.010).

Groups	(VHN)
Mylar Strip	59.91 ± 2.58A
Diamond finishing bur	60.99 ± 1.18A
Sof-lex disc	66.33 ± 2.17B
PoGo	72.58 ± 1.60C

Groups indicated with same letters in the Posthoc test grouping are not statistically significantly different.

Table II. Microhardness (VHN) scores (mean ± standard deviation) in the tested group

Microleakage evaluation

The dye penetration scores according to the cavity wall sites (occlusal and gingival margin) are shown in Table III. No significant difference was detected in leakage scores between finishing and polishing techniques at occlusal margins. A statistically significant difference was found at gingival margins between finishing and polishing techniques ($p<0.05$). The techniques are listed according to the assessed microleakage scores at the gingival margins as; PoGo<diamond finishing bur=Mylar strip<Sof-lex ($p=0.004$).

Groups	Microleakage Scores (n)									
	Occlusal margin					Gingival margin				
	0	1	2	3		0	1	2	3	
Diamond finishing bur	8	3	0	4	A	4	3	0	8	B
Mylar Strip	3	9	1	2	A	4	0	1	10	C
PoGo	11	2	2	0	A	5	7	2	1	C
Sof-lex	4	7	3	1	A	0	0	7	8	D

-Groups indicated with same letters are not statistically significantly different ($p<0.05$)

Table III. The distribution of occlusal and gingival microleakage scores

Discussion

Composites are one of the most commonly used direct restorative materials and nowadays its clinical use has expanded because of the increased esthetic demand by patients, new developments in formulations and simplification of bonding procedure.[20] The surface quality of these dental restorations is an important parameter influencing the clinical behavior. The clinician's objective in esthetic restorations is to achieve the smoothest surface, which will minimize dental biofilm accumulation and stain retention and provide longevity.[21] The mechanical properties tested in the present study, as surface roughness, microhardness and microleakage of composites are affected by finishing and polishing procedures and interfere with the clinical appearance of the restoration.[22]

The surface roughness of resin material is the result of the interaction of multiple factors. Intrinsic factors are including properties of material such as filler type, shape, size and distribution of the particles. Extrinsic factors are associated with the type of polishing systems and light-curing method.[20,23] Roughness has also a major impact on the esthetic appearance and discoloration of restoration, secondary caries and gingival irritation and wear of opposing and adjacent teeth.[24] An inappropriate polishing may result in a residual surface roughness, thus increasing plaque adhesion and impairing the mechanical and esthetic characteristics of the material.[25]

Microhardness, as tested in the present study is defined as the resistance of a material to indentation and is an important mechanical property that predicts the polymerization degree of cure of restorative materials.[4,26] Changes in microhardness may reflect the state of the setting reaction of a material and the presence of an ongoing reaction or maturity of the restorative material.[27,28] In the present study, both SofLex and PoGo, showed statistically significantly higher Vickers hardness values as compare to the other tested finishing procedures.

Finishing and polishing techniques can affect microleakage, probably because of the thermal insults produced with rotary instruments during these procedures.[6,7] Increased leakage has been reported when the finishing procedures were done in dry conditions, suggesting a deficiency in marginal fit.[29] However, Yap et al. found no differences in microleakage among finishing and polishing procedures performed in dry conditions.[28] Therefore, polishing procedures were performed without water as defined by the manufacturers' recommendations in the present study.

The characteristics of the composite resin such as the particle size or the filler content also play an important role in polishing procedures and further survival.[30] One of the most significant advances in the last few years is the application of nanotechnology to resin composites.

Composites which contain nanoparticles have improved filler technology, modified organic matrixes, and offer a greater degree of polymerization that improves their mechanical and physical properties.[22,24,26] Hence, finishing and polishing procedures require a sequential use of instrumentation in order to achieve a highly smooth surface, where the different hardness degree of the contents of the composite material affects the outcome. Ceram-X mono which is a nano-hybrid composite resin was evaluated in the present study to eliminate the filler size effect.

A wide variety of materials and techniques have been introduced for contouring, finishing, and polishing[11,15-18], but there is not a universally accepted method for finishing procedures.[3] With the ultimate goal of achieving a smooth surface of the composite restoration in fewer steps, the one-step polishing systems are appealing to the clinician. In clinical practice, transparent matrices such as a Mylar strip are preferred for forming resin composite and producing the smoothest resin composite surfaces with highest gloss.[20,23,31-33] However, composites polymerized with a clear matrix on the surface will leave a resin-rich surface layer that is easily abraded in the oral environment, exposing unpolished, rough, inorganic filler material. Thus, polishing is required to prevent wear and discoloration on the resin-rich surface.[34] In accordance with the above, the surface roughness results determined by mylar strip in the present study were satisfying but the microhardness was poor. On the other hand, the microleakage scores were not promising as well.

It is mostly necessary to use diamond or carbide burs to contour anatomically structured and concave surfaces.[35]

Brackett et al. reported that the use of carbide burs for finishing procedures caused a higher degree of leakage than other methods tested.[36] However, the results of the present study revealed that diamond finishing bur was showing similar microleakage with mylar strip.

In the present study, PoGo was used as a one-step polishing system, but the manufacturer recommends pre-treatment with Enhance system to obtain favorable results. Some investigators have used this system as a one-step method without any pre-treatment.[17,37] Jung et al. reported no beneficial results on the surface quality with the pretreatment with Enhance system.[38] For this reason, PoGo was used as a one-step method in the present study.

The findings of the present study revealed that finishing and polishing techniques have a significant effect on the surface roughness, microhardness and marginal sealing ability of composite restorations. Considering the reduced number of steps, the current one-step polishing system appears to be more effective than multi-step system and may be preferable for polishing resin composite restorations.

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