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ORIGINAL ARTICLE

Effects of polishing systems on the surface roughness of tooth-colored materials

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Abstract *Background/purpose:* Polishing systems may affect the surface characteristics of the tooth-colored restorative materials. In this in vitro study, we evaluated the surface roughness of various tooth-colored restorative materials after polishing them with three different polishing systems.
Materials and methods: The tooth-colored restorative materials evaluated were conventional glass–ionomer cement, compomer, microhybrid, and nanofil composite. In total, 112 specimens (10 mm in diameter and 2 mm thick) were prepared in a metal mold using four different tooth-colored restorative materials. After the light curing and setting cycle, seven specimens from each group which received no polishing treatment were used as controls. Specimens were randomly polished with Sof-Lex disks, Poli-pro disks, and the Hiluster^{Plus} systems for 30 seconds. The mean surface roughness of each polished specimen was determined with a profilometer and examined using scanning electron microscopy. Data were analyzed using a two-way analysis of variance and Bonferroni's *post-hoc* multiple-comparison test, with a probability level of 0.05.
Results: According to the two-way analysis of variance, the type of tooth-colored materials, polishing technique, and their interactions were statistically significant ($P < 0.001$). The smoothest surfaces of all materials were obtained with the Mylar strip. Glass–ionomer cement demonstrated statistically significantly higher R_a values (1.36 ± 0.77) than the other restorative materials tested ($P < 0.05$). Compomer (0.65 ± 0.28) produced the smoothest surface and did not significantly differ from the microhybrid composite (0.78 ± 0.39; $P > 0.05$). No significant difference was observed between the microhybrid and nanofil composites (1.08 ± 0.83; $P > 0.05$). According to the scanning electron microscopy observations, the surface irregularities of the materials were consistent with the surface roughness profilometric findings.

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Conclusion: The effectiveness of a polishing system on the surface roughness depends on both the polishing system and restorative material.

Introduction

Various types of tooth-colored restorative materials with different physical characteristics and chemistries are available to practitioners. Glass–ionomer cements (GICs) are widely used as lining, luting, and restorative materials due to their favorable adhesive and fluoride-releasing properties. The low mechanical properties and long setting times of GICs have led to the development of resin-modified glass–ionomers and polyacid-modified resin composites (compomers).[1,2] Compomers combine the benefits of resin composites and GICs[2]; however, they behave more like resin composites.[3] The clinical use of compomers and composite restoratives has substantially increased over the past few years due to higher aesthetic demands of patients, improvements in formulations, and simplification of bonding procedures.[4] One of the most important advances in the last few years was the development of resin composites containing nanoparticles.

Regardless of the cavity class and location, the proper finishing and polishing of tooth-colored restorations, which enhance both the aesthetics and longevity of restorations, are essential steps in restorative dentistry.[5,6] The surface texture of dental materials has a major influence on plaque accumulation, which may result in gingival inflammation, increased surface staining, and recurrent caries.[7] Additionally, surface roughness may directly influence wear behavior and the marginal integrity of posterior tooth-colored restorations.[8,9] Therefore, maintaining a smooth surface of a restoration is of utmost importance for its long-term success. Finishing refers to the gross contouring or reduction of a restoration to obtain the desired anatomy, and polishing refers to a reduction in the roughness and removal of scratches created by the finishing instruments.[8,10]

For tooth-colored materials, the smoothest surfaces are obtained when the materials are allowed to polymerize against a matrix.[4,11,12] Despite careful placement of matrices, removing excess material and recontouring of restorations are often clinically necessary. This requires some degree of finishing and polishing, which may alter the smoothness obtained with a matrix.[13] A variety of instruments are commonly used to finish tooth-colored restorative materials. These finishing and polishing instruments include carbide and diamond burs, abrasive disks, strips, abrasive impregnated rubber cubs and points, and finishing and polishing pastes.[14–16] However, it is difficult to obtain a smooth surface on tooth-colored materials at the end of polishing due to the shape and size of the filler material and the proportion of the material to the overall composition. Ryba et al[9] reported that the larger the size of filler particles, the rougher the surface will be after polishing. They also showed that with a small quantity of matrix relative to the amount of filler, the largest particles might be dislodged during polishing. In contrast, composites containing small particles are easier to polish.

Various polishing protocols have been tested *in vitro* to evaluate their effects on the surface roughness of tooth-colored restorative materials, and several composite resins were the subject of surface roughness studies; however, there are few studies comparing the surface roughness of GIC, compomer, and resin composites, when using current polishing systems. Therefore, the aim of the present study was to analyze the surface roughness of GIC (Fuji IX GP; GC Corporation, Tokyo, Japan), compomer (Dyract Extra; Dentsply De Trey, Konstanz, Germany), microhybrid composite (Gradia Direct; GC America, Alsip, IL, USA), and nanofil composite (Filtek Supreme XT; 3M ESPE, St. Paul, MN, USA) materials after polishing with three different polishing systems; and to determine the effectiveness of these polishing systems and their possible surface damage using scanning electron microscopy (SEM). The hypothesis tested in this study was that there are no differences among the three different disk-shaped polishing systems on the surface finish of four different tooth-colored materials.

Materials and methods

Four different tooth-colored restorative materials were used in the present study. The restorative materials evaluated were conventional GIC, polyacid-modified resin composite, microhybrid resin composite, and nanofil composite. The properties of these materials are presented in Table 1. The polishing systems tested were Sof-Lex disk (3M ESPE), Poli-pro disk (Premier Dental Products, Norristown, PA, USA), and the Hiluster^{Plus} system (Gloss^{Plus} and Hiluster^{Plus} Dia Polishers; KerrHawe, Bioggio, Switzerland). The composition and manufacturers of the polishing systems tested are given in Table 2.

Preparation of specimens

Twenty-eight disk-shaped specimens were prepared for each tooth-colored restorative material from a total of 112 specimens. Each material was inserted into a cylindrical metal mold (10 × 2 mm) and confined between two opposing Mylar strips (SS White, Philadelphia, PA, USA). A microscopic glass slide (1 mm thick) was placed on the mold, and constant pressure was applied to extrude the excess material. The GIC was allowed to set for 1 hour, while the other restorative materials were polymerized for 40 seconds with a light-curing unit (VIP; Bisco, Schaumburg, IL, USA) operating in standard mode and emitting no less than 600 mW/cm^2, as measured with a light meter that was placed on the curing unit before initiating polymerization. The guide of the light curing unit was placed perpendicular

Table 1 The composition of selected materials according to the manufacturers' data.

Material (manufacturer)	Type	Matrix	Filler loading		Average particle size	Lot no.
			(vol.%)	(wt.)%		
Fuji IX GP (Capsulated) (GC Corporation, Tokyo, Japan)	Glass ionomer cement	Polyacrylic acid, fluoroaluminosilicate glass, polybasic carboxylic acid	—	—	10 μm	0803191
Dyract Extra (Dentsply DeTrey, Konstanz, Germany)	Polyacid-modified resin composite (Compomer)	Strontium-fluoro-silicate glass, strontium fluoride, TCB resin, UDMA, photoinitiator, stabilizers	50	73	0.8 μm	0304001491
Gradia Direct (GC America, Alsip, IL, USA)	Microhybrid composite	Microfine silica, prepolymer resin fillers, UDMA, comonomer matrix	77	65	0.85 μm	0712072
Filtek Supreme XT (3M ESPE, St. Paul, MN, USA)	Nanofilled composite	Bis-GMA, TEGDMA, UDMA, bisphenol A Polyethylene glycol diether dimethacrylate	59.5	78.5	Nanoclusters: 0.6–1.4 μm Nanosilica: 5–75 nm	7CB

Bis-GMA = bisphenol A diglycidyl ether dimethacrylate; TCB resin = butane tetracarboxylic acid; TEGDMA = triethylene glycol dimethacrylate; UDMA = urethane dimethacrylate.

to the specimen surface at a distance of 1 mm. Immediately after the light curing and setting cycle, specimens were removed from the mold and immersed in double-distilled water at 37°C for 7 days before the finishing procedures. To reduce variability, all specimen preparation, finishing, and polishing procedures were performed by the same investigator.

Specimens from each material group were examined for obvious voids, labeled on the bottom, and randomly separated into four treatment groups, each containing seven specimens.

Group I (control group, Mylar strip group) contained specimens which received no finishing or polishing treatment.

In the finishing and polishing groups, the Mylar strip-finished surface of each sample was wet-finished with 1200-grit silicon carbide (SiC) abrasive paper on a rotary polisher (Metaserv; Buehler, Düsseldorf, Germany). One side of each sample was prepared as a standard surface to simulate a clinical finishing procedure.

In group II (Sof-Lex group), specimens were sequentially polished with medium, fine, and superfine aluminum oxide-impregnated disks (Sof-Lex) under dry conditions for 30 seconds. After each polishing step, specimens were thoroughly rinsed with water for 10 seconds to remove debris, air-dried for 5 seconds, and then polished with another disk of lower grit for the same period of time until final polishing.

In group III (Poli-pro disk), specimens were sequentially polished with medium, fine, and extra-fine aluminum oxide abrasive disks (Poli-pro disk) for 30 seconds, as described for group II.

In group IV (Hiluster^{Plus} system), specimens were polished with disk-shaped aluminum oxide-integrated polishers (Gloss^{Plus} Polishers) under dry conditions for 30 seconds, then treated with a diamond polishing system (Hiluster^{Plus} Dia Polishers) using a planar motion under dry conditions for an additional 30 seconds.

In the present study, disk-shaped polishers were used to obtain direct contact with the surfaces of specimens. A slow-speed handpiece rotating at a maximum of 15,000 rpm was used with light hand pressure for all systems. For each specimen, a new polishing disk and a new polisher (aluminum oxide or diamond) were used and discarded after each use.

Surface roughness test

After polishing, specimens were washed, allowed to dry, and stored in double-distilled water for 7 days before measuring the mean surface roughness (R_a) values. R_a values of each specimen were measured four times, and mean R_a values were determined with a cutoff value of 0.8 mm, a transverse length of 0.8 mm, and a stylus speed of 0.1 mm/s near the center of each specimen using a surface profilometer (Taylor Hobson Surtronic 3$^+$; Taylor Hobson, Leicester, UK), which was calibrated against a standard before each new measuring session.

Observations by SEM

After performing the surface roughness test, one representative specimen from each group was prepared for the

Table 2 The composition and batch numbers of the polishing systems.

Polishing system	Composition	Batch number
Sof-Lex Disks (3M ESPE, St. Paul, MN, USA)	Aluminum oxide-coated disk Medium (40 μm) Fine (24 μm) Ultrafine (8 μm)	P060725
Poli-pro Disks (Premier Dental Products Co., Norristown, PA, USA)	Aluminum oxide-coated disk Medium (40 μm) Fine (30 μm) Extra-fine (9 μm)	2019070
Hiluster^{Plus} System (KerrHawe, Bioggio, Switzerland)	Gloss^{Plus} aluminum oxide particle-integrated polishers (10 μm) Hiluster^{Plus} diamond particle-integrated polishers (5 μm)	2932638

SEM examination. Specimens were mounted on aluminum stubs and sputter-coated with gold palladium to a thickness of approximately 200 Å in a Polaron SC7620 mini-sputter coater (Quorum Technologies, East Sussex, UK) for 5 minutes at a current of 10 mA. Each specimen was examined by SEM (Jeol JSM 6360LV; Jeol, Tokyo, Japan) at a magnification of 500× and an accelerating voltage of 10 kV, and photographs were taken.

Statistical analysis

Mean R_a values were compared between the control and treatment groups by a two-way analysis of variance (ANOVA) at a 95% confidence interval (CI). To determine which group differences accounted for significant differences, a one-way ANOVA and *post-hoc* pairwise multiple comparisons with Bonferroni's correction were performed with the probability level set to $\alpha = 0.05$ for statistical significance. All analyses were performed using a commercially available software package (SPSSWIN 15.0; SPSS, Chicago, IL, USA).

Results

Surface roughness test results

Mean R_a values (μm) and standard deviations produced by the Mylar strips, Sof-Lex disks, Poli-pro disks, and Hiluster^{Plus} system on four tooth-colored restorative materials are summarized in Table 3 and presented graphically in Fig. 1. Results of the two-way ANOVA demonstrated that the type of tooth-colored materials ($F = 15.713$, $P < 0.001$), polishing technique ($F = 42.477$, $P < 0.001$), and the interaction between them were statistically significant ($F = 4.408$, $P < 0.001$; Table 4). The Mylar strip exhibited significantly lower roughness values than the other polishing systems tested ($P < 0.05$) except for the Hiluster^{Plus} system on Dyract Extra and for Sof-Lex on Gradia Direct (Table 3). There were no statistically significant differences between Sof-Lex and Poli-pro disks with any of the tooth-colored material groups ($P > 0.05$) or between Poli-pro disks and the Hiluster^{Plus} system for the Fuji IX GP, Gradia Direct, and Filtek Supreme XT groups ($P > 0.05$). In the Dyract Extra group, the Hiluster^{Plus} system produced significantly lower roughness values than did Sof-Lex and Poli-pro disks ($P < 0.05$). In the Filtek Supreme group, Sof-Lex produced significantly higher roughness values, and the difference was statistically significant compared to the other combinations ($P < 0.05$), with the exception of the Poli-pro disk (Table 3). On the other hand, in the Gradia Direct group, Sof-Lex produced lower roughness values than the other finishing/polishing systems, but the difference was statistically insignificant ($P > 0.05$). For the Mylar strip group, Filtek Supreme XT produced the lowest surface roughness values compared to the other restorative materials, with no significant differences from Dyract Extra or Gradia Direct. Fuji IX GP produced the highest surface roughness values compared to the other restorative materials, but did not significantly differ from Dyract Extra or Gradia Direct. For the Sof-Lex groups, Gradia Direct produced the lowest surface roughness values compared to the other restorative materials ($P < 0.001$), but did not significantly differ from Dyract

Table 3 Mean surface roughness values (R_a, μm), standard deviations (SDs), and differences for the tested restorative materials and polishing systems.

Polishing systems	*n*	Restorative materials			
		Fuji IX GP	Dyract Extra	Gradia Direct	Filtek Supreme XT
Mylar strip	7	$0.56 \pm 0.15\ ^{a,1,3}$	$0.39 \pm 0.10\ ^{a,2,3}$	$0.44 \pm 0.11\ ^{a,2,3}$	$0.33 \pm 0.17\ ^{a,2}$
Sof-Lex	7	$1.45 \pm 0.20\ ^{b,1}$	$0.86 \pm 0.23\ ^{b,c,2}$	$0.65 \pm 0.24\ ^{a,b,c,2}$	$2.05 \pm 0.92\ ^{b,1}$
Poli-pro disk	7	$1.99 \pm 0.93\ ^{b,1}$	$0.84 \pm 0.25\ ^{c,2}$	$0.99 \pm 0.35\ ^{b,c,2}$	$1.20 \pm 0.37\ ^{b,c,1,2}$
Hiluster	7	$1.46 \pm 0.71\ ^{b,1}$	$0.51 \pm 0.20\ ^{a,2}$	$1.02 \pm 0.47\ ^{c,1,2}$	$0.74 \pm 0.41\ ^{c,d,1,2}$

Different superscript letters in the same column and different superscript numbers along with letters in the same row indicates surface roughness (R_a) values represent statistical significance (one-way ANOVA and *post-hoc* tests by Bonferroni, $P < 0.05$).

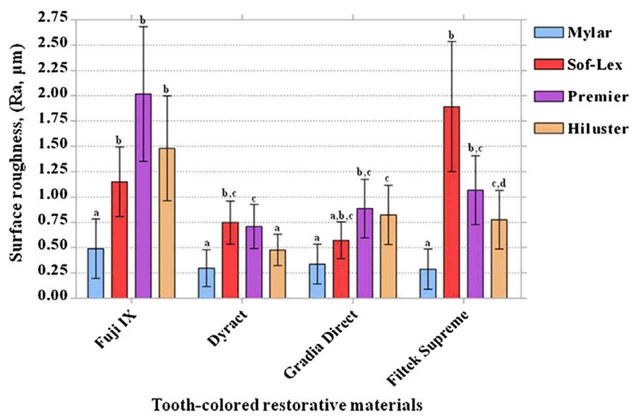

Figure 1 Surface roughness values (R_a; µm) of each tooth-colored restorative material at a given finishing/polishing system; each bar represents mean value and standard deviation of $n = 7$ specimens. Different small letters (shown above the bars) indicate significant differences within each restorative material group.

Extra ($P > 0.05$). Filtek Supreme XT produced the highest surface roughness values, but did not significantly differ from Fuji IX GP. For the Poli-pro disk groups, Dyract Extra produced the lowest surface roughness values, but did not significantly differ from Gradia Direct or Filtek Supreme XT ($P > 0.05$). Fuji IX GP produced significantly higher surface roughness values than Dyract Extra and Gradia Direct ($P < 0.05$), but did not significantly differ from Filtek Supreme XT ($P > 0.05$). For the Hiluster^{Plus} polishing system, Dyract Extra produced the lowest surface roughness values compared to the other restorative materials, but did not significantly differ from Gradia Direct or Filtek Supreme XT ($P > 0.05$). Fuji IX GP produced the highest surface roughness values and significantly differed from Dyract Extra ($P < 0.05$), while no significant differences were observed among the two other materials (Table 3).

SEM examination

Representative SEM photographs of polished specimens and Mylar strip surface are presented in Figs. 2–5. The SEM observations revealed that surface irregularities of the materials were consistent with the surface roughness profilometric findings. The data showed air voids and microcracks in the Mylar strip specimens of GIC (Fig. 2), and the smoothest surfaces were observed for compomer (Fig. 2) and resin composite specimens (Figs. 4 and 5). Rougher surfaces with protruding filler particles for GIC specimens were observed with all polishing systems (Fig. 2). Sof-lex disks created scratches on the surfaces of the compomer (Fig. 3) and nanofil resin composite, and dislodged the particles (Fig. 4), whereas a uniform finish was obtained with the Hiluster^{Plus} system (Figs. 3–5).

Discussion

The present study results showed that different disk-shaped polishing systems caused different surface roughness values on the tested tooth-colored materials. Therefore, the hypothesis of this study that there were no differences among the three different disk-shaped polishing systems on the surface finish of four different tooth-colored materials was rejected.

The ability to polish a dental material is an important property that influences the clinical behavior of dental restorations. The surface quality of tooth-colored restorative materials affects plaque accumulation,[7,17] physical properties,[18] the abrasiveness, and wear resistance.[9,19] Surface roughness is associated with a patient's discomfort in terms of tactile perceptions,[20] aesthetic appearances,[16,21] and stain resistance of the restorative materials.[7,22] However, tooth-colored restorative materials cannot be finished to an absolutely smooth surface. After finishing and polishing, the surface micromorphology of tooth-colored restorative materials was demonstrated to be influenced by the size, hardness, type, and amount of filler particles in restorative materials, and by the flexibility of the finishing material, the hardness of the abrasive, the grit size, and the instrumental application method.[23,24] In the present study, a planar motion was used with all specimens, as a previous study demonstrated that this motion produced significantly lower mean surface roughness values.[25] Several studies demonstrated that the smoothest surface of tooth-colored restorative materials was achieved with Mylar strips.[4,11,12,16] The present study results obtained for Mylar stripped surfaces were consistent with those of previous studies. Even though a smooth surface was obtained with Mylar strips, which contacts the tooth-colored restorative material, it contains a resin-rich layer on the top which needs to be eliminated. Therefore, removal of the outermost resin layer by finishing and polishing procedures tends to produce a more wear-resistant and aesthetically stable surface.[7,9] In addition, all procedures used for finishing and polishing of the restorations decrease the smoothness obtained with the Mylar strips.

Table 4 Two-way ANOVA results for comparison of surface roughness (R_a) values.

Source variation	Type III sum of squares	*df*	Mean square	*F*	P
Corrected model	39.781(a)	16	2.486	15.999	<0.001
Restorative material	7.326	3	2.442	15.713	<0.001
Polishing technique	19.803	3	6.601	42.477	<0.001
Restorative material × polishing technique	6.165	9	0.685	4.408	<0.001
Error	14.919	96	0.155		
Total	54.700	112			

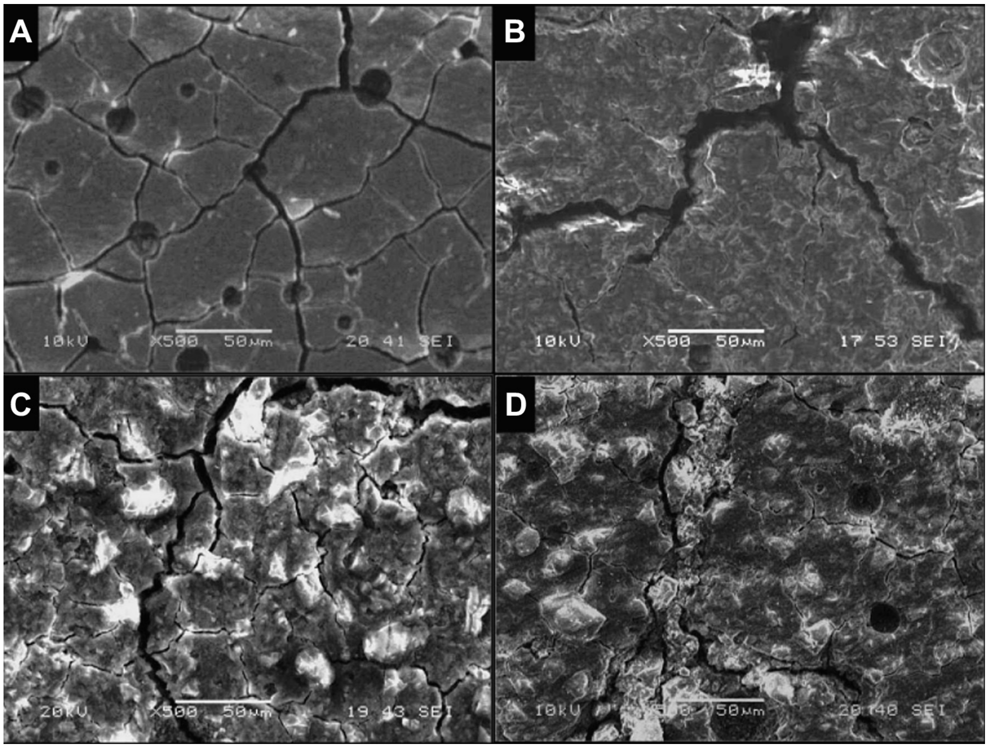

Figure 2 Surface of Fuji IX GP specimen polished with different polishing systems on SEM examination (×500 magnification). (A) Control (Mylar strip); (B) polished with Sof-lex; (C) polished with Poli-pro disk; (D) polished with Hiluster^{Plus} system.

Clinically, some functional adjustment is necessary in almost all restorations; thus, in the present study, finishing was carried out with 1200-grit SiC paper under running water to simulate the clinical finishing procedure.[26]

Tooth-colored restorative materials tested in this study were selected to represent all four types of routinely used restorative materials because they have different filler and matrix compositions and superior properties,

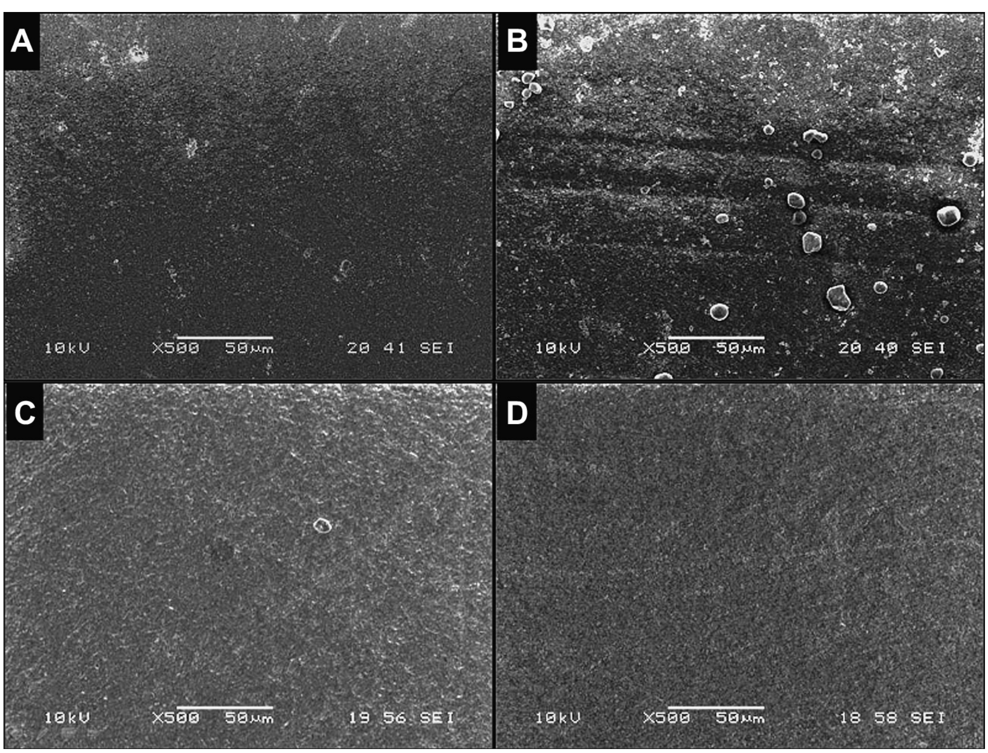

Figure 3 Surface of Dyract Extra specimen polished with different polishing systems on SEM examination (×500 magnification). (A) Control surface (Mylar strip); (B) polished with Sof-lex; (C) polished with Poli-pro disk; (d) polished with Hiluster^{Plus} system.

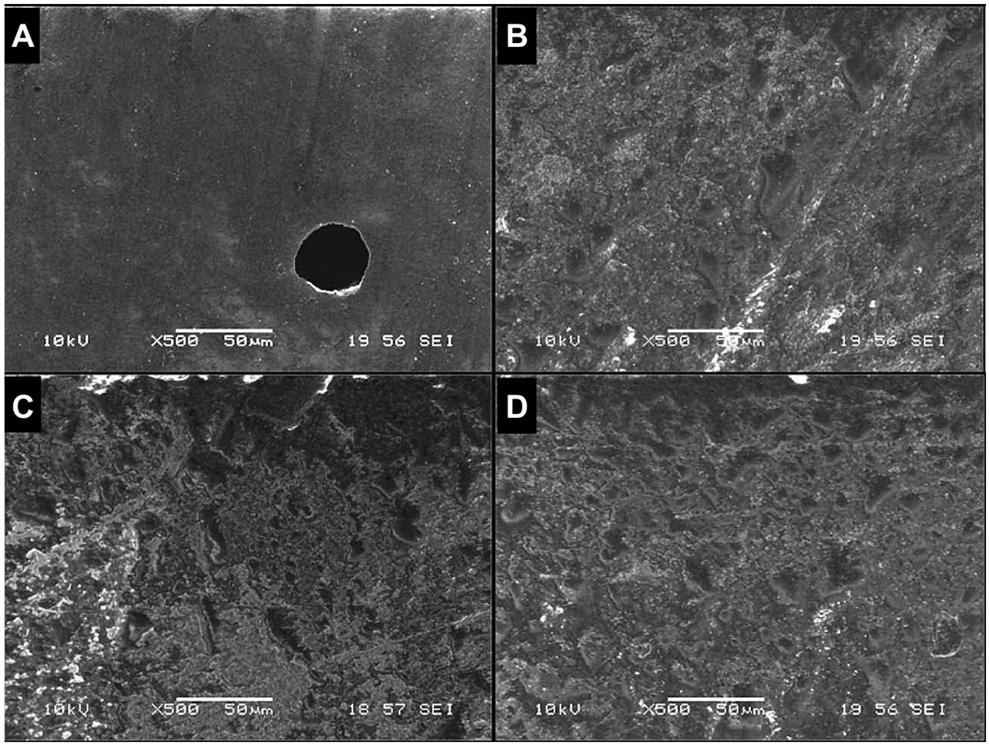

Figure 4 Surface of Gradia Direct specimen polished with different polishing systems on SEM examination (×500 magnification). (A) Control surface (Mylar strip); (B) polished with Sof-lex; (C) polished with Poli-pro disk; (D) polished with Hiluster^{Plus} system.

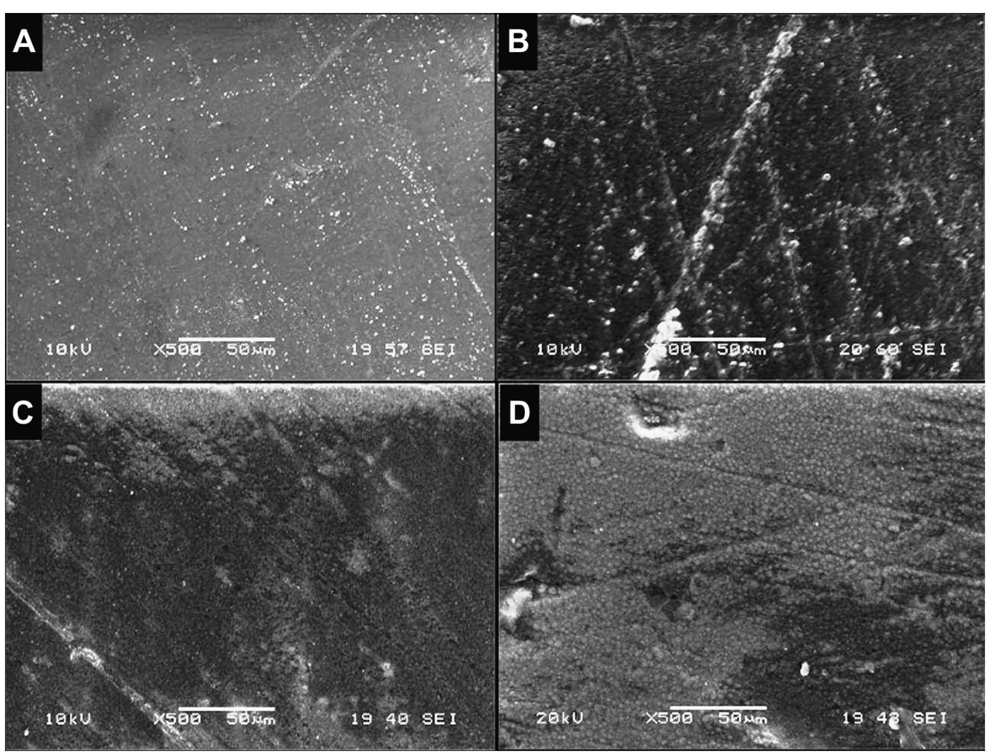

Figure 5 Surface of Filtek Supreme specimen polished with different polishing systems on SEM examination (×500 magnification). (A) Control surface (Mylar strip); (B) polished with Sof-lex; (C) polished with Poli-pro disk; (D) polished with Hiluster^{Plus} system.

as claimed by the manufacturers for use in dental applications.

The surface roughness property of a material is the result of interactions of multiple factors such as the filler (type, shape, size, and particle distribution), the type of resinous matrix, the ultimate degree of cure reached, and the bond efficiency at the filler/matrix interface.[15] Furthermore, a direct correlation was found between the hardness and surface roughness, indicating that a composite with a higher hardness value is usually associated with a higher surface roughness.[19]

GICs are heterogeneous and biphasic in nature. The set material consists of unreacted fluoroaluminosilicate glass particles embedded in a polysalt matrix. During finishing and polishing, the softer matrix phases are preferentially removed, leaving the harder, unreacted glass particles protruding from the surface. GICs with larger particle sizes are expected to be rougher after finishing and polishing. In the present study, the mean particle size of Fuji IX GP was 10 μm, and the large particle size of this material led to a significant increase in R_a values observed with all finishing and polishing procedures.

Compomers are basically composites and were introduced to the market in an attempt to combine the benefits of resin composites and GICs.[2] Gladys et al[27] pointed out that the better polish obtained with Dyract likely reflects its smaller filler particles and the absence of air bubbles. Among the tooth-colored materials investigated, Dyract Extra with the lowest percentage of filler by volume (50%) was found to have the lowest surface roughness. This difference in surface roughness can be attributed to differences in interparticle spacing and filler particle sizes. The average size of filler particles in Dyract Extra is 0.8 μm, and compared to the other tested resin composites, it has the same mean particle size, which may partially explain the lower roughness obtained with this tooth-colored restorative material.

Microhybrid composites contain particles that range 0.01—2 μm; therefore, these materials can be polished to a smoother surface than conventional composites containing larger filler particles.[19,28] The size of the aggregated filler particles of nanofil composite is 0.6—1.4 μm, and is clustered with 5—20- and 75-nm primary particles, which is similar to the filler size of microhybrid resin composites. In the present study, a smoother surface was achieved with the microhybrid resin composite compared to the nanofil resin composite, but the difference was not statistically significant. Thus, there must be another factor influencing the behavior of nanoparticle surfaces during polishing. Differences in surface texture among the composite resins tested can be attributed to differences in the size, hardness, and distribution of the fillers.[23] The roughness data after polishing correlated well with the filler content in terms of the weight and volume of the composite materials under investigation. Gradia Direct was smoother than the nanofil composite material; its volumetric filler content (77%) was far greater than the filler content of Filtek Supreme (59.5%). Thus, it could be expected that in microhybrid composites, a greater number of particles will be present on the surface, which will create a larger contact area with rotating instruments. Additionally, Filtek Supreme is composed of UDMA and high-molecular-weight Bis-EMA (ethoxylated bisphenol A glycol dimethacrylate) that form fewer double bonds resulting in a slightly softer matrix. This may allow exfoliation of some filler particles as the weak resin matrix is worn away during finishing and polishing procedures. Koh et al[28] investigated the surface roughness of Gradia Direct and Filtek Supreme resin composites and found that the surface smoothness of these materials did not significantly differ from each other after polishing, which is in agreement with the present study.

Finishing and polishing procedures require sequential use of instrumentation in order to achieve a highly smooth surface.[24] For a tooth-colored restorative material finishing system to be effective, abrasive particles must be relatively harder than filler materials. If this is not the case, the polishing system will only remove the soft resin matrix and leave the filler particles protruding from the surface.[19] The efficiency of finishing and polishing procedures with aluminum oxide-based abrasive devices for tooth-colored restorative materials was already proven.[6,16,28] However development of new types of dental composites involves the appearance of adapted polishers. Poli-pro disks by Premier Dental were chosen as a newly developed polishing system, which contains the same abrasive as Sof-Lex. The main difference is the safe centered mandrel that is completely covered by the disk. Also, a two-step disk-shaped polisher as in the Hiluster^{Plus} system which contains diamond particles was used to achieve a similar goal with a reduced number of finishing procedures.

Although the microstructure of tooth-colored restorative materials plays an inevitable role in the surface roughness, finishing and polishing systems also have very important effects. Therefore, differences in roughness values between materials could be dependent on the surface treatment. In the present study, the Hiluster^{Plus} system most frequently provided a smooth surface finish for most of the tooth-colored restorative materials investigated, followed by Sof-Lex and Poli-pro disks. The hardness of aluminum oxide is significantly higher than that most of the filler materials used in tooth-colored restorative material formulations.[23] The lowest mean R_a mean values obtained with Gradia Direct by Sof-Lex can be attributed to the particle size of the abrasives on the disk. They are made of aluminum oxide that gradually are exchanged from medium to superfine grains, resulting in a smooth surface. Additionally, this finishing/polishing disk system provided a relatively smoother surface for Fuji IX GP even though it was made up of large particle sizes (10 μm). This can be explained by the presence of harder aluminum oxide abrasives which can abrade the glass filler particles and softer matrix at an equal rate. Bouvier et al[29] reported that the smoothest compomer surface was obtained using graded aluminum oxide disks. Contrary to their findings, in the present study, the Hiluster^{Plus} system resulted in significantly smoother surfaces compared to the graded aluminum oxide disk systems (Sof-Lex and Poli-pro disks). The results of the present study indicated that the aluminum oxide disks (Sof-Lex and Poli-pro disk) produced a statistically equivalent rough surface finish with mean values ranging from 0.65 ± 0.24 to 2.05 ± 0.92 μm compared to the other tested polishing systems, regardless of the tooth-colored restorative used. This can possibly be attributed to the fact that compared to other polishing systems containing aluminum oxide particles, the flexible Hiluster^{Plus} polisher disk is the only polisher disk that contains fine diamond particles which resulted in better polishing. Diamond is harder than alumina; therefore, it may cause deeper scratches on the surface of the composites, resulting in higher roughness.[30,31] The reverse was found in this study; the use of aluminum oxide-integrated disks, followed by the diamond-integrated disks system (Hiluster^{Plus}), resulted in significantly smoother surfaces compared to the other polishing systems for both the Dyract Extra and Filtek Supreme specimens. However, alumina-based systems, such as Sof-Lex and Poli-pro disks, respectively represented the second and third best tools that produced a smooth surface after the Hiluster^{Plus} polishers. Aluminum oxide disks (Sof-Lex and Poli-pro disk) produced significantly higher surface roughness on Filtek Supreme specimens. Increased surface roughness of Filtek Supreme specimens might reflect the incomplete breakdown of aggregate fillers. The findings of the present study are in agreement with previous studies,[32,33] which also showed increased surface roughness of Filtek Supreme specimens using an aluminum oxide polishing system. In this study, the surface roughness analysis demonstrated that smoothness was independent of the use of a systematic series of instruments and polishing materials with smaller abrasive particle sizes.

The capacity of disks impregnated with aluminum oxide particles to achieve smooth surfaces is related to their ability to equally remove particles and the organic matrix. However, these systems have limitations due to their geometry. When using the disks, it is often difficult to efficiently create, finish, and anatomically polish contoured surfaces, specifically in the posterior regions of the mouth.[16,34]

In the present study, mean values of surface roughness ranged from 0.51 to 2.05 μm. It was reported that a surface roughness in the range of 0.2–0.6 μm is achievable using submicron polishing pastes on materials including submicron filler particles.[35] Specimens of the present study were finished without using polishing pastes which may partially explain the reason for the greater mean surface roughness values than the expected range (0.2–0.6 μm). However, Kaplan et al[36] reported that R_a values of <10 μm are clinically undetectable; thus, any system achieving a surface roughness of <10 μm is acceptable. With roughness values of <10 μm, the polished specimens of this study achieved an acceptable surface finish.

Profilometers are used to measure surface roughness for *in vitro* studies. Although profilometers provide limited two-dimensional information, the average roughness is arithmetically calculated and used in choosing treatments by offering various material/polishing surface combinations.[37] However, the complex structure of a surface cannot be fully characterized using surface roughness measurements alone. Thus, in addition to a quantitative evaluation by profilometry, surfaces of tooth-colored restorative materials were qualitatively analyzed by SEM in the present study.

According to the SEM photographs, the smoothest surfaces were achieved with the Mylar strip, except for Fuji IX GP, which exhibited air voids and many microcracks in the surface. For Fuji IX GP, all polishing systems produced a rougher surface than the Mylar strip specimens with protruding filler particles and consequently greater surface roughness as measured by the profilometer. SEM images revealed that the Sof-Lex system damaged the surfaces of Dyract Extra and Filtek Supreme specimens by dislodging particles and creating scratches. All polishing systems produced a thin filmlike deformed area, almost masking the filler particles, on the surfaces of Gradia Direct composite specimens. The Hiluster^{Plus} system produced a smooth surface on the Dyract Extra specimen similar to that obtained with the Mylar strip. The profilometric measurements were largely confirmed by the SEM analysis.

Under the conditions of this *in vitro* study, it was concluded that the effect of a finishing and polishing system on surface roughness is dependent on both the polishing system and the restorative material. However, the results of *in vitro* studies should be interpreted with caution since in clinical practice, the use of restorative materials and polishing systems may be limited to the accessibility and flatness of the surfaces to be finished, as most of the newest polishing systems are disk shaped. Further studies are needed to determine the most appropriate finishing technique in clinical practice when access is limited and restoration surfaces are not flat.

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