Effect of Finishing/Polishing Systems on the Surface Roughness of Novel Posterior Composites

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ABSTRACT

Purpose: The aim of this in vitro study was to evaluate and compare the surface finish of some direct posterior resin composites with new novel ones, which are based on a resin matrix other than the ordinary dimethacrylate, after fine finishing and polishing with eight different systems.

Materials and Methods: Forty-eight disk-shaped specimens of the posterior composites were prepared in a split Teflon mold and irradiated by an Astralis 10 light cure (560 mW/cm^2 for 10 seconds) at four quadrants on each sample's side. The specimens were divided into eight groups according to the designed finishing and/or polishing protocols. The surface roughness in the form of surface finish (Ra) was recorded using a contact profilometer. The surface of the specimens was observed under the scanning electron microscope.

Results: Analysis of variance revealed highly significant differences between the materials for the Ra roughness parameter at each finishing and polishing system used ($p < 0.05$). On the one hand, Filtek P90 (3M ESPE Dental Products, Seefeld, Germany) and Definite (Degussa, Dental Centrum, Hanau, Germany) provided the smoothest surface finish (Ra) when they were finished and polished with a series of Sof-Lex pop-on disks (3M ESPE Dental Products) and Astropol (Ivoclar Vivadent, Schaan, Liechtenstein), respectively. On the other hand, Filtek P60 (3M ESPE Dental Products) presented the roughest surface when it was finished with Fini disks (Jeneric/Pentron Clinical Technologies, Wallingford, CT, USA). Scanning electron microscope images indicated a uniform surface topography for Filtek P90 with most finishing/polishing systems. Contrary to CompoSite polishers (Shofu Inc., Kyoto, Japan), Astropol showed the smoothest surface finish with most of the investigated composites.

CLINICAL SIGNIFICANCE

The smoothest surface finish was achieved by most of the finishing/polishing systems investigated specifically on cationic (Filtek P90) and *or*ganically *mo*dified *ce*ramics (Definite) composites compared with dimethacrylate-based composites, suggesting their successful clinical use.

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INTRODUCTION

The main target of any developing esthetic restorative material, as posterior composite, is to have a durable restoration that can withstand function as well as a highly finished and polished surface that may contribute to a good appearance. Both finishing and polishing of resin composites are important procedures in restorative dentistry. Finishing refers to gross contouring of a restoration to obtain the desired contour.

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However, polishing refers to smoothness as well as to reduction of the scratches created by the finishing instruments.[1] It has been shown that the longevity and the maintenance of a restoration can be achieved by having a smooth, highly polished surface than a rough one.[2] Moreover, establishing a smooth-polished restoration can reduce plaque accumulation, thereby minimizing patient's discomfort from gingival irritation, surface staining, and development of secondary caries.

Various tools and techniques have been developed to obtain highly finished and polished surfaces of resin composite restorations. A variety of instruments provided by manufacturers can be classified into four categories: (1) coated abrasive disks and strips; (2) cutting carbide, diamond, and stones; (3) rubberized abrasives; and (4) loose particulate abrasives in the form of polishing pastes and powders.

Since the development of resin materials, several types of dental composites have been introduced into the market. The resin composites have been modified through improving the filler technology, resin matrices, and the adhesion between their two main components. Several attempts have been made to increase the filler content of the posterior composites in order to have a strong restoration that withstands the masticatory forces. Unfortunately, this method increases the surface roughness of the restoratives with the associated negative sequels.[3]

Several studies have been reported in the literatures evaluating the effect of various finishing and polishing systems on resin composites. On the material scale, it has been found that microfilled composites were appreciably smoother than the hybrid ones.[4] Another study showed that Sof-Lex disks (3M ESPE Dental Products, Seefeld, Germany) and Jiffy points produced the smoothest surfaces for the packable resin composites.[3] Early studies have shown that the smoothest surface finish of a resin restoration was attained when it was polymerized against a Mylar strip.[5] Moreover, a smooth surface finish was associated with anterior composites when they were polished with Super-Snap and Moore's disks, but comparable results were demonstrated in posterior composites.[6] However, finishing with diamond burs only showed a significantly higher surface roughness of packable and microhybrid composites.[7,8]

Recently, a novel cationic-posterior composite known as silorane has been developed with an assumption that it can be used in the posterior dental region. The silorane composite has a different resin chemistry from the commonly used dental composites that are based on dimethacrylate resin. The silorane is composed of two main components. The first one is siloxane, which is a hydrophobic part giving the stability of the material. The second part is oxirane, which is responsible for cationic polymerization reaction. This reaction is initiated by an acidic cation that allows cationic ring-opening expansion and stress relaxation, thereby reducing polymerization shrinkage of the composite.[9,10] *Or*ganically *mo*dified *ce*ramics (ormocer), however, is based on inorganic–organic hybrid polymers that are nearly as hard as glass aiming to reduce shrinkage and wear rate. It possesses a modified organic matrix formed by a monomer with a single polymerizable end and an alkoxy-inorganic group in the other end. The latter end can bond to other monomers through a condensation reaction by which monomer precursors are converted to a complex structure of polymeric inorganic condensates that are made at a nanoscale. This reaction results in a three-dimensional polymeric network allowing the incorporation of fillers in order to adjust the properties of the ormocer.[11] Therefore, the purpose of the current study was to evaluate and compare the effect of different finishing and polishing systems on the surface roughness of novel posterior resin composites.

MATERIALS AND METHODS

Materials

Six posterior resin composites examined in this study are listed in Table 1. Four dimethacrylate-based composites (Rok [VOCO, Cuxhaven, Germany], Filtek P60, Filtek Z250 [3M ESPE Dental Products] and X-tra fil [VOCO]), one cationic composite (Filtek P90, 3M ESPE Dental Products), and one ormocer (Definite, Degussa, Dental Centrum, Hanau, Germany) were investigated. The finishing and polishing systems used are tabulated in Table 2.

Methods

Specimen Preparation

A total of 48 disk-shaped samples (10-mm diameter × 2-mm thick) of the posterior composites were fabricated at room temperature in a split Teflon mold. The unpolymerized material was carefully packed inside the mold, which was rested on a glass plate (76 × 26 × 1-mm Surgipath glass). Both upper and lower surfaces of the unset specimen were covered with thin Mylar strips (KerrHawe Neos Dent, Bioggio, Switzerland). Then, another glass plate was pressed on top of it to remove the excess of the material, resulting in a flat surface finish.

The resin composites were irradiated by using an Astralis 10 light-curing unit (Ivoclar Vivadent, AG, Schaan, Liechtenstein) at 560 mW/cm^2 for 10 seconds. The polymerization of the disk was carried out at four quadrants on each top and bottom sides against the strip and glass plate, and then for another similar amount of irradiation but without the glass plates. The power density of the light-curing unit was periodically monitored with an external handheld radiometer (Demetron/Kerr, Danbury, CT, USA). The hardened specimens were then unmolded and lightly finished manually from one side after 24 hours from the preparation. This preliminary finishing step was carried out at 1,000 grit silicone carbide (SiC) abrasive paper under running water for 5 seconds. It will allow removal

TABLE 1. MANUFACTURERS' COMPOSITION OF THE POSTERIOR RESIN COMPOSITES.

Material	Code	Type	Shade	Type of filler	MPS (µm)	Filler (wt. %)	Resin matrix	Batch no.	Manufacturer
Filtek P90	F90	Cationic silorane	A2	Epoxy functional silane-treated SiO_2 and ytterbium fluoride	0.47	76	Silorane (oxirane and siloxane)	8AP	3M ESPE Dental Products, Seefeld, Germany
Definite	DF	Ormocer	A2	Ba_2SiO_4, SiO_2 modified apatite	1 to 1.5	77	Siloxane polymer Ormocer, dimethacrylate	01847	Degussa, Dental Centrum, Hanau, Germany
Filtek Z250	Z25	Microhybrid	A3	Zirconia/silica	0.01 to 3.5 Average 0.6	82	Bis-GMA, Bis-EMA, UDMA, TEGDMA	20041002	3M ESPE Dental Products, Seefeld, Germany
Filtek P60	F60	Packable	A3	Zirconia/silica (non-silanated)	0.01 to 3.5 Average 0.6	83	Bis-GMA, UDMA, Bis-EMA	20030411	3M ESPE Dental Products, Seefeld, Germany
X-tra fil	XF	Posterior hybrid	U	Multi-hybrid filler, Ba_2SiO_4	—	86	Bis-GMA, UDMA TEGDMA, BHT	541384	VOCO, Cuxhaven, Germany
Rok	RK	Posterior hybrid	A3	Multi-hybrid filler	0.04 to 2.5	82.3	Bis-EMA, UDMA TEGDMA	070967	VOCO, Cuxhaven, Germany

MPS = Mean Particle Size; Bis-GMA = bisphenol A glycol dimethacrylate; TEGDMA = Triethylene glycol dimethacrylate; BHT = Butylated Hydroxy Toluene.

TABLE 2. FINISHING AND/OR POLISHING SURFACE TREATMENT PROTOCOLS.

Surface treatment	Type	Composition	Batch no.	Manufacturer
Fini	Abrasive disks	Silicone carbide (medium), aluminum oxide (fine, x-fine)	49533	Jeneric/Pentron Clinical Technologies, Wallingford, CT, USA
Sof-Lex pop-on	Abrasive disks	Aluminum oxide Medium (40 µm), fine (24 µm), x-fine (8 µm)	P060821	3M ESPE Dental Products, Seefeld, Germany
Flexidisc/Flexiwheel	Abrasive disks/rubber wheel	Aluminum oxide Medium, fine, x-fine + rubber wheel (superfine pink)	34221	Cosmedent, Chicago, IL, USA
Optidisc/Hiluster polisher	Abrasive disks/rubber wheel	Aluminum oxide particles (medium, fine, x-fine) + silicone carbide and diamond rubber polishing wheel (superfine blue)	0086	KerrHawe Neos Dent, Bioggio, Switzerland
Astropol	Diamond-impregnated polishers	Caoutchouc, silicone carbide, aluminum oxide, titanium oxide, iron oxide (coarse gray [45 µm], fine green [1 µm]), Caoutchouc, silicone carbide, aluminum oxide, titanium oxide, iron oxide, diamond dust (extra-fine-pink [0.3 µm])	14545	Ivoclar Vivadent, Schaan, Liechtenstein
CompoSite polishers	Shofu abrasives	CompoSite (aluminum oxide 40 µm), CompoSite Fine (zirconium oxide 25 µm)	0291	Shofu Inc., Kyoto, Japan
Enhance	Aluminum oxide-coated wheel	Aluminum oxide—silicone dioxide finishing wheel-impregnated UDMA (40 µm), Prisma gloss polishing paste fine (1 µm) and x-fine (0.3 µm)	060511	Dentsply DeTrey GmbH., Konstanz, Germany
Occlubrush	Regular cup polisher bristles	Silicone carbide	0120	KerrHawe Neos Dent, Bioggio, Switzerland

of a weak resin-rich layer and having a standard finished surface before the application of different finishing/polishing systems. Then, they were stored in dark bottles containing distilled water at 37 ± 0.5°C for 1 week.

Finishing/Polishing Protocols and Group Organization

Following the storage period, the specimens were divided into eight groups and randomly allocated according to one of the finishing and/or polishing protocols that are used (Table 2). The first and second groups (abrasive disks of Sof-Lex pop-on [3M ESPE Dental Products] and Fini [Jeneric/Pentron Clinical Technologies, Wallingford, CT, USA], respectively) involved three grits system sequentially starting from medium, fine to extra-fine or superfine. The third and fourth groups utilized three grits system of abrasive disks followed by one rubber polisher (Flexidisc/Flexiwheel [Cosmedent, Chicago, IL, USA] and Optidisc/Hiluster [KerrHawe Neos Dent] polishers). The fifth and sixth groups had a rubber wheel polisher system, three abrasive polishers for Astropol (Ivoclar Vivadent) and two polishers for CompoSites (Shofu Inc., Kyoto, Japan). The seventh and eighth groups involved a finishing foam wheel-impregnated UDMA (Urethane dimethacrylate) with two polishing paste systems (Enhance, Dentsply DeTrey GmbH, Konstanz, Germany) and a one-step polishing system (Occlubrush, KerrHawe Neos Dent), respectively.

All finishing and polishing procedures were accomplished wet with a low-speed handpiece at 10,000 rpm speed for 10 seconds each step under light uniform intermittent pressure in a circular pattern. The finishing or polishing tool was subsequently discarded after its use with each material. Then, the specimens were thoroughly rinsed with distilled water and air-dried before starting the next finishing or polishing step.

Experimental Surface Roughness Measurement Procedures

At the completion of the finishing and polishing instrumentation, the specimens were ultrasonically cleaned in distilled water. Afterward, the examined surface was assessed for any defects or scratches by stereomicroscope (Meiji Techno America, San Jose, CA, USA). The surface roughness was measured by using a contact profilometer (Surfcorder SE 1700, Kosaka Corp., Tokyo, Japan) equipped with a 5-µm radius diamond-tipped stylus that was attached to a pickup head. The stylus traversed the surface of the specimen at a constant speed of 0.5 mm/second with a force of 4 mN and automatic return. Each specimen was traced in four parallel locations near the center across the finished and/or polished surface with an evaluation length of 4 mm. The data were filtered with a cut off (λc) of 0.8 mm (Gauss profile filter), and the tracings were 0.8 mm in length because the standard JIS94 was selected as a measuring profile. Leveling of all parts of the apparatus was achieved by adjusting the pickup head knob.

All preparation of specimens and finishing/polishing procedures were performed by only one operator to minimize the bias. A calibration block was used periodically to check the performance of the profilometer. The surface roughness parameter values were monitored on a computer. The overall roughness of the surface, which is called *surface finish* (Ra), was measured. It is defined as the arithmetical average height of surface component irregularities (the absolute distance of the roughness profile) from the mean line within the measuring length.

The data were statistically analyzed by SPSS software (Version 11.5, SPSS Inc., Chicago, IL, USA) and graphically plotted utilizing Sigma (Σ) Plot Version 8.0 software. A two-way analysis of variance (ANOVA) was calculated for the differences between the two independent variables ($p < 0.05$). If there is a significant interaction between them, then one-way ANOVA and post hoc Scheffe's test were used to detect specific differences between the surface roughness values within the materials as well as finishing/polishing systems ($p < 0.05$).

Scanning Electron Microscope Evaluation

Additionally, after the use of each finishing/polishing system, the finished surfaces of the specimens were gold sputter-coated to a thickness of approximately 60 Å in a vacuum evaporator with auto fine coater (JFC-1600, Joel, Tokyo, Japan). The surface topography of some of the specimens was examined under the scanning electron microscope (SEM) (JSM 6360LV, Joel) at a magnification of 700 and 1,500× and an accelerating voltage of 20 kv.

RESULTS

The mean values and standard deviations of surface roughness parameter Ra (µm) for each resin composite are summarized in Table 3 and presented graphically in Figure 1. Two-way ANOVA showed a high significant difference of the Ra roughness parameter among the examined posterior composites and the eight finishing/polishing systems ($p = 0.000$). Also, there was a high significant interaction between these two independent variables ($p = 0.000$). Therefore, the surface finish of the material was treatment-group dependent, and one-way ANOVA was used to analyze the significant differences. One-way ANOVA revealed highly significant differences between the materials for the Ra surface roughness parameter at each finishing and polishing system ($p < 0.05$).

The smoothest surface (Ra) was observed in Filtek P90 and Definite when they were finished and polished with a series of Sof-Lex pop-on disks (0.130 µm) and Astropol (0.133 µm), respectively. However, the roughest surface was noted in Filtek P60 when

TABLE 3. MEAN (SD) OF ARITHMETIC SURFACE ROUGHNESS Ra (μm) FOR THE POSTERIOR COMPOSITES.

Material	Surface roughness (Ra) mean and SD (μm) after using different finishing /polishing systems							
	Fini	Sof-Lex pop-on	Flexidisc/Flexiwheel	Optidisc/Hiluster polisher	Astropol	CompoSite	Enhance	Occlubrush
Filtek P90	0.256 (0.093)^{b,c,d}	0.130 (0.024)^{a}	0.154 (0.007)^{a,b}	0.208 (0.037)^{a,b,c}	0.190 (0.060)^{a,b,c}	0.335 (0.022)^{d}	0.150 (0.011)^{a}	0.266 (0.076)^{c,d}
Definite	0.287 (0.054)^{c,d}	0.225 (0.016)^{b,c}	0.267 (0.037)^{c,d}	0.177 (0.018)^{a,b}	0.133 (0.015)^{a}	0.316 (0.031)^{d}	0.170 (0.051)^{a,b}	0.277 (0.051)^{c,d}
Filtek Z250	0.307 (0.085)^{d}	0.286 (0.031)^{c,d}	0.271 (0.010)^{b,c,d}	0.208 (0.046)^{a,b,c}	0.166 (0.021)^{a}	0.330 (0.037)^{d}	0.203 (0.015)^{a,b}	0.205 (0.012)^{a,b,c}
Filtek P60	0.544 (0.095)^{c}	0.379 (0.073)^{b}	0.158 (0.019)^{a}	0.208 (0.049)^{a}	0.183 (0.010)^{a}	0.505 (0.041)^{c}	0.146 (0.007)^{a}	0.226 (0.038)^{a}
X-tra fil	0.256 (0.020)^{a}	0.248 (0.015)^{a}	0.395 (0.017)^{c,d}	0.334 (0.014)^{a,b,c}	0.321 (0.075)^{a,b}	0.331 (0.030)^{d}	0.305 (0.054)^{a,b}	0.382 (0.057)^{c,d}
Rok	0.335 (0.041)^{c}	0.188 (0.021)^{a}	0.346 (0.028)^{c}	0.342 (0.075)^{c}	0.287 (0.067)^{b,c}	0.317 (0.019)^{c}	0.284 (0.063)^{b,c}	0.213 (0.002)^{a,b}

Superscript letters indicate homogenous subsets (within which $p > 0.05$) where comparison has been made with respect to finishing/polishing systems for each posterior composite.

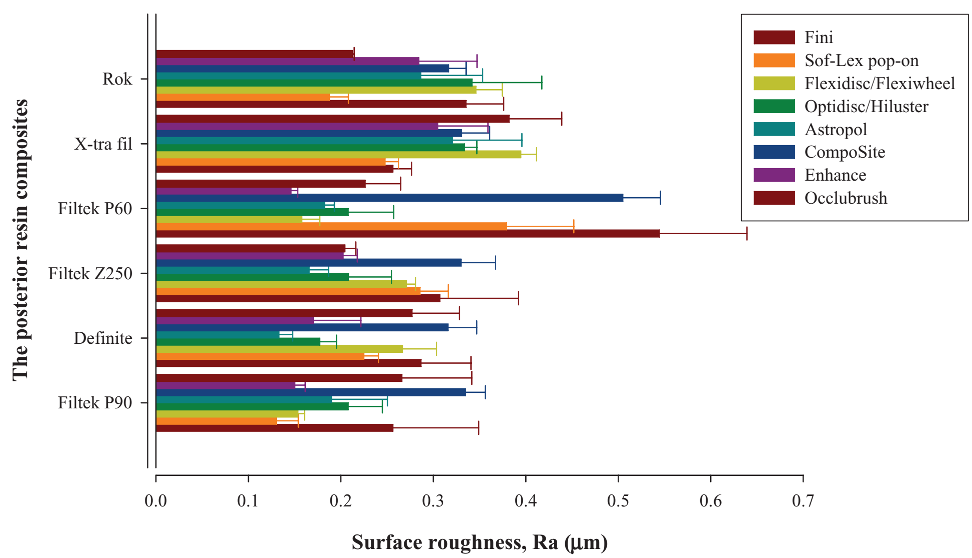

Figure 1. Surface roughness finish (Ra) of each posterior resin composite at a given finishing/polishing system.

it was finished with Fini disks (Jeneric/Pentron Clinical Technologies) (0.544 μm). SEM analysis showed a good agreement of these profilometric data, as shown in Figures 2 through 4, where smooth surface texture without striations was observed in Filtek P90, whereas surface scratches and striations were evident in Filtek P60. Among the examined composites, Filtek P90 provided the smoothest surface finish with a wide range of the tested finishing and polishing systems, such as Sof-Lex pop-on, Flexidisc/Flexiwheel, Astropol, and Enhance. On the contrary, X-tra fil showed the most frequent rough material when it was finished and polished with Flexidisc/Flexiwheel, Optidisc/Hiluster polisher, Astropol, Enhance, and Occlubrush. These results were correlated well with some randomly selected scanning electron micrographs, which showed plucked out and exposed large filler particles of X-tra fil (Figure 5).

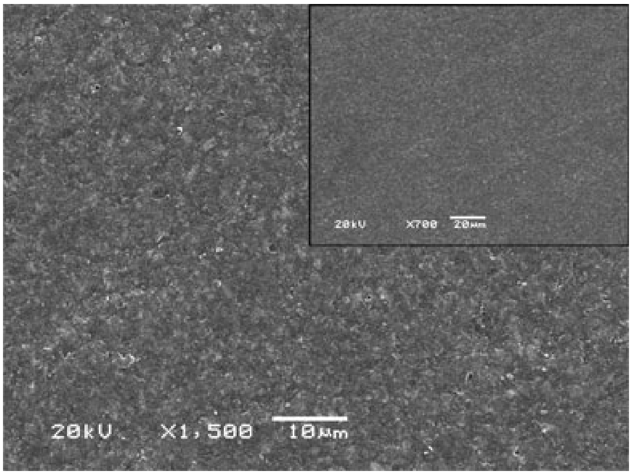

Figure 2. Scanning electron microscpe image of Filtek P90 finished by Sof-Lex disk pop-on system.

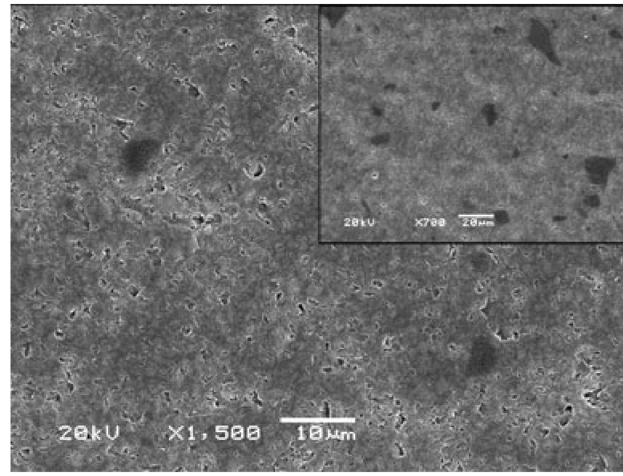

Figure 3. Scanning electron microscope image of Definite finished by Astropol system.

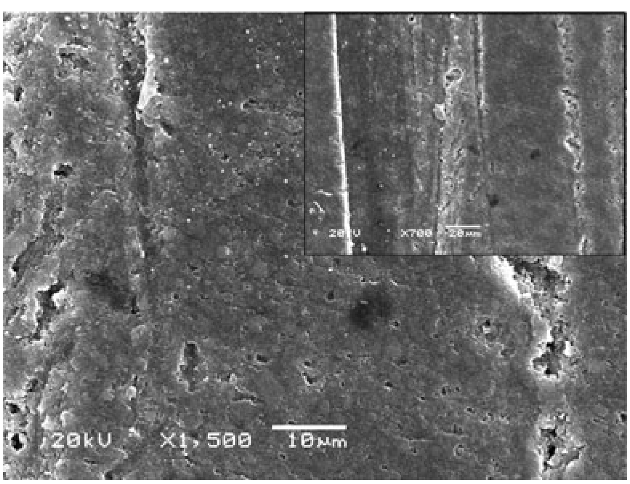

Figure 4. Scanning electron microscope image of Filtek P60 finished by Fini system.

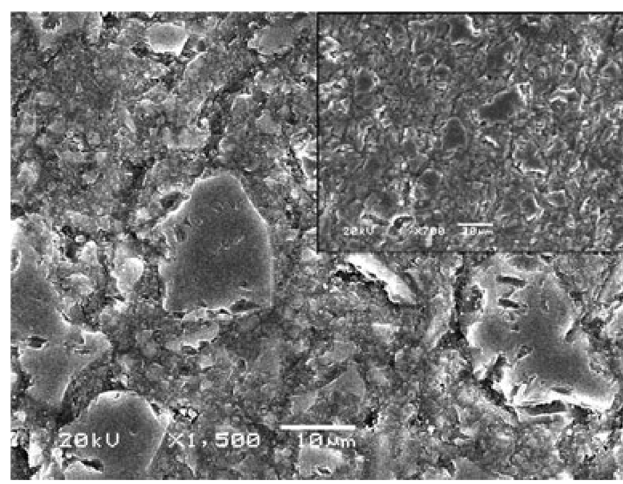

Figure 5. Scanning electron microscope image of X-tra fil finished by Flexidisc/Flexiwheel system.

A trend of low surface roughness was noted with aluminum oxide disks rather than with a rubber polisher made of zirconium dioxide. The Astropol polishers showed the smoothest surface finish (Ra ranged between 0.133 and 0.321 µm) for most of the posterior resin composites investigated, followed by Enhance (Ra ranged between 0.150 and 0.305 µm), and then Sof-Lex pop-on system (Ra ranged between 0.130 and 0.379 µm). On the other hand, CompoSite rubber polishers expressed the roughest surface finish, followed by Fini, and then Occlubrush polishers. The abrasive finishing disks that were followed by rubber polishers (Optidisc/Hiluster polisher and Flexidisc/Flexiwheel) demonstrated the intermediate roughness value (Ra) that ranged between 0.154 and 0.395 µm.

DISCUSSION

Finishing and polishing procedures require a sequential use of instrumentation in order to achieve a highly smooth surface.[12] In the current study, a graded abrasive system that ends gradually with a smaller grain size was selected to obtain an optimum surface finish. Also, a one-step polisher as in Occlubrush was used to achieve a similar goal but with a minimal number of finishing procedures. Moreover, the surface finish that was obtained by the Mylar strip was not used as a control group. Although the surface finish produced by the Mylar strip is perfectly smooth, it is resin-polymer rich and may contain some voids.[13] Therefore, removal of the outermost resin by finishing it lightly with 1,000 grit SiC abrasive paper is essential to produce a relatively standard and stable surface. It has been shown that removal of this superficial layer will increase the wear resistance of the surface.[14] All specimens tested were submitted to the same parameters of light-curing method and initial finishing. The experimental finishing and polishing procedures were kept to a minimum time, 10 seconds for each step, as they are inherently destructive to the restoration and may lead to micro-cracks formation.[15] These materials were selected because they had different filler and resin matrix compositions as well as superior properties, as claimed by manufacturers, to be used as posterior restoratives.

The surface roughness property of any material is the result of the interaction of multiple factors. Some of them are intrinsic that are related to the material itself, such as the filler (type, shape, size, and distribution of the particles), the type of resinous matrix as well as the ultimate degree of cure reached, and the bond efficiency at the filler/matrix interface.[2] Furthermore, a direct correlation was found between the hardness and the surface roughness, indicating that a composite with a higher hardness value was usually associated with a higher surface roughness.[16] Other factors are extrinsic that are associated with the type of polishing system used, such as the flexibility of the packing material in which the abrasives are embedded, the hardness of abrasives, the geometry of instruments, the light-curing method, and the way by which the finishing tools are used.

In this study, the average roughness (Ra) values ranged from 0.130 (0.024) for Filtek P90 to 0.544 (0.095) for Filtek P60. The Filtek P90 and Definite yielded the lowest Ra values after the finishing/polishing procedures. These values were below the critical threshold value of 0.2 µm, which allows plaque accumulation. So the surface roughness may be clinically relevant as the Ra values were above this critical threshold.[17] The lower surface roughness of these two materials may be attributed to their composition. Among the materials investigated, both composites comprise low filler content by weight (76–77%). The former composite is characterized by a special resin matrix made up of silorane, which is polymerized cationically by a ring-opening expansion mechanism.[9,10] This expanded network is based on oxirane and siloxane backbones. Siloxane exhibits a more stable chemical structure, as it is conjugated with a silicone atom.[18] Furthermore, it has a relatively smaller filler particle size (0.47 µm) that may also contribute to the low surface roughness value.

The latter composite is an ormocer that has a distinct siloxane polymer made of a multifunctional polycondensate matrix. It consists of an inorganic–organic backbone based on SiO_2 functionalized with polymerizable organic units formed by polycondensation.[11] The filler particles that are made of barium glass and silica are embedded into this cross-linked inorganic–organic network matrix.[19] A combination of the complex novel network matrix and small filler particles giving a hard structure may result in its superior surface finish. This is in agreement with previous studies that found that composites based on ormocer were significantly smoother than those based on microfilled or hybrid.[20–22] As the filler content and size play a major role in surface roughness, the resin matrix composition may also have a substantial effect on the final smoothness of the restoration. The degree of cure of the silorane- and ormocer-based matrices might influence the surface texture of these novel posterior composites.[23]

Moreover, X-tra fil, and then Rok, presented the most frequent rough materials with a wide range of finishing/polishing systems that are used. The high filler volume fraction and the larger filler size of both composites may contribute to their high surface roughness. It was previously found that larger filler particles of hybrid composites could be a possible consequence of increased surface roughness.[24]

The posterior packable hybrid composite, Filtek P60, expressed the highest surface roughness among the materials examined when it was finished by Fini disk and CompoSite polisher. This material exhibited an average particle size of 0.6 µm with a range of 1 to 3.5 µm and a filler loading of 82% wt. It has been noted that the largest particles present in the composites contribute more to the surface roughness than do the average particle size.[25] Additionally, it comprises UDMA and high molecular weight Bis-EMA (Ethoxylated bisphenol A glycol dimethacrylate) that form fewer double bonds resulting in a slightly softer matrix.[25] Another possible explanation could be related to the deficiency of coherence between the matrix and the fillers yielded from non-silanization of the latter. This may cause exfoliation of some filler particles as the weak resin matrix is worn away during finishing and polishing procedures. Dislodgment of larger filler particles is usually associated with preferential loss of the resin, which is unable to adequately stabilize these particles, causing detectable surface irregularities, thereby increasing the Ra value.[26]

Although the microstructures of composites play an inevitable role in their surface roughness, finishing and polishing systems also have a more important effect. Therefore, differences in roughness values between materials could be surface-treatment dependent. In this study, Astropol showed the most frequent tool in providing a smooth surface finish with most of the composites investigated, followed by Enhance, and then Sof-Lex pop-on system. A contradictory result was presented by another study that showed the reverse of the previous ranking order of the instruments in achieving a smooth surface finish.[27] This occurred when they were used specifically with microfilled and microhybrid composites. Another study found that aluminum oxide disks provided a smoother surface than rubber polishers in several resin composites examined. However, the same study showed that the rubber polishers provided a significantly smoother surface with highly filled composites such as Filtek P60.[25] A possible explanation of these variations could be the finishing procedures that were utilized. Most investigators have concluded that flexible aluminum oxide disks are the best instruments for providing low roughness values of most dental composites.[16,28]

The lowest Ra mean value obtained in Filtek P90 by Sof-Lex pop-on disk can also be attributed to the particle sizes of the abrasives on the disk. They are made from aluminum oxide that can be exchanged gradually from medium to superfine grains, resulting in a smooth surface. Additionally, this finishing disk system provided a relatively smoother surface for Rok composites even though it was highly filled and made of multi-filler sizes that ranged from 0.04 to 2.5 µm. It may be explained by the presence of the harder aluminum oxide abrasives, which can abrade the filler particles and the softer resin matrix at an equal rate. This is in concurrence with a previous finding that demonstrated a smooth surface when the hybrid composites were finished by Sof-Lex disks.[29] The hardness of aluminum oxide and SiC is significantly higher than that of silicone dioxide, and generally higher than most filler particles used in composite formulation.[30] In general, for the finishing system to be effective, the abrasive grit particles should be relatively harder than the filler material. Otherwise, the finishing tool only removes the soft resin matrix, leaving the filler particles protruded.[24,31]

Also, the ormocer (Definite) presented a smooth surface finish by Astropol polishers. It can be explained by the presence of multigrain types of caoutchouc, silicone oxide, aluminum oxide, titanium oxide, iron oxide, and diamond dusts impregnated into the polishers. However, a contradictory result was presented by another study that showed that a significantly rough surface of microhybrid composites was expressed by Astropol polishers.[32]

In the current study, data revealed that the aluminum oxide and diamond pastes of Enhance as well as the silicone-impregnated polisher in the form of Astropol produced a smooth surface for most composites examined except X-tra fil. The micro-polisher disk of Enhance is made from a flexible rubber-like material into which a light-cured UDMA resin is impregnated with an abrasive. This polishing system may contribute to the smoothest surface finish of Filtek P90, Filtek P60, and Definite composites. High surface polish of microfilled and hybrid composites by Enhance polishing system was previously reported.[12] However, the high roughness value of X-tra fil produced by this system can be explained by the fact that the abrasives may abrade the minimum amount of resin matrix available in this composite, leaving the large filler particles protruding. Furthermore, it was demonstrated that using polishing paste following abrasive-impregnated finishing disk did not greatly improve the surface smoothness of the composite materials.[33]

CompoSite demonstrated the most frequent rough polishers for a wide range of the materials investigated. This can be attributed to the presence of hard abrasive grains made of zirconium oxide impregnated in the polisher component. This finding is consistent with the results obtained by previous studies.[34,35] However, rubber polishers were found to be effective on microfilled and, possibly, on some microhybrid composites.[16]

The extra-fine rubber polisher of Astropol has more diamond-impregnated dusts, whereas Sof-Lex pop-on utilizes alumina as abrasive particles. Diamond is always harder than alumina, thereby, it may cause deeper scratches on the surface of the composites, resulting in high roughness.[30,36] The reverse was found in this study; Astropol produces the smoothest surface on most of the materials except the highly filled ones, X-tra fil and Rok. However, alumina-based systems, such as Sof-Lex pop-on and Flexidisc/Flexiwheel, represented the third tool that produces a smooth surface after Astropol and Enhance polishers. This result is in contradiction with a previous finding.[32] However, in another study, it was noted that there were no significant differences between Astropol and Sof-Lex.[7] Therefore, the hardness difference among various composites as well as between finishing/polishing abrasives may have an effect on the surface roughness. The current study could provide a clue of which finishing and/or polishing system is the best to each resin composite investigated.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions can be made:

1. Surface roughness is affected by both the material composition and polishing system used.
2. Posterior composites (X-tra fil and Filtek P60) based on larger

filler particle sizes and high filler content result in higher Ra values.
3. Filtek P90 silorane composite based on cationic polymerization and having a relatively small filler size and low filler volume fraction expressed the lowest Ra value among the materials investigated.
4. Definite ormocer composite based on unique, organically modified ceramics of polycondensate organic–inorganic oligomers also exhibited the smoothest surface finish with Astropol polishing series.
5. The most frequent finishing/polishing system that results in high surface roughness of the examined materials was CompoSite polisher, whereas the most frequent one that produces a smooth surface finish was Astropol.

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