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Original Paper

Effect of one-step polishing systems on surface roughness of different flowable restorative materials

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The purpose of this study was to investigate the influence of one-step polishing systems on the surface roughness of different flowable composites and a microhybrid composite. A total of 120 disks were fabricated and divided into six groups according to the different composite restorative materials tested (n=20). Each group was further divided into four subgroups according to the polishing system (n=5). For the control group, samples were left undisturbed after removal of Mylar strip. For the other three subgroups, samples were polished with PoGo, OptraPol, or Sof-Lex disks. Surface roughness was determined using a profilometer and observed under scanning electron microscope (SEM). Data were analyzed by one-way ANOVA and Duncan's multiple range test. For Tetric Flow, Grandio Flow, Filtek Supreme XT Flow, and Admira Flow, their lowest surface roughness values were obtained in Mylar Strip and PoGo groups. For Compoglass Flow, there were no significant differences between Mylar Strip, PoGo, and OptraPol. For Filtek Z250, the lowest surface roughness value was obtained with Mylar Strip. In light of the surface roughness results obtained, one-step polishing systems seemed to be a good choice for polishing flowable composites.

Key words: Polishing, Surface roughness, Flowable composite

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INTRODUCTION

The introduction of flowable composites provides new, expanded options for restorative procedures. A key characteristic of flowable composites is the reduced filler volume. In parallel, the resin content is increased, thereby leading to a reduced viscosity of the mixture[1]. Flowable composites were developed in response to requests for special handling properties rather than for any clinical performance criteria; as such, their limitations are unknown[1]. Nonetheless, flowable composites may be used for resurfacing composite or glass ionomer restorations or for rebuilding worn composite contact areas[1]. Of late, many dentists have accepted flowable composites for a wide variety of clinical applications[2]. This could be ascribed to the application of nanotechnology to resin composites — one of the most important advances and breakthroughs in the field of dentistry in the last few years. A new class of composite materials resulting from nanotechnology research and application are the nano-flowable composites.

The esthetic aspect of tooth-colored restorative materials is partly dependent on surface roughness[3]. A rough surface increases plaque retention, which may then result in gingival inflamation, superficial staining, secondary caries, and color change[4]. On the contrary, smooth, highly polished restorations have been shown to be more easily maintained than restorations with rougher surfaces[5,6].

On the surface finishing of tooth-coloured restorative materials, a variety of finishing and polishing procedures are commonly used — such as carbide burs and diamond points, abrasive disks, abrasive finishing strips, and polishing pastes[4,7-9]. For the polishing of resin-based composite restorations, a set of highly flexible, polyurethane-based finishing and polishing disks coated with aluminum oxide particles are widely used[9]. Recently, systems that utilize diamond polishers were introduced to reduce the clinical time for restorative procedures. These are known as one-step polishing systems because contouring, finishing, and polishing can be completed using a single instrument and which meet the clinical criteria in achieving a smooth surface in minimal amount of time[10,11]. Amongst which is PoGo, which is a one-step diamond micro-polisher. Besides, OptraPol is a recently introduced one-step high-gloss polishing system for composite resins, and which is a special mixture of silicones as well as a specific composition and distribution of abrasive particles.

Although the surface finish of composites, compomers, conventional and resin-modified GICs has been widely investigated both *in vitro* and *in* *vivo*[12-16], information about the quality of surface finish of flowable composites is scarce and limited. Therefore, the purpose of this *in vitro* study was to investigate the influence of two one-step polishing systems, *versus* a multi-step disk-based polishing system, on the surface roughness of five different flowable composites and a microhybrid composite.

MATERIALS AND METHODS

Composite materials and polishing systems

Five flowable composites, Tetric Flow; Grandio Flow; Admira Flow; Compoglass Flow, and Filtek Supreme XT Flow, and a microhybrid composite Filtek Z250, were used in this study. Table 1 shows the properties of these materials.

The finishing and polishing systems evaluated were PoGo, OptraPol, and Sof-Lex Pop-On disks. Table 2 lists the compositions and manufacturers of the polishing systems tested.

Specimen preparation

A total of 120 specimens for all the six restorative materials (n=20 for each restorative material group) were fabricated using a plexiglass well (10 mm diameter, 2 mm thickness), covered with a Mylar matrix strip, and pressed flat with a microscope glass slide. Restorative materials were polymerized according to manufacturers' instructions using a halogen curing light (Optilux 501, Kerr Corp., Orange, CA, USA) with the Mylar strip (SS White Co., PA, USA) on top of the specimens. The curing light was placed perpendicular to the specimen's surface at or less than a distance of 1.0 mm. Curing night intensity was measured at 620 mW/cm^2 and monitored with a light meter.

Specimens were examined for obvious voids, labeled on the bottom, and randomly separated into

Table 1 Charactheristics of the composite restorative materials tested

Restorative material	Material category	Manufacturer	Composition	Filler content (vol%)
Tetric Flow	Flowable Microhybrid Composite	Ivoclar-Vivadent, Schaan, Liechtenstein	Barium glass, ytterbium trifluoride, Ba-Al-fluoro-silicate glass, highly dispersed silicon dioxide, spheroid mixed oxide, Bis-GMA, UDMA, TEGDMA	43.8
Grandio Flow	Flowable Nanohybrid Composite	Voco, Cuxhaven, Germany	silicium dioxide, glass ceramic particles Bis-GMA, TEGDMA, HEDMA	65.6
Admira Flow	Flowable Ormocer	Voco, Cuxhaven, Germany	Barium-aluminium-boro-silicate glass, silicone dioxide ormocers, Bis-GMA, UDMA, TEGDMA	50.5
Compoglass Flow	Flowable Compomer	Ivoclar-Vivadent, Schaan, Liechtenstein	Mixed oxide silanized, ytterbiumtrifluoirde, Bs-Al-Flurosilikateglass silanized, catalysts, stabilizers, pigments, UDMA, PEGDMA, cycloaliphat. dicarbonic acid dimethacrylate,	41.8
Filtek Supreme XT Flow	Flowable Nanofill Composite	3M ESPE, St. Paul, MN, USA	Non-agglomerated/non-aggregated 75nm silica nanofiller; non-agglomerated/non-aggregated 15-20nm ziriconia nanofiller and loosely bound agglomerated zirconia/silica nanocluster, consisiting of agglomerates of 5-20 nm primary zirconia/silica particles, Bis-GMA, TEGDMA, Bis-EMA	55
Filtek Z250	Microhybrid Composite	3M ESPE, St. Paul, MN, USA	Zirconia/silica particles, Bis-GMA, UDMA, Bis-EMA	60

Bis-GMA: bis-phenol A diglycidylmethacrylate
TEGDMA: triethyleneglycol dimethacrylate
HEDMA: hexanediol dimethacrylate
UDMA: urethane dimethacrylate
PEGDMA: polyethyleneglycol dimethacrylate
Bis-EMA: bis-phenol A polyethoxylated dimethacrylate

Table 2 Compositions and manufacturers of the polishing systems tested

Polishing system	Composition	Manufacturer
PoGo (One-Step)	Polymerized urethane dimethacylate resin, fine diamonod powder, silicon oxide (20 μm)	Dentsply/Caulk, Milford, DE, USA
OptraPol (One-Step)	Caoutchouc, silicon carbide, aluminum oxide, titanium oxide, iron oxide (12 μm)	Ivoclar-Vivadent, Schaan, Liechtenstein
Sof-Lex Pop-On Discs (Multi Step)	Medium aluminium oxide disc (40 μm) Fine aluminium oxide disc (24 μm) Ultra-fine aluminium oxide disc (8 μm)	3M ESPE, St. Paul, MN, USA

four treatment subgroups (n=5). Except for the Mylar strip groups, specimens in the other three subgroups were wet-ground with 1200-grit silicon carbide paper on a metallurgical finishing wheel to provide a baseline before applying the polishing systems.

Treatment Subgroups

Procedural details of the four treatment subgroups in this study, Groups A to D, are given as follows.

Group A (control): Mylar strip (no application).

Group B (PoGo): The flat, broad surface of PoGo's diamond micro-polisher disk was first applied using light hand pressure, followed by a gentle buffing motion for 30 seconds at 15.000 rpm with a low-speed handpiece.

Group C (OptraPol): The same procedure in Group B was performed on specimens in OptraPol group.

Group D (Sof-Lex): Sof-Lex Pop-On disks at medium, fine, and super-fine grits were used for 30 seconds each on the specimens. After each step of polishing, the specimens were throughly rinsed with water and air-dried before the next step until final polishing.

To reduce variability, the preparation, finishing and polishing pocedures of all specimens were performed by the same operator. All polishing materials — disks and diamond or silicon polishers — were discarded after use. After polishing, the specimens were stored at deionized water for 24 hours.

Surface roughness measurement

Surface roughness test was performed with a contact profilometer (Perthometer M1, Mahr GmbH, Göttingen, Germany). Three successive measurements in different directions were recorded for all specimens in each group, and the avarage surface roughness (Ra) value thereof obtained. The cut-off value for surface roughness was 0.25 mm, and the sampling length for each measurement was 1.25 mm.

Statistical analysis

Mean values and standard deviations were determined. Data were analyzed using two-way ANOVA and one-way ANOVA at a significance level of 0.05 for surface roughness results. Multiple comparison test was performed using Duncan's multiple range test.

Scanning electron microscopy analysis

One representative specimen of each group was prepared for scanning electron microscopy (SEM; JSM 6400, JEOL, Tokyo, Japan) analysis. Specimens were sputter-coated with gold to a thickness of approximately 200Å in a vacuum evaporator. Photographs of representative areas of the polished surfaces were taken at ×500 magnification.

RESULTS

Surface roughness measurement

Two-way ANOVA found the interaction effect to be statistically significant ($p<0.05$). Therefore, instead of using two-way ANOVA to examine the effects of material and polishing system, one-way ANOVA was used. Table 3 lists the average surface roughness values and standard deviations produced by Mylar strip, OptraPol, PoGo, and Sof-Lex disks on five flowable composites and one microhybrid composite.

For Tetric Flow, Grandio Flow, and Admira Flow, the ranking of surface roughness values from the lowest to the highest were as follows: Mylar Strip = PoGo < OptraPol < Sof-Lex ($p<0.05$).

For Compoglass Flow, there were no statistically significant differences between Mylar Strip, PoGo, and OptraPol ($p>0.05$). On the other hand, Sof-Lex showed significantly higher surface roughness values than Mylar Strip, PoGo, and OptraPol ($p<0.05$).

For Filtek Supreme XT Flow, no significant differences were observed between Mylar Strip and PoGo ($p>0.05$), as well as between PoGo and OptraPol ($p>0.05$). However, OptraPol showed statistically significant difference from Mylar Strip ($p<0.05$). Similarly, Sof-Lex exhibited significantly higher surface roughness values than Mylar Strip, PoGo, and OptraPol ($p<0.05$).

For Filtek Z250, the lowest surface roughness value was obtained with Mylar Strip ($p<0.05$). No statistically significant differences were observed between OptraPol and Sof-Lex ($p>0.05$), as well as between Sof-Lex and PoGo ($p>0.05$). However, PoGo exhibited statistically significant difference from OptraPol ($p>0.05$).

According to the finishing and polishing procedures, the results were summarized as follows:

- For Mylar Strip and PoGo: Compoglass Flow = Tetric Flow = Admira Flow = Filtek Supreme XT Flow < Grandio Flow < Filtek Z250 ($p<0.05$).
- For OptraPol: Compoglass Flow < Admira Flow = Filtek Supreme XT Flow = Tetric Flow

Table 3 Mean values and standard deviations of surface roughness for each group (Ra)

Material	Polishing group			
	Mylar strip	PoGo	OptraPol	Sof-Lex
Tetric Flow	$0.033\pm0.001^{a,A}$	$0.040\pm0.010^{a,A}$	$0.070\pm0.005^{b,B}$	$0.134\pm0.015^{c,A}$
Grandio Flow	$0.052\pm0.007^{a,B}$	$0.075\pm0.011^{a,B}$	$0.138\pm0.008^{b,c}$	$0.172\pm0.039^{c,B}$
Admira Flow	$0.036\pm0.004^{a,A}$	$0.043\pm0.007^{a,A}$	$0.064\pm0.004^{b,B}$	$0.109\pm0.016^{c,A}$
Compoglass Flow	$0.032\pm0.003^{a,A}$	$0.039\pm0.006^{a,A}$	$0.042\pm0.004^{a,A}$	$0.105\pm0.012^{b,A}$
Filtek Supreme XT Flow	$0.036\pm0.002^{a,A}$	$0.046\pm0.005^{a,b,A}$	$0.069\pm0.003^{b,B}$	$0.201\pm0.041^{c,B}$
Filtek Z250	$0.058\pm0.002^{a,C}$	$0.200\pm0.024^{b,c}$	$0.165\pm0.022^{c,D}$	$0.178\pm0.022^{b,c,B}$

Different small superscript letters showed statistically significant difference among polishing systems.
Different capital superscript letters exhibited statistically significant difference among flowable composites.
Significance was determined at a probability value of p = 0.05.

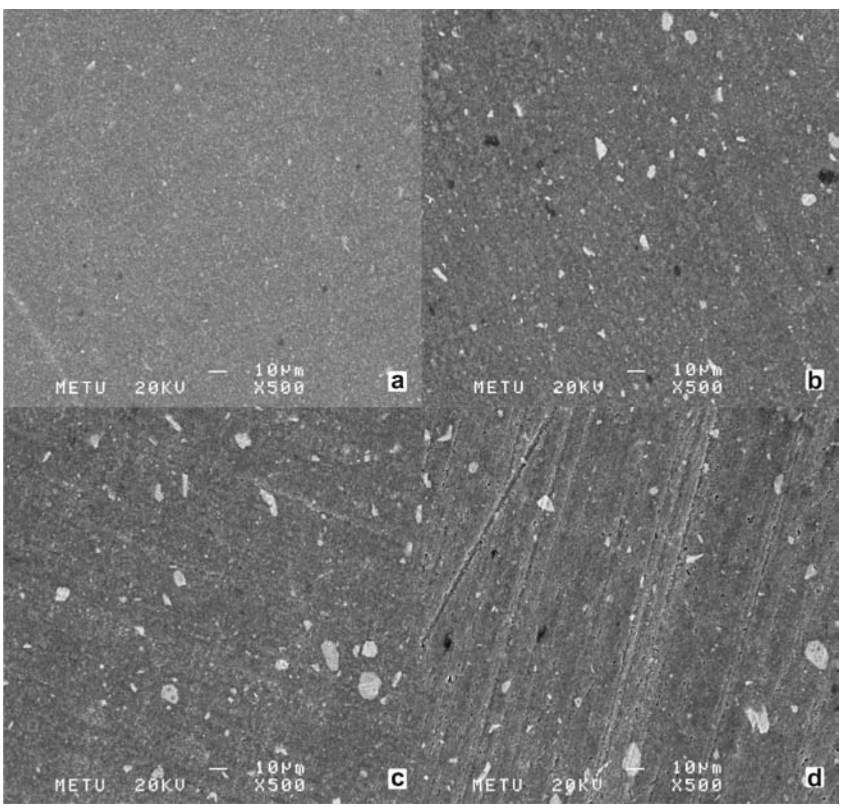

Fig. 1 Tetric Flow surfaces polished with different systems (×500 magnifcation). (a) Control surface with Mylar strip; (b) Polished with PoGo; (c) Polished with OprtaPol; (d) Polished with Sof-Lex.

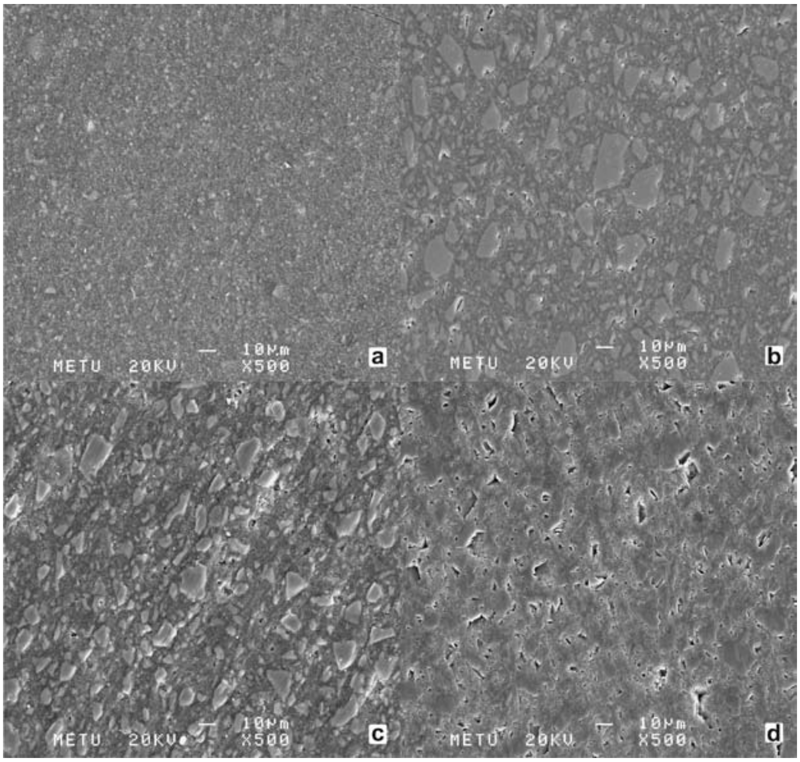

Fig. 2 Grandio Flow surfaces polished with different systems (×500 magnifcation). (a) Control surface with Mylar strip; (b) Polished with PoGo; (c) Polished with OprtaPol; (d) Poished with Sof-Lex.

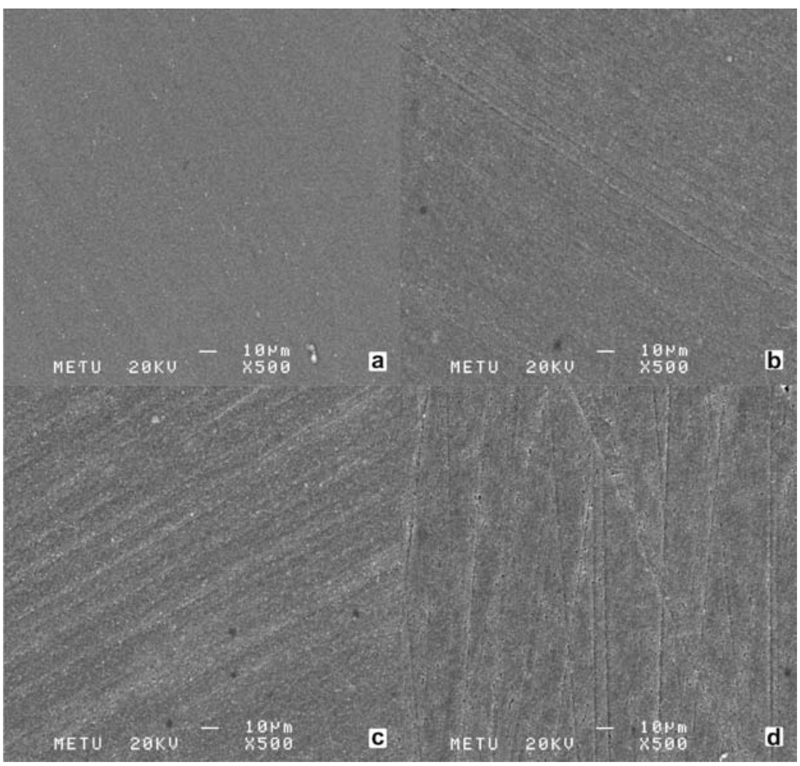

Fig. 3 Admira Flow surfaces polished with different systems (×500 magnifcation). (a) Control surface with Mylar strip; (b) Polished with PoGo; (c) Polished with OprtaPol; (d) Polished with Sof-Lex.

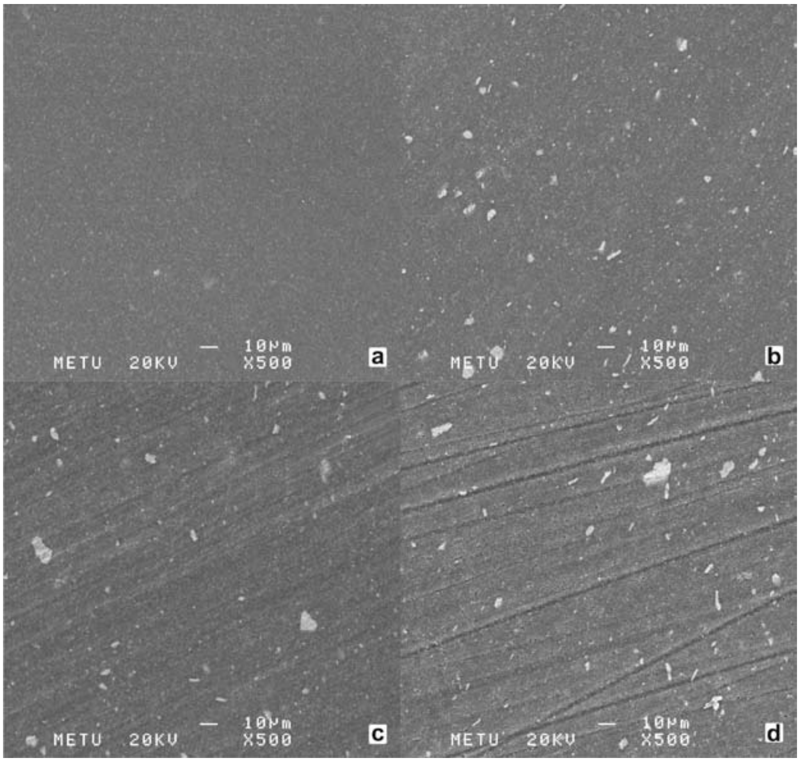

Fig. 4 Compoglass Flow surfaces polished with different systems (×500 magnifcation). (a) Control surface with Mylar strip; (b) Polished with PoGo; (c) Polished with OprtaPol; (d) Polished with Sof-Lex.

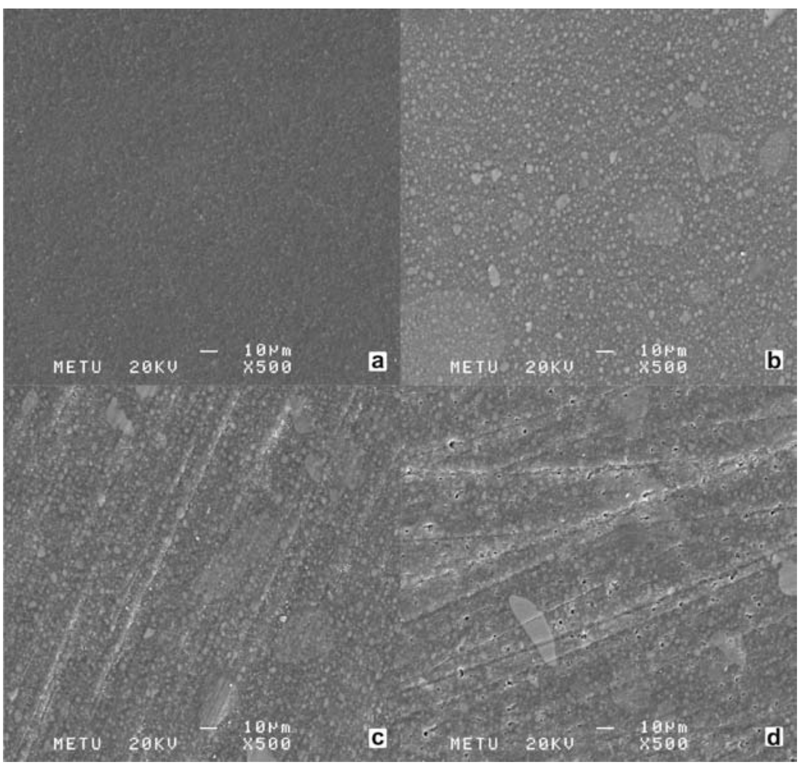

Fig. 5 Filtek Supreme XT Flow surfaces polished with different systems (×500 magnifcation). (a) Control surface with Mylar strip; (b) Polished with PoGo; (c) Polished with OprtaPol; (d) Polished with Sof-Lex.

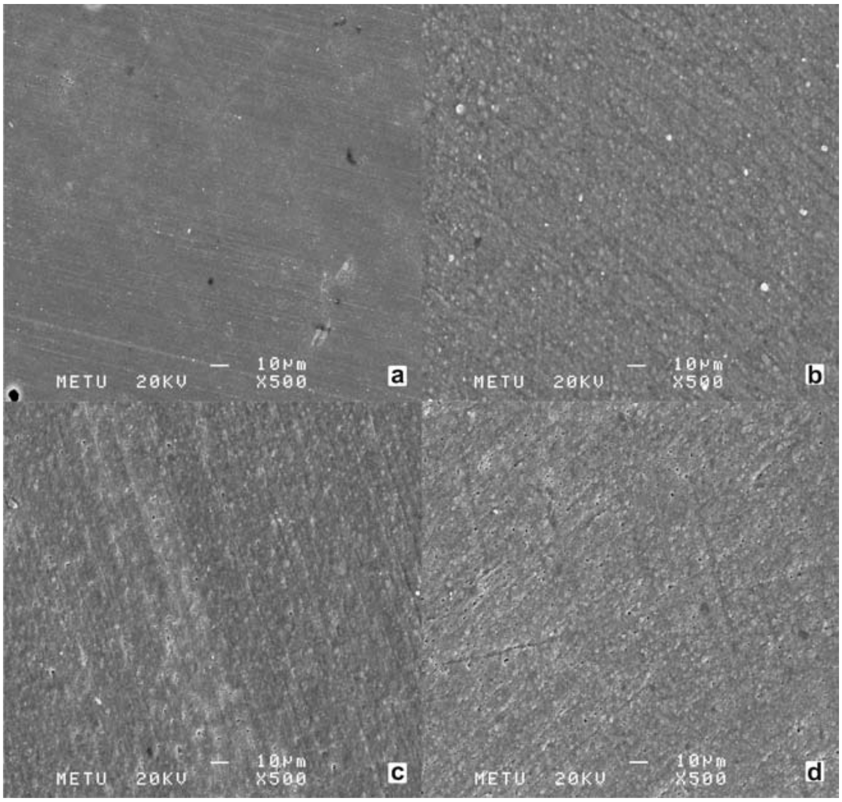

Fig. 6 Filtek Z250 surfaces polished with different systems (×500 magnifcation). (a) Control surface with Mylar strip; (b) Polished with PoGo; (c) Polished with OprtaPol; (d) Polished with Sof-Lex.

< Grandio Flow < Filtek Z250 ($p<0.05$).

- For Sof-Lex: Compoglass Flow = Admira Flow = Tetric Flow < Grandio Flow = Filtek Z250 = Filtek Supreme XT Flow ($p<0.05$).

SEM analysis

SEM images of the materials are given as follows: Tetric Flow specimens are presented in Fig. 1 (a－d), Grandio Flow specimens in Fig. 2 (a－d), Admira Flow specimens in Fig. 3 (a－d), Compoglass Flow specimens in Fig. 4 (a－d), Filtek Supreme XT Flow specimens in Fig. 5 (a－d), and Filtek Z250 specimens in Fig. 6 (a－d).

SEM analysis of Tetric Flow, Grandio Flow, Admira Flow, and Filtek Supreme XT Flow specimens polished with PoGo revealed the same surface appearance as the Mylar strip, while the surface polished with Sof-Lex revealed some scratches. SEM analysis of Compoglass Flow specimens, polished with PoGo and OptraPol revealed the same surface appearance. Likewise, Filtek Z250 specimens polished with Sof-Lex, OptraPol, and PoGo revealed a similar surface appearance. Therefore, the results of profilometric measurements were largely confirmed by the SEM images.

DISCUSSION

It is widely acknowledged that finishing and polishing procedures directly affect the esthetics and longevity of dental restorations[17]. However, resin composite materials cannot be finished to an absolutely smooth surface. Surface micromorphology of resin composites after finishing and polishing has been shown to be influenced by the size, hardness, and amount of filler particles in the composites[18]. Nonetheless, maintaining the surface texture is critical to the esthetics of restorations[19,20].

Flowable composites are a result of the continuous research and progresive development of composite materials. At the present time, flowable composites of different filler types are introduced into the market — and that filler types affect both their handling characteristics and physical properties. The main difference between composites and flowable composites lies in the modifications to the filler or resin component[21]. For the flowable composites tested in this study, the differences in surface topography could be attibuted to differences in their interparticle spacing and filler particle size. The filler content of Grandio Flow was higher than the other flowable composites tested, which might be the reason for the relatively rougher surfaces after different polishing treatments when compared to other flowable composites. On the influence of filler particle size, Yazici *et al.*[22] investigated the surface roughness of four different flowable materials (a flowable microhybrid composite, a flowable liquid microhybrid composite, a flowable compomer, and a flowable ormocer) and reported no significant differencess in Ra values among the unpolished specimens of Dyract Flow, Tetric Flow, and Admira Flow. They noted that this result might due to similarity in mean filler particle size among the three flowable resins.

With the Mylar strip, perfectly smooth surfaces were obtained although they were rich in the resin organic binder. Therefore, removal of the outermost resin by finishing-polishing procedures would tend to produce a harder, more wear-resistant, and hence a more esthetically stable surface[23].

For years, specially designed diamonds of very fine abrasive particle size and white Arkansas stones have been used to polish resin-based composite restorations[24]. However, diamond points are limited to initial contouring because of their ability to remove equal amounts of adjacent enamel[25]. Subsequently, the attention and emphasis was shifted to applying progressively finer grits of abrasives to polish resin-based composites[26]. Recently, one-step polishing systems utilizing diamong micro-polishers were introduced to achieve the last three steps of the trimming procedure with one instrument and within a very short time.

Numerous studies have reported on the finishing of composite resins[10,14,27,28]. Most of these studies evaluated the induced surface roughness with profilometers, as surface roughness has been used as a criterion to assess and predict the deterioration of restorations of different material types[29]. The most commonly used parameter to describe surface roughness is Ra, which is the arithmetic mean of vertical departure of a profile from the mean line[27,30].

Clinically, some functional adjustment is necessary in almost all restorations. In this study, finishing was carried out with 1200-grit silicon carbide paper under running water to simulate diamond-point texture and produce specimens without undulations. On the results obtained, one-step polishing systems offered similar roughness values when compared to Mylar strip in flowable composites. On the other hand, for the microhybrid composite group, the lowest Ra value was obtained with Mylar strip. It seemed that composite resin fillers played an intrinsic role in how well a composite may be finished. For the flowable composites, they have a higher resin matrix content which may be lost during polishing and finishing[21].

On the influence of filler particle size on surface roughness, it was found that the Sof-Lex system scratched the flowable composites and produced rougher surfaces than the one-step polishing systems. Sof-Lex disks have a higher avarage particle size than the other polishing systems, which could have accounted for the surface roughness results observed in this study.

Other studies have shown the ability of aluminum oxide disks to produce smooth composite surfaces[30,31]. However, the geometry of a disk poses a disadvantage and limitation. When using disks, it is often difficult to efficiently create, finish, and anatomically polish contoured surfaces, especially in the posterior regions of the mouth. On the other hand, finishing and polishing systems with instruments of varied shapes may lend themselves to more efficient and consistent composite finishing in many clinical situations.

In the present study, PoGo polisher produced smoother surfaces for Tetric Flow, Grandio Flow, and Admira Flow than OptraPol. This could be a result of twofold factors: the flexible micro-polisher disks in PoGo contained fine diamond particles and that the size of abrasive particles in PoGo were larger than those of OptraPol. Furthermore, visual inspection of the polished specimens with PoGo revealed an enamel-like glossy surface, while OptraPol system created a dull appearance[32]. Based on these results, it could be suggested that for a composite finishing system to be effective, the cutting particles must be harder than the filler particles[33]. Otherwise, the polishing agent will remove only the soft resin matrix and leave the filler particles protruding from the surface[34].

Studies have reported no appreciable differences in plaque accumulation among the surfaces polished by different methods and which resulted in Ra values within a range of 0.7−1.4 μm[6,35,36]. The highest mean Ra value for the composite materials tested in the present study was 0.20 μm. Therefore, in this study, all the evaluated flowable composites and microhybrid composite produced acceptable Ra values with all the tested polishing systems.

In a study by Turkun and Turkun[10], the surface roughness values produced by PoGo were statistically similar to those produced by the Mylar strip. Likewise in this study, PoGo exhibited statistically similar surface smoothness results when compared to the Mylar strip for all the flowable composites tested.

In the composition of resin composites, an interdependent relationship exists between the amount of inorganic filler particles and that of organic matrix. More filler particles means less organic matrix presence by volume. A higher percentage of filler particles will then result in a rougher surface. In the present study, Grandio Flow exhibited a relatively rough surface when compared with the other flowable composites. This result correlated with the filler content of Grandio Flow, which was 65.6 vol%.

In Filtek Z250 group, there were no significant differences among the surface roughness results yielded by the different polishing systems. This result was partly attributable to the size, hardness, and amount of filler particles of this composite resin.

Results from this *in vitro* study could correlate only to clinical situations involving accesssible and relatively flat surfaces. Further studies are needed to determine which finishing technique is best suited for clinical situations where access is limited and where restoration surface is not flat.

CONCLUSION

The effectiveness of polishing systems on resin-based composite restorations seemed to be material-dependent. Nonetheless, by virtue of their reduced polishing steps and application time coupled with the achievement of Mylar-like surfaces, one-step polishing systems seemed well poised for polishing different types of flowable composites.

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