Evaluation of the effects of finishing and polishing procedures on the surface texture of compomer materials

Fouad S. Salama*, BDS, MS, DABPD, FAAPD
Nouf Al-Hammad**, BDS, MS

هدفت هذه الدراسه إلى تقييم تأثير عمليات الإنهاء والتلميع على سطوح مواد الكومبومر (دايراكت و كومبوجلاس) باستخدام نظام للإنهاء والتلميع الزائد.

تم تحضير ٤٥ عينه اسطوانيه من كل مادة، ١٥ عينه من كل مادة استخدمت للمقارنة حيث تمت عمليه البلمره من خلال شريط مايلر دون إنهائها او تلميعها. أيضا تم إنهاء ١٥ عينة من كل مادة باستخدام نظام للإنهاء فقط، كما تم إنهاء وتلميع ١٥ عينه من كل مادة بإستخدام نظام للإنهاء والتلميع الزائد. جميع العينات حضرت في درجه حرارة الغرفة وحفظت في فرن معملي بدرجه حرارة ٣٧° لمدة ٣ أيام قبل اختبارها. تمت دراسة وتصوير جميع العينات بدرجات تكبير مختلفة باستخدام المجهرين المجسامي والإلكتروني، كما تمت دراسة خشونة السطح باستخدام جهاز تحليل خشونة السطح.

أظهرت النتائج أن السطح الأنعم هو الذي استخدم فيه شريط مايلر دون إنهاء أو تلميع، أما السطح الذي يليه في النعومة فهو سطح مادة الدايراكت بعد الإنهاء والتلميع، يليه سطح مادة الكومبوجلاس بعد الإنهاء فقط.

يستنتج من هذه الدراسه ان عمليات الإنهاء وعمليات الإنهاء والتلميع فشلت في إنتاج سطوح مماثلة في النعومة للسطوح التي لم يتم إنهائها او تلميعها واستخدم فيها شريط مايلر.

The purpose of this study was to evaluate the effects of finishing and polishing procedures on the surface texture of compomer materials (Dyract and Compoglass) using the Enhance finishing and polishing system. Forty-five cylindrical specimens were prepared from each material. Fifteen specimens of each material were light cured against a Mylar strip with no finishing or polishing (control), 15 others were finished only using the Enhance finishing system (experimental) and another 15 specimens were finished and polished using the Enhance finishing and polishing system (experimental). All specimens were prepared at room temperature and stored for 3 days in closed containers of distilled water (300 ml) in a laboratory oven at 37°C before testing. Both control and experimental specimens of each material were examined and photographed at different magnifications using a stereomicroscope and an SEM. Also, the surface roughness of all specimens was measured with a surface roughness analyzer. The surfaces cured against the Mylar strip demonstrated the smoothest surface. Following the Mylar strip surface, the next smoothest surface was seen in finished and polished Dyract followed by finished Compoglass. Finishing and polishing procedures of compomer materials failed to reproduce the smoothness of surfaces created by mylar strips.

Introduction

Compomers or polyacid modified resin composite materials combine the desirable features of traditional glass ionomers with those of composite restorative resins.[1,2] Despite the scanty information available to describe the surface roughness of compomer materials, they are nevertheless considered to be suitable for restorative treatment of primary and permanent teeth.[3-24] Surface roughness of restorative materials is responsible for many clinical problems ranging from plaque adhesion and its harmful effects on the tooth and the periodontium to surface discoloration and fatigue failure of the restoration. Also, patients' consciousness of the restorations with possible irritation of the tongue, lips, and cheeks is a matter of concern.[25,26] Therefore, one of the prime requisites for a satisfactory restoration is a smooth surface which is also a crucial feature regarding avoidance of plaque retention.[26] The ease with which plaque may be mechanically removed decreases as the surface roughness increases.[27] The final surface of materials depends on several factors related to finishing and polishing procedures such as the flexibility of the backing material in which the abrasive is embedded, the hardness of the abrasive and the grit size, the geometry of the instruments, and how the instruments are used.[28,29] The surface of restorative materials can be finished and polished using a variety of techniques. Evaluation of these techniques on compomer materials is necessary. The purpose of this study was to evaluate the effect of finishing and polishing procedures on the surface texture of compomer materials using the Enhance finishing and polishing system.

Materials and Methods

Forty-five disk-shaped specimens (10 mm

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*Associate Professor and Director, Pediatric Dentistry Postgraduate Program, Department of Preventive Dental Sciences, College of Dentistry, King Saud University, Riyadh, Saudi Arabia
**Lecturer, Department of Preventive Dental Sciences, Division of Pediatric Dentistry, College of Dentistry, King Saud University, Riyadh, Saudi Arabia

Address reprint requests to:
Dr. Fouad S. Salama
P.O. Box 60169
Riyadh 11545 Saudi Arabia
E-mail: fsalama@ksu.edu.sa

diameter, 2 mm thickness) were prepared from each of the two compomer mateials, Dyract (Dentsply De Try, D-78467, Konstanz, Germany) and Compoglass (Vivadent ETS., FL-9494, Schaan /Liechtenstein, Germany) using Teflon molds.

The specimens of both materials were prepared according to the respective manufacturers' instructions. Immediately following placement of the material into the mold, a mylar strip was placed on the surface, covered with a plastic slide and stabilized using a C-clamp. Each specimen was cured using a visible light curing unit (Optilux 150, Demetron Research Corp., Danbury, CT, USA) at 3 mm distance for 40 seconds. The mylar strip was removed and no further trimming, finishing or polishing was carried out in 15 specimens of Dyract (Group 1) and 15 of Compoglass (Group 2). Another 15 specimens of Dyract (Group 3) and 15 of Compoglass (Group 4) were finished using the Enhance system (L.D. Caulk Division, Dentsply International Inc. Milford, DE 19963-0359, USA) with light intermittent pressure simulating a clinical situation. The specimens were finished using an Enhance finishing disc for 10 seconds. Another 15 specimens of Dyract (Group 5) and 15 of Compoglass (Group 6) were finished using the Enhance system as in groups 3 and 4 and subsequently polished using the Enhance system with light pressure and a circular motion. One Enhance polishing cup was used for each 3 specimens as follows: 15 seconds with Prisma Gloss without water followed by 15 seconds with water and 10 seconds using Prisma Gloss-extra fine without water followed by 10 seconds with water. Table 1 shows the material and surface treatment of each group.

Table 1. Material and surface treatment of each group.

Group number	Material / Surface treatment
1	Dyract / Mylar strip
2	Compoglass / Mylar strip
3	Dyract / Finishing
4	Compoglass / Finishing
5	Dyract / Finishing and polishing
6	Compoglass / Finishing and polishing

All specimens were prepared at room temperature (approximately 22° to 23°C) and were stored for 3 days in closed containers of distilled water (300 ml) in a laboratory oven (Laboratory oven, Imperial V, Lab-Line Instruments Inc., IL, USA) at 37°C before testing.

a. **Stereomicroscopic examination**

The specimens from all the control and experimentals groups were examined and photographed at different magnifications ranging from 4x to 25x using a stereomicroscope (Wild Photomakroskop M400, Heerbrugg, Switzerland) to obtain an overview of surface textures.

b. **Scanning electron microscopic examination**

Impressions to form replicas were made of 5 representative specimens from each group using light body polyvinylsiloxane impression material (President, Coltine/Whaledent Inc., N.Y. 10001, USA). If artifacts were discovered in one of the impressions, another impression was made. The specimens were removed from the impression after 30 minutes and stored in distilled water at 37°C. Impressions were left in air for one hour to eliminate emission of hydrogen gas before making replicas. Five epoxy replicas for each group were prepared in the impressions using 2-Ton Epoxy (Devcan Corporation, Danver, MA 01923, USA). The replicas were removed from the impressions and prepared for Scanning Electron Microscope (SEM) examination. Specimens were mounted on aluminum stubs and sputter-coated with gold palladium (60:40 ratio) using a sputter-coater (Jeol Fine Coat Ion sputter JFC-1100, Tokyo, Japan). The quality of the replica technique was verified using 3 extra specimens and the surface texture of the replicas was compared with that of the original specimens using SEM (Jeol, JSM T330A, Jeol Ltd., Tokyo, Japan) at x1000 magnification and accelerating voltage of 15 kV. The surface texture and topography of the specimens (control and experimentals) were examined carefully and evaluated at different magnifications, and representative photomicrographs were made. Visual evaluation of the surface texture for descriptive reasons was performed by two examiners who were unaware of the exact nature of the groups. Evaluation was done independently by each examiner using predetermined criteria which included smoothness, homogenity of the surface texture, presence of pits, voids, cracks, grooves, projections, granular appearance, and filler particles protruding from the matrix. A consensus was required for any discrepancy between the examiners. No attempt was made to calculate the inter-rater reliability.

c. **Surface roughness analysis**

Surface roughness analysis of all specimens (groups) was performed with a surface roughness analyzer (Perthen, Perthometer/Perthograph,

Mahr, D3000 Hannover 1 Postfach 4720, Germany). To determine surface roughness, a typical profile for each specimen and average surface roughness (R_a) values were recorded. The R_a values are the arithmetic mean values of the deviation of the roughness profile from the base line generated by the machine.

For surface roughness analysis, non parametric Friedman two-way analysis of variance and non parametric Tukey's type multiple range tests were used to compare the 2 materials and the 3 types of surface treatment. In addition, descriptive statistics (mean, standard deviation, range and coefficient of variation) of all the parameters were tabulated.

Results

a. **Stereomicroscopic examination**

Stereomicroscopic examination of the surface texture of the Dyract control specimens (Group 1) revealed mostly intact, smooth and homogenous surfaces with the presence of a few small pits . The Compoglass specimens (Group 2) had more pits than those present in Dyract surfaces. Following finishing of the specimens, the surface texture of Dyract (Group 3) and Compoglass (Group 4) specimens exhibited clearly finishing marks with some pits and defects similar to those in the control surfaces. The number of marks and the distance between them varied from one area to another. Following finishing and polishing of the specimens, the surface texture of Dyract (Group 5) revealed less defined finishing marks, and in some areas, larger pits and defects were observed than in Group 3. For Compoglass (Group 6), the disc marks were more defined than in Group 5 specimens while the defects were larger than in Group 4.

b. **Scanning electron microscopic examination**

SEM examination of the surface texture of the replicas of Dyract (Group 1) revealed slight to moderate rough surfaces with many small pits, defects, cracks, and projections (Fig. 1). A similar appearance was observed for Compoglass (Group 2) with more pits, defects, cracks, and projections (Fig. 2). SEM examination following finishing of the specimens showed that the surface texture of the replicas of Dyract (Group 3 - Fig. 3) and Compoglass (Group 4 - Fig. 4) had clear marks of the finishing disc with some pits, voids, cracks, porosity, smeared areas which may be where the resin remained unpolymerized, and projections similar to those in control surfaces. Following the finishing and polishing of the specimens, the surface texture of Dyract (Group 5) replicas showed less defined finishing disc marks as well as pits, cracks, and voids (Figs. 5 & 6). For Compoglass (Group 6), the disc marks were more defined than the finished and polished Dyract specimens with evidence of pits, cracks, voids, and projections (Figs. 7 & 8).

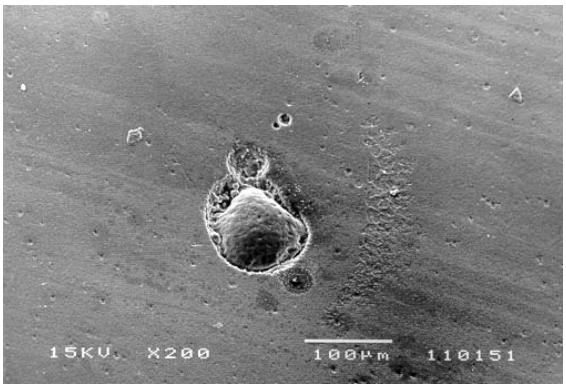


Fig. 1. Scanning electron micrograph of control Dyract surface showing pits and defects (200 x).

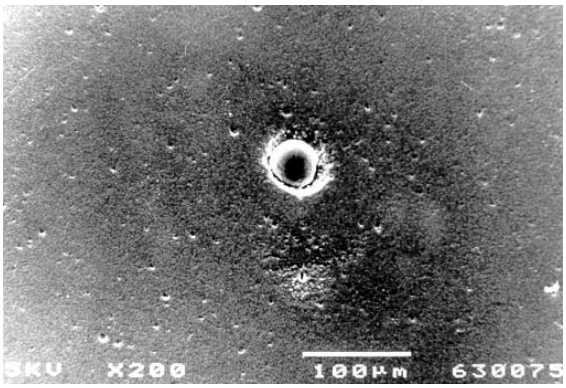


Fig. 2. Scanning electron micrograph of control Compoglass surface showing pitted surface with defective areas (200 x).

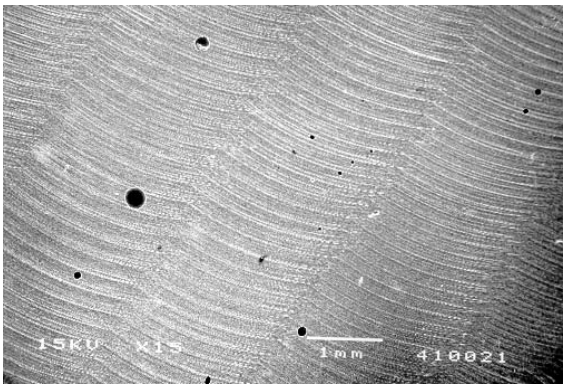


Fig. 3. Scanning electron micrograph of finished Dyract surface with evident finishing marks (15 x).

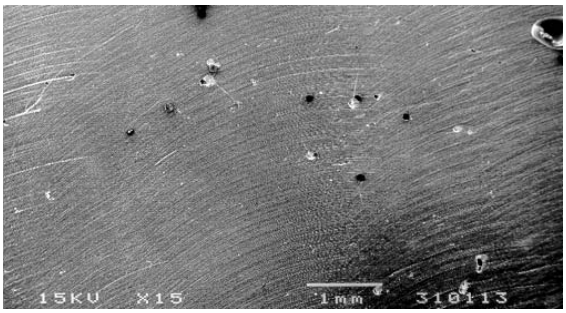


Fig. 4. Scanning electron micrograph of finished Compoglass surface showing areas of defects and marks of the finishing disc (15 x).

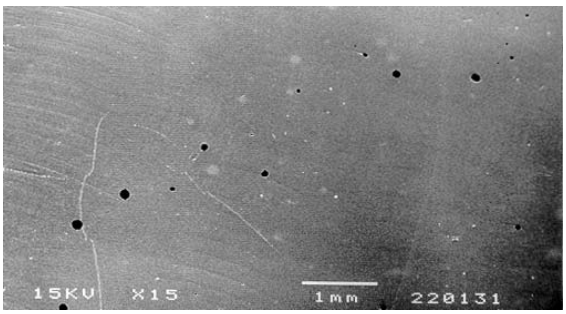


Fig. 5. Scanning electron micrograph of finished and polished Dyract surface showing smooth area as well as areas of remaining finishing marks and voids (15 x).

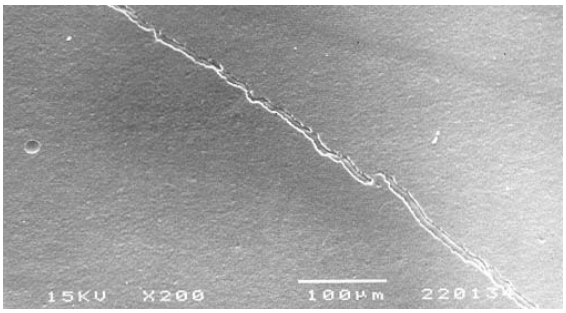


Fig. 6. Scanning electron micrograph of finished and polished dyract surface with evident crack and some pits (200 x).

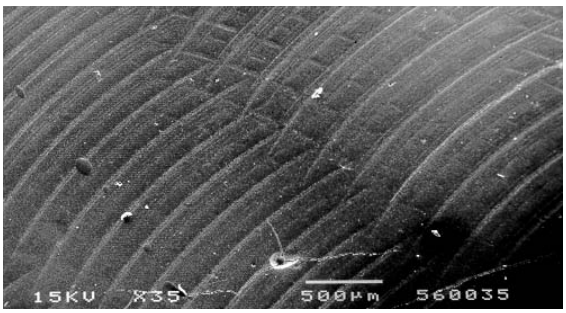


Fig. 7. Scanning electron micrograph of finished and polished compoglass surface showing finishing disc marks (35 x).

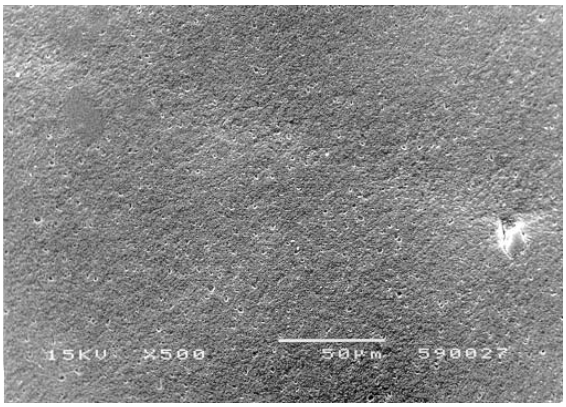


Fig. 8. Scanning electron micrograph of finished and plished compoglass surface with many pits (500 x).

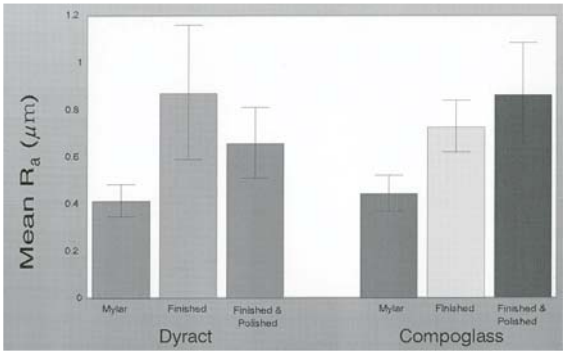
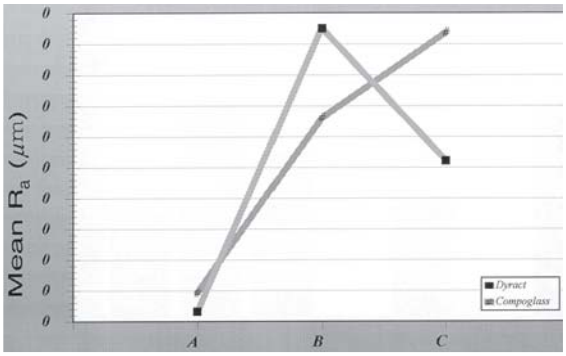


Fig. 9. Histogram of the mean and standard deviation of surface roughness values for different finishing procedures.



A. Control no finishing or polishing
B. Finishing
C. Finishing and Polishing

Fig. 10. Line diagram of the interaction of the mean surface roughness of materials and surface treatments.

c. Surface roughness analysis

The mean, standard deviation, range, and coefficient of variation percentage of the arithmetic mean roughness values (R_a) for all groups are given in Table 2. The histograms depicting mean values of surface roughness are shown in Fig. 9. Specimens in Groups 1 and 2

(Control) for both materials demonstrated significantly lower R_a values compared to Groups 3-6 (Experimental) followed by either finishing only or finishing and polishing.

Table 2. Surface roughness (R_a) in micrometers for compomer materials with different surface treatments.

*Group No.	Material/ Surface treatment	Mean R_a	S. D.	Range	C.V. (%)
1	Dyract/Mylar strip	0.47	0 .07	0.30 - 0.56	16.59
2	Compoglass/ Mylar strip	0.45	0.08	0.30 - 0.62	17.00
3	Dyract/Finishing	0.88	0.28	0.35 - 1.25	32.46
4	Compoglass/ Finishing	0.73	0.11	0.53 - 0.92	15.05
5	Dyract/Finishing and polishing	0.66	0.15	0.30 - 0.84	22.69
6	Compoglass/ Finishing and polishing	0.87	0.22	0.55 - 1.47	24.74

*N = 15 for each group

Two way analysis of variance (ANOVA) for materials and surface treatments showed no statistically significant difference between the two materials. In contrast, there was a statistically significant difference between the three surface treatment methods used (Table 3). Also, there was a statistically significant difference in the interaction of materials and surface treatment (Fig. 10). Tukey's multiple range test showed that Groups 1 and 2 (Control) were significantly different from Groups 3 and 4 (finished only) as well as Groups 5 and 6 (finished and polished) for both materials, while Groups 3 and 4 of both materials were not significantly different from Groups 5 and 6 (Table 4). Further analysis of the data by material (Scheffe test at 5% significant level) showed that all surfaces were significantly different from each other for both materials (Table 4). Splitting the data by surface treatments using t-test showed that Dyract was significantly different from Compoglass only when the surfaces were finished and polished (Table 6).

Table 3. Analysis of variance of surface roughness for the materials and surface treatments.

Source of variation	DF	Sum of Squares	Mean square	F Value	P-value
Material	1	0.022	0.022	0.770	0.3828
Surface	2	2.511	1.256	43.754	< 0.0001 S*
Material/ Surface	2	0.466	0.233	8.127	0.0006 S*
Residual	84	2.410	0.029		

S* = significant

Table 4. A comparison of the mean surface roughness scores for Dyract and Compoglass with different surface treatments.

Surface treatment	Mean difference	Crit. difference	P-value
A, B (Dyract / Mylar strip & Compoglass/Mylar strip)	- 0.373	0.087	<0.0001 S*
A, C (Dyract/Finishing & Compoglass/ Finishing)	- 0.334	0.087	< 0.0001 S*
B, C (Dyract / Finishing and polishing & Compoglass / Finishing and polishing)	0.038	0.087	0.3916

*S = significant

Table 5. Comparison between Dyract and Compoglass specimens with different surface treatments.

Groups	P-value
Dyract / Mylar strip vs Dyract / Finishing	< 0.0001
Dyract / Mylar strip vs Dyract / Finishing and polishing	<0.01
Dyract / Finishing vs Dyract / Finishing and polishing	<0.05
Compoglass/Mylar strip vs Compoglass/Finishing	< 0.0001
Compoglass / Mylar strip vs Compoglass / Finishing and polishing	< 0.0001
Compoglass / Finishing vs Compoglass / Finishing and polishing	< 0.05

Table 6. An overall comparison of Dyract and Compoglass with different surface treatments.

Material	Surface*		
Dyract	Mylar strip (Control)	Finish	Finish and polish
Compoglass	Mylar strip	Finish	Finish and polish
P-Value	0.2564 NS*	0.0766 NS*	0.0047 S**

*NS = not significant *S = significant

Discussion

The results of this study indicated that, for the two compomer materials tested, the surfaces cured against the Mylar strip (control) produced the smoothest surface (lowest R_a value). Neither finishing nor finishing and polishing procedures used in this study could reproduce the smoothness of the control surfaces. This observation is similar to previously reported results for composite resin, glass ionomer cement, and resin modified glass ionomer cement materials.[27-35] Other studies also showed that the untouched surface cured against a polyester matrix,[36] glass plate,[37,38] or a cervical metal foil[39] was the smoothest when compared to those after finishing and polishing procedures. Such untouched surfaces, however, cannot be maintained clinically because further contouring and finishing of the restoration is usually necessary to fulfill clinical objectives. In this study, the next smoothest surface, after that resulting from the Mylar matrix, was seen for finished and polished Dyract specimens (Group 5) (mean R_a = 0.661 micrometers) followed by finished Compoglass specimens (Group 4) (mean R_a = 0.731 micrometers).

The results of the surface roughness measurements showed marked variations, even for specimens treated by the same regimen. This is shown by the high standard deviations. Finishing these materials in a consistent manner using the large specimens required for the surface roughness analyzer seems to be the source of the variation. Finishing with Enhance finishing disks for both materials increased the average surface roughness when compared to the Mylar-strip surface. This increase in surface roughness may be attributed to the presence of scratches and tracks of the finishing disks (average particle size = 60-100 µm aluminum oxide in Enhance disks) or the presence of pits and cracks which might be related to the filling of the Teflon mold and finishing process. Finishing with the Enhance finishing system followed by polishing cups (foam) and pastes roughened the Compoglass surfaces, but lowered the R_a values of Dyract when compared to the finished specimens. This result was observed although the Dyract average particle size (2.5 µm) is larger than that of Compoglass (1.6 µm). This may be related to the bond between the filler particles and the matrix material, as the detached particles of the material act as an additional abrasive agent themselves and increase the abrasion of the finishing or polishing paste. Also, this might be related to the percentage of filler particles in the material (Dyract 50% by volume, Compoglass 79% by volume).

The increase in R_a values of the restorative materials after finishing or finishing and polishing has been explained by different investigators in different studies. Pratten and Johnson[28] reported that the increase in R_a values could be due to abrasion of the resin-rich surface of composite materials formed by the Mylar strip after finishing and polishing processes and exposure of the filler particles. Another study reported that the increased roughness was due to rubber abrasive and polishing pastes preferentially abrading the softer polysalt and resin matrix and had a minimal effect on the filler particles with light activated glass ionomer cement materials.[35]

The present study suggests that the surface treatment methods appear to be more significant than the material itself since the statistical analysis showed significant differences between the three surface treatment methods ($P = < 0.0001$) and the interaction of materials and surface treatment ($P = 0.0006$) but did not show a significant difference between the two materials tested ($P = 0.3828$). These findings were confirmed by a Scheffe test at 5% significant level as all surfaces were significantly different from each other for both materials, and by a t-test which showed that Dyract was significantly different from Compoglass only when surfaces are finished and polished ($P = 0.0047$). Another study also found no statistically significant difference in surface roughness between Dyract and Compoglass restorative materials after being cured against a Mylar matrix.[40] Glasspoole and Erickson[41] and Leinfelder[42] reported that the wear rate is inversely related to the degree of cure and they recommended no less than 1 minute curing time for the final restoration surface to increase the resistance to wear.

In this study, the qualitative evaluation (Stereomicroscopic and SEM) of the examined surfaces confirmed the quantitative surface measurements obtained by the surface roughness analyzer. The results from this *in vitro* study correlate only with the clinical situations where there are accessible and relatively flat surfaces present. When finishing complex surfaces, as with restorations showing occlusal areas with limited access, the effectiveness of the finishing and polishing procedures may be different. Future laboratory studies should attempt to simulate

concave and complex surfaces for finishing and polishing.

Conclusion

1. Surface roughness analysis, stereomicroscopic, and scanning electron microscopic evaluations of Dyract and Compoglass cured against a Mylar strip demonstrated the smoothest surfaces.
2. Neither finishing nor finishing and polishing procedures used in this study could reproduce the smoothness of the surfaces initially created by the Mylar strip.
3. The smoothest surface, apart from the Mylar strip surface, was seen in Dyract material after being finished and polished followed by finished Compoglass surfaces.

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