

Influence of polishing duration on surface roughness of resin composites

Tamayo Watanabe[§], Masashi Miyazaki^{§,†}, Toshiki Takamizawa^{§,†},
Hiroyasu Kurokawa^{§,†}, Akitomo Rikuta^{§,†} and Susumu Ando^{§,†}

[§]Department of Operative Dentistry, Nihon University School of Dentistry, Tokyo, Japan

[†]Division of Biomaterials Science, Dental Research Center,
Nihon University School of Dentistry, Tokyo, Japan

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Abstract: There is a need for effective polishing instruments for resin composite restorations with highly polished surfaces. The purpose of this study was to investigate the influence of polishing duration on surface roughness of light-cured resin composites. Four polishing systems, Compomaster (Shofu), Silicone Points C Type (Shofu), Super Snap (Shofu) and Enhance Finishing and Polishing System (Dentsply/Caulk), were used to polish two commercially available resin composites, Clearfil AP-X (Kuraray Medical) and Lite-Fil II A (Shofu). Resin pastes were condensed into molds (10 mm in diameter, 5 mm in depth) and light irradiated for 40 s. Composite surfaces were ground with # 600 SiC paper followed by polishing with an instrument for 30 s, and the surface roughness was measured every 10 s during polishing procedures. The average surface roughnesses (Ra) were determined using a profilometer. Data were analyzed by Tukey HSD test ($P = 0.05$). After 30 s of polishing, mean Ra values ranged from 0.07 to 0.50 for Clearfil AP-X, and from 0.11 to 0.57 for Lite-Fil II A. Although the time required for polishing was longer, the surface finish produced by multiple-step polishing systems was superior to that obtained with one-step polishing systems. (J. Oral Sci. 47, 21-25, 2005)

Keywords: polishing system; resin composite; surface roughness.

Introduction

Regardless of cavity class and location, a smooth surface finish is clinically important as it determines the quality of composite restorations (1,2). A smooth surface on a restoration can be obtained after polymerizing the resin composite against an appropriate matrix strip, but further counterering and finishing are required to remove excess material and to obtain a smooth glossy surface (3,4). The presence of surface irregularities arising from poor polishing can create clinical problems such as gingival irritation, surface staining, plaque accumulation and secondary caries (5-9). In addition, rough restoration surfaces on occlusal contact areas can cause excessive wear of the opposing enamel (10). High quality finishing and polishing can improve the esthetics and longevity of resin composite restorations (11-13).

The esthetic appearance of a restoration depends on the polishing methods and finishing techniques employed. The surface roughness of the restoration is determined by the mechanical properties of the resin composites as well as the flexibility of the backing materials in which the abrasive is embedded, the hardness and grit size of the polishing material, and its geometry (14-16). Most of these studies involved various polishing systems and concluded that multi-step systems gave the smoothest surface finish. Finishing and polishing procedures require sequential use of instrumentation with gradually smaller-grained abrasives in order to achieve the desired glossy surface. A set of highly flexible polyurethane-based

Correspondence to Dr. Masashi Miyazaki, Department of Operative Dentistry, Nihon University School of Dentistry, 1-8-13 Kanda-Surugadai, Chiyoda, Tokyo 101-8310, Japan
Tel. +81-3-3219-8141
Fax +81-3-3219-8347
E-mail: miyazaki-m@dent.nihon-u.ac.jp

finishing and polishing disks, coated with aluminum oxide were widely used for polishing resin composite restorations. Recently, diamond polishers have been introduced to reduce clinical time for restoration. These are known as “one-step” polishing systems because contouring, finishing, and polishing procedures can be completed using a single instrument (17). This type of polishing concept meets the clinical demand for achieving a smooth surface within a minimal period of time (18). It has been reported that the effect of polishing systems on surface finish was material dependent and that the effectiveness of one-step systems was product dependent (19).

The purpose of this study was to evaluate the surface roughness of resin composites after polishing with different polishing systems. The surface roughness obtained with different durations of polishing was compared.

Materials and Methods

The resin composites used in this study were Clearfil AP-X (Kuraray Medical., Tokyo Japan) and Lite-Fil A II (Shofu, Kyoto, Japan), as listed in Table 1. Cylindrical blocks of light-cured resin composite, 10 mm in diameter and 5 mm in depth, were prepared in a Teflon mold. Resin composites were inserted and pressed into the mold, then polymerized with a curing unit (Optilux 501, sds Kerr, CT, USA) for 40 s through transparent strips on the both sides of the specimen. The light intensity of the curing unit was adjusted to 600 mW/cm², as measured by a dental radiometer (Model 100, sds Kerr). Resin blocks were finished to a uniform surface using # 600 grit silicone carbide papers (standard finished surface) with tap water. After 24 h, each specimen group received a different surface preparation.

The four polishing systems used in this study are listed in Table 2. The two point-type polishing systems used were Compomaster (CM, No. 13S, Shofu) and Silicone Point C (SC, No.13S, Shofu). The multi-step polishing systems used were the Super-Snap Rainbow Technique Kit (SS, Shofu) fine (green, SS-G) and superfine (red, SS-R), and Enhance system (ES, Dentsply/ Caulk, DE, USA) comprising a pointed shape Enhance Finishing Point (ES-P), a foam polishing cup with Prisma Gloss Composite Polishing Paste (ES-1), and a foam polishing cup with Prisma Gloss Extra Fine Composite Polishing Paste (ES-2).

Five samples from each of the three resin composites were polished using one of the four polishing systems. A slow-speed handpiece (5,000 rpm) with a contact pressure of 1.0 N monitored by a digital balance (AT200, Mettler, Switzerland) underneath the specimen was used for all polishing.

After completing polishing procedures, specimens were rinsed, cleaned in an ultrasonic cleaner for 3 min and air dried. The surface roughness of the specimen was measured using a surface profilometer (Surfcoder SE-30H, Kosaka Laboratory, Tokyo, Japan), with a standard cutoff of 0.8 mm, a transverse length of 0.8 mm, and a stylus speed of 0.1 mm/second. The roughness average (Ra) of a specimen was defined as the arithmetic average height of roughness component irregularities from the mean line measured within the sampling length. Three profilometer tracings were made near the center of each specimen and the numerical average was determined for each group.

The results were analyzed by calculating the mean and standard deviations for each group. The data for each material were tested for homogeneity of variance using Bartlett's test, and were then subjected to ANOVA followed by Tukey's HSD test and Student's t-test at a P-value of 0.05. Strength of the association between pairs of variables was obtained using the Pearson Product Moment Correlation. Statistical analysis was carried out using the Sigma Stat[®] software system (SPSS, IL, USA).

Results

Mean and standard deviations of surface roughness (Ra, μm) are listed in Tables 3 and 4. Surface roughness of the resin composites had a tendency to decrease with longer polishing duration. After 30 s of polishing, the multi-step polishing systems SS and ES showed the lowest Ra value for the resin composites tested, followed by the one-step polishing systems CM and SC. CM produced the third-smoothest surfaces, but significantly smaller Ra values were obtained when compared with SC for all polishing durations. There were significant differences in Ra values between the resin composites used for all polishing systems.

Discussion

Many studies on the polishing of resin composites have been conducted and the most commonly used parameter to describe surface roughness is Ra (10-16), which is the arithmetic mean of the vertical departure of the profile from the mean line. The profilometer first determines the mean line of the surface profile by fitting the data to the least square straight line when calculating Ra. Carbide paper creates peaks and valleys on the surface of the specimens. After polishing, the peaks rather than the valleys on the surface are abraded off. The least square line is again fitted to the data to obtain the mean line when calculating the new Ra, and thus the new mean line is different from the previous one. Some studies have expressed concern about the limitations of mechanical instrumentation for measuring the surface roughness because of the effect of

Table 1 Resin composites used

Code	Composite	Filler composition	Filler size (Range)	Filler load
CLX	Clefil AP-X	Splintered barium glass Colloidal silica	3.0 (0.2 - 15) μm 0.04 μm	85.5 wt%
LFA	Lite-Fil IIA	Splintered alumino-silicate Colloidal silica	2.7 (0.04 - 20) μm 0.04 μm	83.5 wt%

Table 2 Polishing systems used in this study

Code	Polishing system	Polishing step		Manufacturer
CM	Compomaster	No.13S	6- μm diamond	Shofu
SC	Silicone Points C type	No.13S	25- μm zirconium oxide	Shofu
SS-G	Super-Snap	Green: ϕ 12-mm Disk	20- μm aluminum oxide	Shofu
SS-R		Red: ϕ 12-mm Disk	7- μm aluminum oxide	
ES-FP	Enhance System	Enhance Finishing Point	40- μm aluminum oxide	Dentsply/
ES-P1		Prisma-Gloss Composite Polishing Paste	1- μm aluminum oxide	Caulk
ES-P2		Extrafine Composite Polishing Paste	0.3- μm aluminum oxide	

Table 3 Effect of polishing duration on surface roughness (R_a , μm) of Clearfil AP-X

Time (sec)	CM	SC	SS-G	SS-R	ES-P	ES-1	ES-2
0 *	0.57 (0.12)	0.56 (0.10)	0.58 (0.09)	0.17 (0.01)	0.58 (0.14)	0.50 (0.08)	0.11 (0.03)
10	0.25 (0.08)	0.46 (0.11)	0.21 (0.01)	0.08 (0.01)	0.54 (0.09)	0.31 (0.06)	0.12 (0.06)
20	0.24 (0.04)	0.45 (0.13)	0.19 (0.01)	0.08 (0.01)	0.53 (0.11)	0.17 (0.03)	0.10 (0.03)
30	0.18 (0.03)	0.45 (0.08)	0.17 (0.01)	0.07 (0.01)	0.50 (0.08)	0.11 (0.03)	0.09 (0.01)

Values connected by lines indicate no significant difference ($P > 0.05$).

*: Standard finished surface ground with # 600 SiC paper.

Table 4 Effect of polishing duration on surface roughness (R_a , μm) of Lite-Fil II A

Time (s)	CM	SC	SS-G	SS-R	ES-P	ES-1	ES-2
0*	0.68 (0.13)	0.65 (0.09)	0.69 (0.08)	0.16 (0.01)	0.68 (0.12)	0.45 (0.06)	0.18 (0.05)
10	0.49 (0.06)	0.63 (0.08)	0.21 (0.01)	0.13 (0.01)	0.58 (0.07)	0.33 (0.05)	0.16 (0.04)
20	0.34 (0.04)	0.58 (0.09)	0.18 (0.02)	0.13 (0.01)	0.55 (0.09)	0.25 (0.02)	0.13 (0.01)
30	0.26 (0.02)	0.57 (0.10)	0.16 (0.01)	0.11 (0.01)	0.45 (0.06)	0.18 (0.01)	0.12 (0.01)

Values connected by lines indicate no significant difference ($P > 0.05$).

*: Standard finished surface ground with # 600 SiC paper.

stylus size (20). Surface roughness is a function of the microstructure created by the series of physical processes used to modify the surface, and is related to the scale of the measurement. When using the same polishing system for different resin composites, differences between material compositions should be responsible for different Ra values. Caution should be exercised as the number of irregularities remains largely unconsidered in most studies.

In order to effectively polish the resin composite, an abrasive should remove the matrix resin as well as cut the relatively harder filler particles. CM and SC are pointed shape abrasives that contain 6- μm diamond and 25- μm zirconium oxide particles, respectively. SS uses polishing disks attached by a polymeric collar with four different abrasives, and the disks with 20- μm aluminum oxide (green, fine) and 7- μm aluminum oxide (red, super fine) were used. ES combines an abrasive point with 40- μm aluminum oxide, and a foam polishing cup used with two different polishing pastes (1- and 0.3- μm aluminum oxide particles). In this study, SS and ES created smoother surfaces when compared to those obtained with the pointed shape abrasives for the resin composites used. Because the resin surface employed in this study was flat, it might be easy to create a smoother surface with relatively short polishing duration. The ability to produce a smooth surface with the use of the aluminum oxide disks depends on their cutting filler particles and matrix resin equally. Though smoother surfaces were obtained with multi-step polishing systems, the use of the one-step polishing system CM might be clinically recommended, considering the time and cost savings (21).

The appearance of the restoration is also affected by the degree of surface gloss after polishing (22) and is based on the reflected light from the restoration. The incident light beam is reflected from the surface of the restoration, which is composed of numerous minute flat surfaces. With increased surface roughness, the degree of random light reflection increases, resulting in decreased gloss. A smooth and glossy surface is the final objective of any polishing procedure (23). In clinical situations, resin composites are usually polished and exposed to the oral environment immediately after restoration. Maintaining the surface texture is critical to the esthetics of the restoration (1,2,11-13). Additional factors affecting the polishing results might include the load applied to the restoration, the orientation of the abrading surface, and the amount of time spent with each polishing system (17,24,25).

Based on the results of this study, the effects of polishing system on surface roughness was dependent on both the system and materials employed. Numerous filler systems, monomer systems and coupling agents have been developed

to improve the mechanical properties and surface appearance of resin composites. It has been suggested that filler size and load have the potential to influence the surface characteristics of a resin composite (26-28). Filler particles should be situated as close as possible in order to protect the resin matrix from abrasives. Reduced inter-particle spacing in resin composites is achieved by decreasing the size and increasing the volume fraction of fillers (29). Harder filler particles are left protruding from the surface during polishing as the softer resin matrix is preferentially removed. Resin composites with larger filler particles are expected to have higher Ra values after polishing. Since the resin composites used in this study were highly filled hybrid composites with relatively large filler particles, further investigation focusing on differences in filler particle size, for example, in microfill composites, is needed (2).

Although the smoothest composite surface was obtained with the multi-step polishing systems, the one-step polishing point composed of diamond particle-impregnated rubber produced a clinically acceptable surface with relatively short polishing duration (30). Further studies are needed to incorporate the type of resin composites used and the determination of surface gloss produced by the polishing systems. This type of investigation may reveal the clinical relevance of Ra value and the relationship between polishing procedures and their effect on surface roughness.

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