Surface Roughness of Denture Base Acrylic Resins After Processing and After Polishing

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Purpose: **Circumstances exist in which the need to adjust denture base acrylic resins is necessary. This process obviously alters the surface of the polished denture base. The purpose of this study was to compare the effects of three chairside polishing kits and conventional polishing on four denture acrylic resins.**

Materials and Methods: **Twenty-four 30 × 30 × 2 mm acrylic resin specimens were fabricated with each of four acrylic resins: autopolymerizing, heat processed, injection molded, and microwaveable. One side was polished conventionally with pumice and polishing compound. The other side was polished with one of three chairside polishing kits: Axis, Brasseler, and Shofu. Each side was evaluated by a Dektak 8 Programmable Stylus Profiler to determine the surface roughness (Ra).**

Results: **One-way analysis of variance (ANOVA) revealed that: (1) There was no significant difference in the time it took to polish the specimens with the chairside polishing kits ($F = 2.118, p = 0.14$). (2) There was a significant difference in surface roughness between the acrylic resins before any polishing, with the injection-molded and heat-processed being less rough than the autopolymerizing ($F = 4.588, p = 0.005$). (3) There was a significant difference in surface roughness between the acrylic resins when conventionally polished, with the injection-molded and microwavable being less rough than the autopolymerizing ($F = 4.503$, $p = 0.005$). Factorial ANOVA revealed that: (1) There was no significant difference in the surface roughness among the chairside polishing kits ($F = 1.209$, $p = 0.30$). (2) There was a significant difference between the acrylic resins, with the heat-processed, injection-molded, and microwaveable being significantly less rough than the autopolymerizing ($F = 6.610, p = 0.0001$). (3) There was no significant interaction between the acrylic resins and the chairside polishing kit in the amount of surface roughness ($F = 1.728, p = 0.12$). An independent t-test revealed that conventional polishing was significantly smoother than polishing with the chairside polishing kits ($t = 3.847, p = 0.0001$).**

Conclusions: **It was concluded that time was not a factor in using any of the chairside polishing kits. It is recommended that conventional polishing be used after adjustments to the cameo surface of denture acrylic resin.**

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INDEX WORDS: autopolymerizing, heat processed, injection molded, microwaveable, biofilm, chairside polishing kits, conventional polishing

IN THE CLINICAL practice of dentistry, there are many circumstances in which the need to adjust denture base acrylic resin is necessary. This process ultimately alters the finished and polished surface of the original denture base. When such procedures are performed, a rougher surface is produced. This roughened surface may cause plaque accumulation as well as staining. Several authors have reported on the finishing and polishing of acrylic resins.[1,2] Both Craig and Rudd recommend polishing acrylic resins with a wet cloth wheel and a slurry of pumice.

Dental plaque and associated biofilms have been generally accepted to be the etiology of dental caries and periodontal disease. Dental plaque

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is considered a dense, noncalcified bacterial mass firmly adherent to the tooth surface. The plaque attaches to the tooth pellicle, an amorphous membranous layer, which covers the enamel surface and can be 0.1 to several microns thick. The microcolonies increase in size and eventually coalesce to form a continuous bacterial layer that grows in thickness. Bacterial accumulation is most commonly observed around irregularities of the tooth surface and along the gingival margin.[3]

This concept is of clinical importance because patients need to have a smooth surface to deter the formation of a biofilm. This is an esthetic concern as well as an overall concern for maintaining good oral hygiene.

Bollen et al found that the surface roughness of acrylic resin can be dependent on the polishing grit.[4] *Streptococcus sanguis*, *Bacteriodes gingivalis*, and *Candida albicans* adhere in very high numbers to roughened acrylic resin versus smooth acrylic resin.

In a study performed by Kagermeier-Callaway et al, both *Streptococcus oralis* and *Actinomyces viscosus* adhered to rough denture surfaces.[5] This study used four acrylic resin materials: chemically, heat, light, and microwave polymerized. The specimens were subjected to *S. oralis* or *A. viscosus*. This study tested both unpolished and polished specimens. Within 24 to 48 hours, the oral bacteria had colonized on the specimens. In some cases, the unpolished specimens had more bacterial colonization than the polished specimens. The heat-processed and microwaveable acrylic resins used in this study had both higher total and viable cell counts of *A. viscosus* and *S. oralis* on the polished samples versus the unpolished samples.

Morgan and Wilson studied the effect of the nature of denture acrylic resin and the roughness of its surface on biofilm accumulation.[6] They used both heat-polymerized and autopolymerized acrylic resins that were polished by numerous grades of abrasive paper. They tested their susceptibility to *S oralis*. In their study, both the type of acrylic resin and the roughness of the acrylic resin had a significant impact on the adhesion of *S. oralis* to the specimens.

O'Donnell et al investigated two heat-processed acrylic resins polished conventionally, as the control, and also by two chairside polishing kits.[7] Three operators polished the specimens for a prescribed amount of time. Their evaluation of the specimens consisted of both scanning electron microscopy (SEM) and energy dispersive analysis. Both acrylic resins produced a smooth surface when visualized with the SEM. Neither of the chairside polishing kits produced as smooth a surface as conventional polishing. O'Donnell et al concluded that the acrylic resins they tested could be effectively polished with the chairside kits, but conventional polishing produced a smoother surface. In addition, they concluded that the chairside kits produced a smoother surface than not polishing at all.

There is a lack of research pertaining to the surface roughness of acrylic resins, various commercially available chairside polishing kits, and the differences between polishing both conventionally with pumice, and with chairside kits. There is also a lack of studies that reveal what level of surface roughness is clinically acceptable for the cameo surfaces of denture bases. Therefore, the purposes of this study were to: (1) perform a pilot study to determine whether there were differences in the amount of time it took to polish the acrylic resin specimens with the three chairside kits; (2) compare resultant surface roughness before polishing either conventionally or with the chairside polishing kits; (3) compare resultant surface roughness between the four acrylic resins with conventional polishing; (4) compare resultant surface roughness for four acrylic resins, three chairside polishing kits, and the interaction of the acrylic resins polished by chairside polishing kits; (5) compare resultant surface roughness of conventional polishing versus polishing with the chairside kits; and (6) recommend an efficient and effective denture base polishing kit for chairside clinical adjustment.

Materials and Methods

Three chairside denture polishing kits, Axis Dental (Irvington, TX), Brasseler (Savannah, GA), and Shofu (San Marcos, CA), were selected for the polishing of four acrylic resins: Repair Material (Dentsply International, Inc., York, PA), Lucitone 199 conventional denture base material (Dentsply International, Inc.), Lucitone Fas-Por+ liquid pour denture base material (Dentsply International, Inc.), and Arcon MC microwaveable denture base material (GC America, Inc., Chicago, IL).

Ninety-six square wax patterns (30 × 30 × 3 mm) were fabricated as described below using Truwax hard baseplate wax (Dentsply International, Inc.) to facilitate the fabrication of the acrylic resin specimens.

Each group had 24 specimens. Two sheets of baseplate wax (Dentsply International, Inc.), each about 1 mm in thickness, were melted together and cut into 30 × 30 mm squares to fabricate the specimens. Twenty-four of the wax patterns were processed with each of the four types of acrylic resin according to manufacturers' instructions. All specimens were finished and polished by one operator with an acrylic bur (Axis Dental University Cutter UC251E5), coarse grit pumice (Henry Schein, Melville, NY), medium grit pumice (Henry Schein), fine grit pumice (Henry Schein), flour of pumice (Henry Schein), and polishing compound (Motloid, Chicago, IL) on one side to eliminate any visible irregularities.

The 24 specimens in each of the four acrylic resin groups were randomly divided into three groups of eight within each group by using a random numbers table.[8]

Group 1: polished with an Axis Dental polishing kit and its control
Group 2: polished with a Brasseler polishing kit and its control
Group 3: polished with a Shofu polishing kit and its control

On the other side of each specimen, an acrylic bur (Axis Dental University Cutter UC251E5) was used for 15 seconds to simulate a clinical adjustment, and the surface was then polished to the naked eye, by one operator, using one of the three available chairside denture polishing kits (Axis Dental, Brasseler, and Shofu). Each kit contained three burs with surface roughness from coarse to medium to fine. These polishing burs all contained silicone impregnated with silicone. Polishing was performed according to the manufacturers' directions. Polishing was timed with a stopwatch beginning when the bur touched the specimen until all components of the kit were used as recommended by the manufacturer.

The Dektak 8 Programmable Bench-Top Stylus Profiler (Veeco Instruments, Inc., Woodbury, NY) was used to measure the surface roughness of the specimens before polishing, after conventional polishing with pumice and polishing compound, and after polishing with the chairside polishing kits. The profiler was set to move a diamond stylus across the specimen surface under a constant load. The scanning duration for each line was 20 seconds with a constant force of 5 mg on the diamond stylus (12.5 μm in radius). The surface morphology was measured with a linear variable differential transformer. The surface roughness was derived from computing the numerical values of the surface profile. The value of Ra describes the overall roughness of a surface and is defined as the mean value of all absolute distances of the roughness profiles from the mean line within the measuring distance. For each specimen, a central area of 15 × 15 mm was scanned by 15 lines, with a length of 15 mm and incremental distance of 1 mm between each scanning line. The vertical resolution was 160 angstrom, which in turn represents the accuracy of Ra as well. The mean Ra was calculated from 15 lines as the mean roughness of the specimen.

The acrylic resin specimens with the largest Ra value and the smallest Ra value were analyzed by a LEO 1450VP SEM (LEO Electron Microscopy, Inc., Thornwood, NY). The variable pressure mode with a pressure of 20 Pa in the chamber was employed for the analysis of these nonconductive specimens. A sputter coating on the specimen surface before the analysis was not necessary in the variable pressure (VP) mode. The signals were registered by a quadrant backscattered electron detector in the VP mode. Each specimen was imaged by 100× and 200× magnifications, respectively. The scale bar was labeled on the images.

A Factorial ANOVA and a Tukey Honestly Significant Difference (HSD) test were used to determine whether there were significant differences in time. To test for significant differences in the surface roughness of each of the four acrylic resins before any polishing, a one-way ANOVA and Tukey HSD test were performed. To test for significant differences in the surface roughness of each of the four acrylic resins after conventional polishing, a one-way ANOVA and Tukey HSD test were performed. To test for significant differences in the surface roughness of the four acrylic resins, the three kits, and their interactions, a Factorial ANOVA and a Tukey HSD test were performed. The data collected to examine the difference between the resultant surface roughness achieved by conventional polishing versus polishing with the chairside polishing kits were analyzed by a t-test. The Statistical Package for the Social Sciences (SPSS) was used to analyze the data. A $p \leq 0.05$ was considered significant.

Results

Time to Polish

There was no significant difference in the time it took to polish the four acrylic resins ($F = 0.511$, $p = 0.69$). There was no significant difference in the time it took to polish the acrylic resin with the three chairside polishing kits ($F = 2.118, p = 0.14$). There was no significant interaction between the time it took to polish the four acrylic resins and the time it took to polish with the three chairside polishing kits ($F = 0.182, p = 0.98$; Table 1).

SEMs of the Specimens

The least rough specimen of all those tested in this study was an injection-molded specimen polished

Table 1. Time to Polish the Acrylic Resins

	Time (sec)			
	Mean	*SD*	*F*	*P*
Acrylic resin			0.511	0.69*
Microwaveable	137.22	13.26		
Heat-processed	139.78	10.59		
Autopolymerizing	141.89	10.93		
Injection-molded	143.89	10.95		
Chairside kits			2.118	0.14*
Axis	135.33	9.22		
Shofu	141.42	8.94		
Brasseler	145.33	13.54		
Acrylic resin by kits			0.182	0.98*

*Nonsignificant.

conventionally (Fig 1). The roughest specimen of all those tested in this study was an autopolymerizing specimen polished with one of the three chairside polishing kits (Fig 2). Visualization via SEM demonstrated the differences in surface texture between these two specimens.

Before Polishing

There was a significant difference in surface roughness between the four types of acrylic resins before any polishing ($F = 4.588$, $p = 0.005$). The injection-molded and heat-processed acrylic resins were significantly less rough than the autopolymerizing acrylic resin. The microwaveable acrylic resin was neither smoother nor rougher than the heat-processed, injection-molded, and autopolymerizing acrylic resins (Table 2).

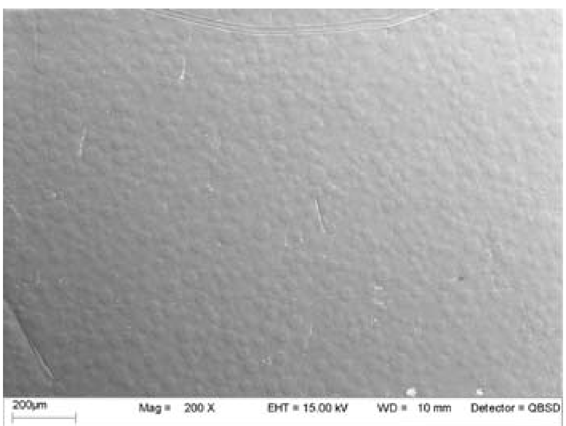

Figure 1. SEM (200×) of injection-molded acrylic resin polished conventionally.

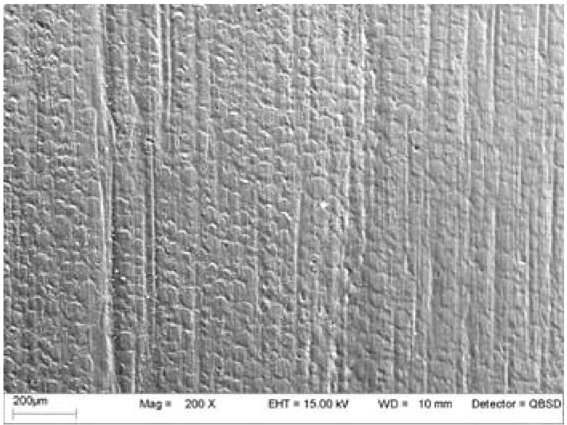

Figure 2. SEM (200×) of autopolymerizing acrylic resin polished with a chairside polishing kit.

After Conventional Polishing

There was a significant difference between the four types of acrylic resins after conventional polishing ($F = 4.503$, $p = 0.005$). The injection-molded and microwaveable acrylic resins were significantly less rough than the autopolymerizing acrylic resin. The heat-processed acrylic resin was neither smoother nor rougher than the autopolymerizing, injection-molded, and microwaveable acrylic resins (Table 3).

Acrylic Resins Polished by Chairside Polishing Kits

There was a significant difference between the types of acrylic resins. The heat-processed, injection-molded, and microwaveable acrylic resins were significantly smoother than the autopolymerizing acrylic resin ($F = 6.610$, $p = 0.0001$). There was no significant difference in the surface roughness between the three chairside polishing kits ($F = 1.209$, $p = 0.30$). There was no significant interaction, with respect to surface roughness, between the type of acrylic resin and the chairside polishing kit ($F = 1.728$, $p = 0.12$; Table 4).

Polishing Conventionally versus Polishing by Chairside Polishing Kits

There was a significant difference between the surface roughness achieved by conventional polishing and the surface roughness achieved by the

Table 2. Surface Roughness Before Polishing

	Ra Value (μm)			
	Mean	*SD*	*F*	*P*
Acrylic resin			4.588	0.005
Injection-molded	196880.63[a*]	120713.81		
Heat-processed	211310.58[a]	133775.75		
Microwaveable	272767.92[a,b]	198038.24		
Autopolymerizing	347833.58[b]	165384.01		

*Groups modified with the same letter are not significantly different.

Table 3. Surface Roughness with Conventional Polishing

	Ra Value (μm)			
	Mean	*SD*	*F*	*P*
Acrylic resin			4.503	0.005
Injection-molded	102874.13[a*]	57867.24		
Microwaveable	123477.58[a]	57034.16		
Heat-processed	133689.96[a,b]	72985.43		
Autopolymerizing	186452.04[b]	122871.73		

*Groups with the same letter are not significantly different.

chairside polishing kits (t = 3.847, p = 0.0001; Table 5).

Discussion

Denture acrylic resin is a hard, nonshedding surface that can accumulate plaque and biofilm. Surface roughness may contribute to the rate of microbial colonization and biofilm formation on acrylic resin. Studies by Morgan and Wilson and by Lamfon showed that bacteria and fungus have more of a propensity to adhere to rough acrylic resins. Since most of the acrylic resins and the chairside polishing kit components used in this study are proprietary, the true differences in the materials used may never be known to their fullest extent.

The injection-molded and heat-processed acrylic resins were less rough than the autopolymerizing acrylic resin before any polishing was performed. With the use of conventional polishing with the four grits of pumice and the

Table 4. Surface Roughness of Four Acrylic Resins Polished by Three Chairside Kits

	Ra Value (μm)			
	Mean	*SD*	*F*	*P*
Acrylic resin			6.610	0.0001
Heat-processed	150779.50[a*]	90604.34		
Injection-molded	160320.46[a]	83712.37		
Microwaveable	195454.17[a]	146922.62		
Autopolymerizing	287582.54[b]	150613.95		
Chairside kits			1.209	0.30
Brasseler	176105.81	116626.61		
Shofu	197218.59	142557.32		
Axis	222278.09	134726.37		
Acrylic resin by kits			1.728	0.12

*Groups with the same letter are not significantly different.

Table 5. Surface Roughness of Conventional Polishing Versus Chairside Kits

	Mean	*SD*	*t*	*P*
			3.847	0.0001
Conventional	136623.43	86625.28		
Chairside Kits	198534.17	131730.79		

polishing compound, the injection-molded, and microwaveable acrylic resins were less rough than the autopolymerizing acrylic resin. With the use of the chairside polishing kits, the heat-processed, injection-molded, and microwaveable acrylic resins were less rough than the autopolymerizing acrylic resin. Therefore, the autopolymerizing acrylic resin tended to have a rougher surface than the other acrylic resins regardless of the polishing method or lack thereof. One possible explanation could be that the autopolymerizing acrylic resin polymer may have a larger acrylic resin precursor bead size than the others used in this study.[9]

The heat-processed acrylic resin was less rough than the autopolymerizing acrylic resin only when using the chairside polishing kits, but not when conventionally polished with pumice and polishing compound. Further studies are necessary to determine which factors relating to the chairside polishing kits make them different from the pumice and polishing compound combination when polishing, in terms of surface roughness achieved.

When comparing the level of surface roughness achieved with conventional polishing versus the chairside polishing kits, conventional polishing was far superior. This, too, warrants further investigation to see what the differences are between the various grits of pumice and polishing compound versus the composition of the chairside polishing kits.

This study also leads to questions about the differences in the physical properties found in each of the acrylic resins. The heat-processed acrylic resin used benzoyl peroxide and di-isobutylazonitrile as initiators whereas the autopolymerizing acrylic resin used benzoyl peroxide and free radicals as initiators. Perhaps the initiator in each acrylic resin system played a role in the differences found in surface roughness before polishing. The heat-processed acrylic resin polymerization reaction was accelerated by heat whereas the autopolymerizing acrylic resin polymerization reaction was accelerated by a chemical. Perhaps the accelerator in each acrylic resin system also played a role in the differences found in surface roughness. Due to the proprietary nature of the ingredients in these acrylic resins, these questions may go unanswered.[9,10]

Yet, another factor to consider was the rubber component found in the powder of the heat-processed acrylic resin. According to the information available, the heat-processed acrylic resin was the only acrylic resin used in this study that had this particular component. Therefore, what impact, if any, this had on the results of this study is unknown.[9]

This study confirms the results as found by O'Donnell et al even though some of the materials tested varied. Additionally, because of the lack of literature available regarding an acceptable Ra value for acrylic resin denture bases, there is a question as to whether these statistically different surface roughnesses are clinically meaningful.

Although one operator was used throughout the study to eliminate any inadvertent bias and ensure a constant pressure when polishing, a calibrated machine might be used to repeat this study. By using a mechanical "operator," the method of polishing would be consistent without any human error.

Some of the limitations of this study include: operator variables, because there was only one operator; material variables, because only four commercially available acrylic resins were tested; and kit variables, because only three commercially available chairside polishing kits were used. Finally, the lack of information about the components of the materials used makes it difficult to draw inferences about the causes of the differences found.

Conclusions

Within the limitations of this study, overall, the autopolymerizing acrylic resin performed least favorably in terms of surface roughness, regardless of the polishing method. None of the tested chairside polishing kits outperformed any other. Conventional polishing with a series of different grits of pumice and polishing compound is highly recommended based on the results of this study.

Every clinician must use his or her best clinical judgment after any adjustment of the cameo surface of a denture base. A smooth denture surface will be beneficial to the patient and contribute to a healthier oral environment. Microorganisms are a normal part of the oral cavity; however, any effort by the dentist to reduce the likelihood of plaque and biofilm accumulation will benefit the patient immensely.

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