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ORIGINAL ARTICLE

The effect of mechanical and chemical polishing techniques on the surface roughness of denture base acrylic resins

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Abstract Smooth polished surface of dental prostheses is important to prevent bacterial colonization and plaque accumulation. The acrylic base of prosthodontic appliances needs to be adjusted by grinding which often alters the surface of the denture base. It is therefore important to know how different polishing techniques affect surface roughness of acrylic resin.

Objective: The aim of this study was to evaluate the effect of mechanical polishing (MP) and chemical polishing (CP) on the surface roughness of heat cured (HC) and auto cured (AC) denture base acrylic resins.

Materials and methods: Sixty acrylic resin specimens ($30 \times 15 \times 3$ mm) were made for each of the two types of acrylic resins. Thirty HC specimens received mechanical conventional lathe polishing using cone with pumice slurry and soft brush with chalk powder. The other thirty HC specimens received chemical polishing by immersing in methyl-methacrylate monomer heated to 75 °C ± 1 °C for 10 s. The sixty AC specimens received mechanical and chemical polishing in the same manner. Surface roughness was measured using surface analyzing instrument in microns. The data were statistically analyzed by two-way analysis of variance (ANOVA) followed by post hoc Tukey's test ($\alpha = 0.05$).

Results: The surface roughness mean in microns in order of decreasing values were: CP-HC: 1.4132 μm; CP-AC: 1.3494 μm; MP-AC: 0.7364 μm and MP-HC: 0.6333 μm. Two-way ANOVA revealed that the MP-HC was significantly different from CP-HC and CP-AC ($P < 0.05$). The MP-AC is also significantly different from CP-HC and CP-AC ($P < 0.05$). There was no significant difference between MP and CP of HC and AC acrylic resin groups.

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Conclusion: It can be concluded that MP produced significantly smoother surfaces than CP. The surface roughness obtained by MP was not influenced by acrylic resin type where as this was not true for CP.

1. Introduction

Acrylic resin has a wide application in dentistry as for bases of removable partial dentures, complete dentures, tooth supported or implant retained over dentures, orthodontic appliances, stents, surgical guides for implant placement and for temporary crowns. Prosthodontic appliances should have a smooth and highly polished surface to maintain comfort and health of oral tissues, and to prevent colonization of micro organisms and plaque accumulation and staining (Craig et al., 2000).

Several investigators have reported that rough acrylic surface promotes bacterial accumulation and plaque formation (Ulusoy et al., 1986; Quirynen et al., 1990; Verran and Maryan, 1997; Bollen et al., 1997). The value reported as characteristic of smooth acrylic resin is 0.12/μm. However, surface roughness of polished acrylic resin may vary between 0.03 and 0.75 μm (Quirynen et al., 1990; Busscher et al., 1984). Significant bacterial colonization would occur if the surface roughness is more than 2 μm (Quirynen et al., 1990).

Traditionally in a dental laboratory, acrylic resin is finished and polished by mechanical procedure using felt-cones and slurry of fine pumice and water followed by felt-cones with chalk powder and water. Mechanical polishing results in surface abrasion and progressively reducing notches until a smooth polished surface results (Craig et al., 2000). The method is efficient but because all steps should be done sequentially, it is laborious and time consuming. To overcome this disadvantage, an alternative finishing and polishing method was presented in 1969 (Ulusoy et al., 1986). An alternative finishing and polishing method was presented in 1969 to overcome this disadvantage (Ulusoy et al., 1986). This new acrylic resin polishing method called the chemical polishing (CP) eliminated the polishing sequence. The acrylic resin finishing stages are the only necessary (Rahal et al., 2004; Oliveira et al., 2008). This technique consists of immersing the prosthesis after finishing procedures into heated methyl-methacrylate monomer bath (75 °C) for 10 s. The advantage of this technique is that it eliminates the polishing sequence and the possibility of smoothening intaglio surfaces (Braun et al., 2003).

Oliveira et al. (2008) investigated the surface roughness of HC and AC resins after submitting them to mechanical polishing (MP) and chemical polishing (CP). They concluded that MP produced lower surface roughness mean values than CP and is not influenced by the acrylic resin type. In contrast, Berger et al. (2006) reported that AC acrylic resin performed less favorably in terms of surface roughness than MP. Rahal et al. (2004) evaluated the influence of MP and CP on surface roughness of HC and AC resins. Their results lead them to conclude the following: MP produced smoother surface than CP and surface roughness was not influenced by acrylic resin type. However, CP results were dependant on acrylic resin type. Radford et al. (1999) reported that acrylic resin has been less frequently investigated for its surface roughness and effect of polishing than other dental materials.

Dentures and several dental appliances may be constructed of heat-cure or auto-cure acrylic resin. A denture made of heat-cure acrylic resins may subsequently be repaired or relined with auto-cure acrylic resins. Therefore, both types of acrylic resins were evaluated for surface roughness in this study. The aim of this study was to evaluate the effect of mechanical polishing and chemical polishing on the surface roughness of heat-cure and auto-cure acrylic resins.

2. Materials and methods

2.1. Preparation of acrylic resin specimens

A total number of 120 specimens, sixty made of HC acrylic resin and sixty made of AC acrylic resin, were used in this investigation and divided according to the polishing method into two equal groups. Group 1 was mechanically polished while Group 2 was chemically polished. Two rectangular patterns (30 × 15 × 3 mm) were made of heavy body condensation silicone material (President, Coltene, AG, Alstatten, Switzerland). The moulds were made by placing the patterns in a metal flask with dental stone (Excaliber, Garrcco Inc., Heber Springs, AZ, USA). The lower half of the flask was filled with mixed dental stone and was allowed to set for 1 h. After the plaster had set, it was trimmed to a flat surface. The two silicone rectangular patterns were placed on the plaster surface and attached with molten. The stone surface was painted with a separating medium (Die Bub, JIM Neg Col. Bloomfield, CT, USA). The upper half of the flask was placed over the lower half and filled with mixed dental stone and allowed to set for 1 h. The halves of the flask were separated, the silicone patterns were removed and the stone surface was painted with separating medium.

An auto polymerized acrylic resin (Dentsply International Inc., York, PA) was mixed according to the manufacturer's instructions and packed during the dough stage into the plaster moulds. The upper and lower flasks were closed and maintained under 2000 lbs of compression for 30 min. The flasks were removed from the hydraulic press and cooled over the bench for 150 min. The specimens once processed were retrieved and stored in water at room temperature for 24 h.

Heat-cure acrylic resin specimens were produced using the same mould. A heat-cure denture base material (Lucitone 199, Dentsply International, York, PA, USA) was mixed according to the manufacturer's instructions and packed into the moulds. The curing procedure was employed by placing the flasks in water bath at 160 °F for 9 h (Craig et al., 2000). The specimens were left in flask overnight before removal. Then specimens were stored in water at room temperature for 24 h (Oliveira et al., 2008).

2.2. Finishing and polishing methods

The test specimens of HC and AC acrylic resin were subjected to grinding with acrylic bur (Axis Dental University, Cutter uc

251 E5). The grinding was performed by holding the specimen in a bench vice with low speed instrumentation, light pressure and intermittent contact under water spray for 15 s.

Mechanical polishing was performed using felt-cone with pumice slurry and a wet felt-cone with caulk powder and water for 15 s. All procedures were done step by step with light pressure and intermittent contact for 15 s. Chemical polishing was accomplished by immersing the HC and AC specimens in methyl-methacrylate monomer heated approximately to 75 °C ± 1 °C for 10 s (Rahal et al., 2004; Oliveira et al., 2008; Braun et al., 2003). The specimens were removed from the solution and allowed to dry at room temperature (2 °C ± 2 °C) for 15 s, followed by washing in running tap water for 1 min. The specimens were allowed to dry at room temperature for 10 min before evaluation (Fig. 1). All finishing and polishing procedures were performed by one investigator.

2.3. Measurement of surface roughness

The surface roughness of test specimens were assessed by surface analyzer instrument, Perthometer (Perthometer C3A, Perthen/Mahr, Hannover, F.D. Germany) and surface profile tracings were recorded by Perthograph (C 40, Mahr Perthen, GmbH, Gottingen, West Germany) simultaneously. The stylus of the Perthometer passed across the specimen surface in a line and the Perthometer calculated arithmetical roughness average (Ra) in microns (Fig. 2). The roughness average (Ra) was chosen for presentation of results as it is the standard parameter in industry. The test conditions were: cut off length = 0.8 mm; drive speed = 0.25 mm/s, sample length = 30 mm; transverse length = 15 mm and cutting depth = 0.03 mm. Six passes of the stylus were made on different areas of the surface of each specimen and the mean of the six readings were used in data analysis (Ulusoy et al., 1986).

The data were statistically analyzed for difference between the two polishing techniques for the two types of material (HC and AC). Minimum, maximum, range, mean and standard deviations were calculated for each technique and material. The data were subjected to two-way analysis of variance (ANOVA) and Tukey's test for post hoc comparison ($\alpha = 0.5$). A statistical package for social sciences (SPSS) was used.

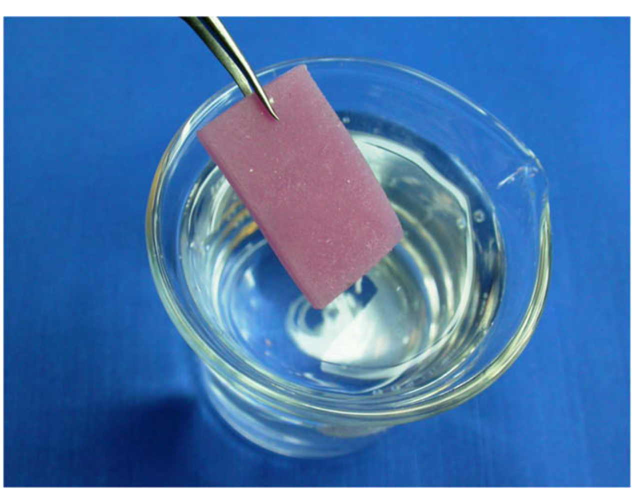

Figure 1 Chemical polishing of acrylic resin specimen by immersing in methyl-methacrylate monomer.

Figure 2 Perthometer recording the surface roughness of acrylic resin specimen.

3. Results

The mean, standard deviation, minimum and maximum values of surface roughness between MP and CP for HC and AC materials are presented in Table 1. The mean roughness values for the combination of polishing technique and material in decreasing order are: CP-HC = 1.4132 µm; CP-AC = 1.3494 µm; MP-AC = 0.7364 µm and MP-HC = 0.6333 µm.

Two way ANOVA showed that surface roughness was influenced by the polishing procedures significantly ($P < .0001$) and not by the acrylic resin materials (see Table 2). There was no significant difference between MP-AC and MP-HC as well as between CP-AC and CP-HC. However, a

Table 1 Mean surface roughness (µm), standard deviation, minimum and maximum values for the two types of acrylic resins after mechanical and chemical polishing.

	N	Mean	Standard deviation	Minimum	Maximum
Mech-Heatcure	30	.633363	.0699964	.4936	.7831
Mech-AutoCure	30	.736493	.1069623	.5291	.9037
Chem-HeatCure	30	1.413273	.4532602	.8140	1.9696
Chem-AutoCure	30	1.349400	.4115522	.6793	1.9634
Total	120	1.033133	.4684493	.4936	1.9696

Table 2 Two-way analysis of variance summary of all effects.

Source	Type III sum of squares	Df	Mean square	*F*	Sig.
Material	.012	1	0.12	.120	.730
Polishing	14.555	1	14.555	148.833	.0000
Polishing * Material	.210	1	.210	2.145	.146
Error	11.344	116	.098		
Total	154.188	120			
Corrected total	26.120	119			

Table 3 Pair wise comparison between all groups using post hoc Tukey's test.

(*i*) Combin	(*j*) Combin	Mean difference (*i* − *j*)	Std. error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
Mech-HeatCure	Mech-AutoCure	−.1031300	.0807424	.204	−.263051	.056791
	Chem-HeatCure	−.7799100*	.0807424	.000	−.939831	−.619989
	Chem-AutoCure	−.7160367*	.0807424	.000	−.875957	−.556116
Mech-AutoCure	Mech-HeatCure	.1031300	.087424	.204	−.056791	.263051
	Chem-HeatCure	−.6767800*	.0807424	.000	−.836701	−.516859
	Chem-AutoCure	−.6129067*	.0807424	.000	−.772827	−.452986
Chem-HeatCure	Mech-HeatCure	.7799100*	.0807424	.000	.619989	.939831
	Mech-AutoCure	.6767800*	.0807424	.000	.516859	.836701
	Chem-AutoCure	.0638733	.0807424	.431	−.096047	.223794
Chem-AutoCure	Mech-HeatCure	.7160367*	.0807424	.000	.556116	.875957
	Mech-AutoCure	.6129067*	.0807424	.000	.452986	.772827
	Chem-HeatCure	−.0638733	.0807424	.431	−.223794	.096047

* The mean difference is significant at $P < .05$.

significant difference in surface roughness was found between all other combinations ($P < .0001$) as shown in Table 3.

4. Discussion

Polished surface of acrylic resin denture material is important, as it affects the oral health of tissues that are in direct contact. Rough surfaces of oral appliances promote colonization of bacteria and plaque accumulation (Quirynen et al., 1990; Verran and Maryan, 1997; Bollen et al., 1997). The threshold surface roughness for bacterial attachment was reported to be 0.2 μm (Quirynen et al., 1990). Surface roughness values more than 0.2 μm may promote plaque formation. Bollen et al. (1997) and Radford et al. (1999) reported that high concentration of bacterial colonization occurs if the surface roughness value is greater than 2.0 μm. The authors considered that characterization of smooth acrylic resin surface may vary between 0.03 μm and 0.75 μm depending upon the technique used for finishing and polishing (Bollen et al., 1997; Radford et al., 1999). The results of this study showed that the mean surface roughness values for MP of HC acrylic resin was 0.6333 μm and 0.7364 μm for CP of AC acrylic resin. The mean values found in this study agree with the range reported by Busscher et al. (1984), Oliveira et al. (2008) and Radford et al. (1999).

Furthermore, the results of this study demonstrated that the surface roughness of MP-HC acrylic resin was not significantly different from MP-AC acrylic resin although superior surface characteristics of HC acrylic resin may be expected due to higher degree of conversion of monomer compared to AC acrylic resin which is concurring with that of Oliveira et al. (2008). Also, MP produced lower surface roughness values than CP for both types of acrylic resins. This finding is in agreement with the results of other studies (Ulusoy et al., 1986; Rahal et al., 2004; Oliveira et al., 2008; Berger et al., 2006). These results were expected because the abrasive mechanical action progressively removes surface notches during polishing.

The polishability of the surface with chemical polishing method may be explained by the penetration of the polishing liquid, which contains methyl-methacrylate monomer molecules, through the superficial polymeric chain of acrylic resin breaking the secondary bonds that join them, promoting a final plasticizing effect of the acrylic resin surface. This superficial layer has no effect on the under lying irregularities caused by finishing procedures (Rahal et al., 2004). It is interesting to note that there was no significant difference in surface roughness values between HC and AC acrylic resin specimens subjected to mechanical polishing, although the surface of AC specimens being more porous than HC resin where a higher surface roughness should be expected.

The polishing of dentures is never performed on completely flat surfaces. The recommended speed and maximum allowable pressure of felt-cone with pumice slurry and wet felt-cone with chalk are not easy to control and therefore, highly operator dependant. Therefore, when comparing the effectiveness of polishing technique by various investigators, a reasonable variability value for surface roughness should be expected. In the present study, the surface roughness of one brand of HC and AC acrylic resin was evaluated. Further investigations of the effectiveness of polishing techniques on different brands of HC and AC acrylic resin materials are needed.

Adjustments of dentures are necessary to correct over extension. The adjustments are made by grinding with tungsten carbide bur which result in rough surface and necessitate polishing afterwards.

5. Conclusions

Within the limitations of this study, the following conclusions were drawn:

1. Mechanical polishing produces lower surface roughness compared with chemical polishing.
2. The mean surface roughness values of mechanical polishing are not influenced by acrylic resin type.
3. Chemical polishing effect on the surface roughness value depends on the acrylic resin type.
4. Mechanical polishing is the most effective polishing technique.

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