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The influence of polishing techniques on pre-polymerized CAD\CAM acrylic resin denture bases

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Abstract

Background: Lately, computer-aided design and computer-aided manufacturing (CAD/CAM) has broadly been successfully employed in dentistry. The CAD/CAM systems have recently become commercially available for fabrication of complete dentures, and are considered as an alternative technique to conventionally processed acrylic resin bases. However, they have not yet been fully investigated.

Objective: The purpose of this study was to inspect the effects of mechanical polishing and chemical polishing on the surface roughness (Ra) and contact angle (wettability) of heat-cured, auto-cured and CAD/CAM denture base acrylic resins.

Methods: This study was conducted at the Advanced Dental Research Laboratory Center of King Abdulaziz University from March to June 2017. Three denture base materials were selected: heat cure poly-methylmethacrylate resin, thermoplastic (polyamide resin) and (CAD\CAM) denture base resin. Sixty specimens were prepared and divided into three groups, twenty in each. Each group was divided according to the polishing techniques into (Mech P) and (Chem P), ten specimens in each; surface roughness and wettability were investigated. Data were analyzed by SPSS version 22, using one-way ANOVA and Pearson coefficient.

Results: One-way analysis of variance (ANOVA) and post hoc tests were used for comparing the surface roughness values between three groups which revealed a statistical significant difference between them ($p_1<0.001$). Heat-cured denture base material of (Group I) in both methods, showed the highest mean surface roughness value (2.44±0.07, 2.72±0.09, Mech P and Chem P respectively); while CAD\CAM denture base material (group III) showed the least mean values (1.08±0.23, 1.39±0.31, Mech P and Chem P respectively). CAD/CAM showed the least contact angle in both polishing methods, which were statistically significant at 5% level ($p=0.034$ and $p<0.001$).

Conclusion: Mechanical polishing produced lower surface roughness of CAD\CAM denture base resin with superior smooth surface compared to chemical polishing. Mechanical polishing is considered the best effective polishing technique. CAD/CAM denture base material should be considered as the material of choice for complete denture construction in the near future, especially for older dental patients with changed salivary functions, because of its wettability.

Keywords: CAD\CAM acrylic resin, Acrylic denture base, Polishing, Surface roughness, Wettability

1. Introduction

Acrylic resin materials have been widely used in dentistry, especially in the field of prosthodontics, to fabricate different types of prostheses. They can be heat cured, auto cured, or microwave-cured. Conventional resins that are used in dentistry are based on poly-methyl methacrylate (PMMA) (1). It has been well known since 1986 that the surface of complete denture acrylic bases must be polished to offer comfort to patients, as well as satisfactory aesthetics, prosthesis cleanliness and to retain lowest level of biofilm (2). Denture-base irregularities are reservoirs for microorganism adhesion and consequent biofilm buildup (3, 4). Prosthodontic appliances made of acrylic resin must be finished and polished properly to attain smooth visible surfaces that contribute to oral hygiene and low

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plaque retention. Furthermore, microporosities resulting from an inadequate polymer monomer ratio, distinct stages of the mass during the packing process, and insufficient pressure inside the flask during the polymerization procedure, are factors that influence the surface smoothness of the acrylic resins (4, 5). Despite the improvement in the physical properties of PMMA over the years, they are subjected to certain condemnation such as volumetric shrinkage, the presence of residual methyl methacrylate monomer, and the tendency to absorb water (6). One drawback of the PMMA based resins is water sorption causing the mechanical properties of the material to decrease and the roughness of the surface to increase producing a malodourous smell (7). Polymerization shrinkage encountered in conventionally cured PMMA, led to the development of a special injection molding technique (thermoplastic resin). The material used nowadays is nylon based plastic (Polyamide). The composition provides strength, flexibility transparency, high impact resistance, color stability, high creep resistance, high fatigue endurance, no porosity, no monomer, good dimensional, and the microcrystalline structure is easy to finish and polish (8). Polishing can be performed through mechanical or chemical methods (9). Mechanical polishing (Mech P) materials include polishing wheels, felt cones, prophylactic pastes, rubber polishers, abrasive stones, aluminum oxide-based polishing pastes, silicone polishers, pumice, and lathe polishing (10, 11). Another method called superficial chemical polishing (Chem P) was introduced as a substitute method (12, 13). Subsequent studies have proven the incompatibility of this technique (14). Lately, computer-aided design and computer-aided manufacturing (CAD/CAM) has broadly been successfully employed in dentistry. The CAD/CAM system has recently become commercially available for fabrication of complete dentures and is considered as another technique to conventionally processed acrylic resin bases. CAD/CAM dentures fabricated by the milling of a denture base from a prepolymerized acrylic resin block, has a hydrophobic surface that repels water. Hydrophobicity of a material can be described using the contact angle (θc) on the material surface that a liquid drop makes when it comes into contact with a solid surface; this angle is a measure of the surface wettability (15, 16). Although some studies have assessed the effects of different polishing techniques on the surface roughness of heat cured, auto-cured, and microwave-cured acrylic resins, few studies have examined the effects of mechanical polishing (Mech P) versus (Chem p) techniques on the surface roughness of CAD\CAM denture base resins (17). Thus, the aim of this study was to assess the effect of the application of different polishing techniques on the surface roughness and wettability of CAD\CAM acrylic denture base resin as well as thermoplastic resin.

2. Material and Methods

2.1. Research design

The study was conducted at the Advanced Dental Research Laboratory Center of King Abdulaziz University during March-June 2017. After statistical consultation, it was found that a sample size of 60 specimens is sufficient to conduct the study. Three denture base materials were selected in this study, Heat cure poly-methylmethacrylate resin, thermoplastic (polyamide resin) and computer-assisted designing and computer-assisted milling (CAD\CAM) denture base resin. Sixty specimens were prepared from denture base materials and divided into three groups, twenty specimens in each. Each group was divided according to the polishing techniques into (Mech P) and (Chem P), with ten specimens in each.

2.2. Preparation of the specimens

In group I, the specimens were prepared from heat cure poly-methylmethacrylate resin (PMMA), (Vertex RS Dentimex Netherlands). The wax pattern specimens were invested in stone using the conventional flasking procedure. After wax removal from the stone molds, the acrylic resin material was packed and processed in accordance to the manufacturer's instructions. In group II, the specimens were prepared from thermoplastic resin (Bre. flex polyamide, Bredent, Gmbh. Co.K.G. Senden, Germany) fabricated using the injection molding technique. The wax specimens (Dental wax, Lordell trading, Australia) were invested in a stone mold in injection molding flask. The wax was then eliminated and the molten thermoplastic material was injected according to the manufacturer's instructions. An injection molding machine was used with the metallic cartridges containing thermoplastic grains that heated to plasticize the resin at injection pressure of 720-750 KPa, 220 °C for 15 minutes. Once the processing was completed, the flask was allowed to bench cool. Polymerized specimens were recovered from the flask and finished to eliminate nodules. Finishing was done by using acrylic-trimming bur mounted on a laboratory lathe. In group III, the specimens were prepared from prepolymerized block of CAD\CAM acrylic resin denture base material (Polident d.o.o. Volčja Draga 42, Sl-5293 Volčja Draga, Slovenia) and cut with a diamond disk (Isomet, Buehler, USA) under water irrigation into quadrilateral samples of dimensions 30 mm in length×15 mm in width and 3 mm in thickness. All the specimens were stored in distilled water at room temperature for 24 hrs. Each specimen was numbered. The test specimens of the three groups were subjected to grinding with acrylic bur and then to polishing.

2.3. Laboratory polishing

2.3.1. *Mechanical polishing (Mech P):*

Mechanical polishing for group I, II, and III specimens were performed using polishing wheels, felt cones with pumice slurry, rubber polishers with high-luster polishing liquid (RHPL) and Universal Polishing Paste (Loose abrasives [aluminumoxide-Al2O3] in paste, Ivoclar Vivadent, Schaan, Liechtenstein), Abraso-Star K50 (K50) as mentioned by the manufacturer with light pressure for 15 seconds.

2.3.2. *Chemical Polishing (Chem P):*

Chemical Polishing for group I, II and III specimens were performed by immersing them in a preheated jar at 75±1 °C containing MMA (Lang Dental Mfg. Co., USA.) monomer for 10 seconds (Figure 1).

2.4. Surface roughness measurements

The surface roughness of the acrylic resin specimens of all the groups after the polishing techniques were determined with a surface profilometer (Surftest SJ-201P, Mitutoyo; America Corporation). The stylus of the meter was passed across, and perpendicular to the abraded surface of the specimen under constant pressure. Three measurements were obtained from different areas of each specimen, and then the average of these readings of surface roughness was calculated and expressed as (Ra) value, which is defined as the average vertical deviation along the surface of the specimen measured in micrometer (μm).

2.5. Contact angle measurements

This method was used to characterize the wettability of each group specimen. It was determined by a drop shape analysis system (DSA 100, Co. Kruss, Germany). The surface was gently air dried before measuring the contact angle. Each specimen was moistened with 10 μl of distilled water by a micropipette from a standard height of 2 cm above the polished surface. Photographic records were done in triplicate by means of a digital camera positioned at a distance of 20 cm from the pipette tip, and the images were analyzed with the software program. The contact angle was defined as the angle at which the liquid interface met the solid surface of the specimens (Figure 2).

2.6. Statistical Analysis

A well-planned study design was used and constant checks were performed to filter out the confounding variables. All statistical analyses were performed using IBM© SPSS© Statistics version 22 (IBM© Corp., Armonk, NY, USA). One-way analysis of variance (ANOVA) test was used and data was expressed as means and standard deviations. Significance of the obtained results was judged at the 5% level. ANOVA with post hoc test for pairwise comparisons was used for comparison between the groups. Pearson coefficient (r) was used to correlate between two normally distributed quantitative variables.

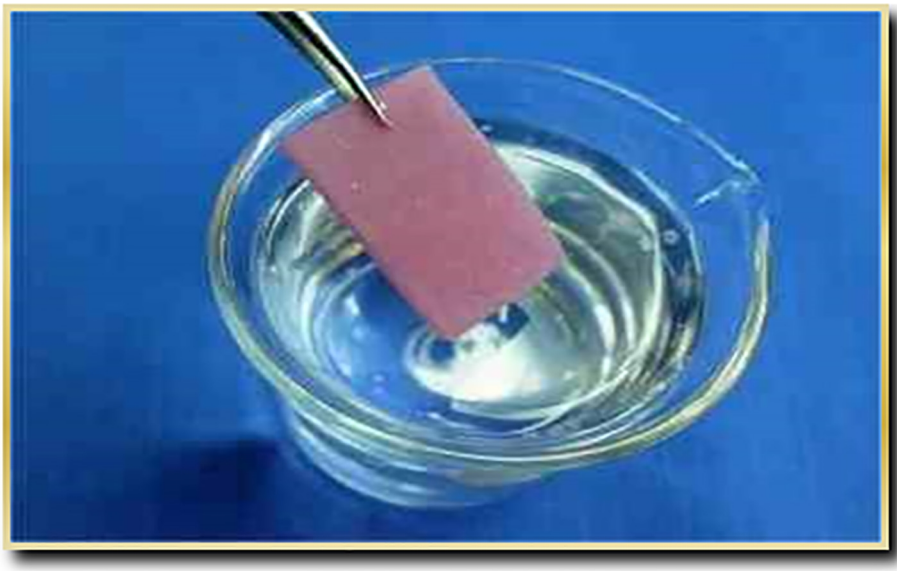

Figure 1. Chemical polishing of acrylic resin specimen immersed in methyl-methacrylate monomer

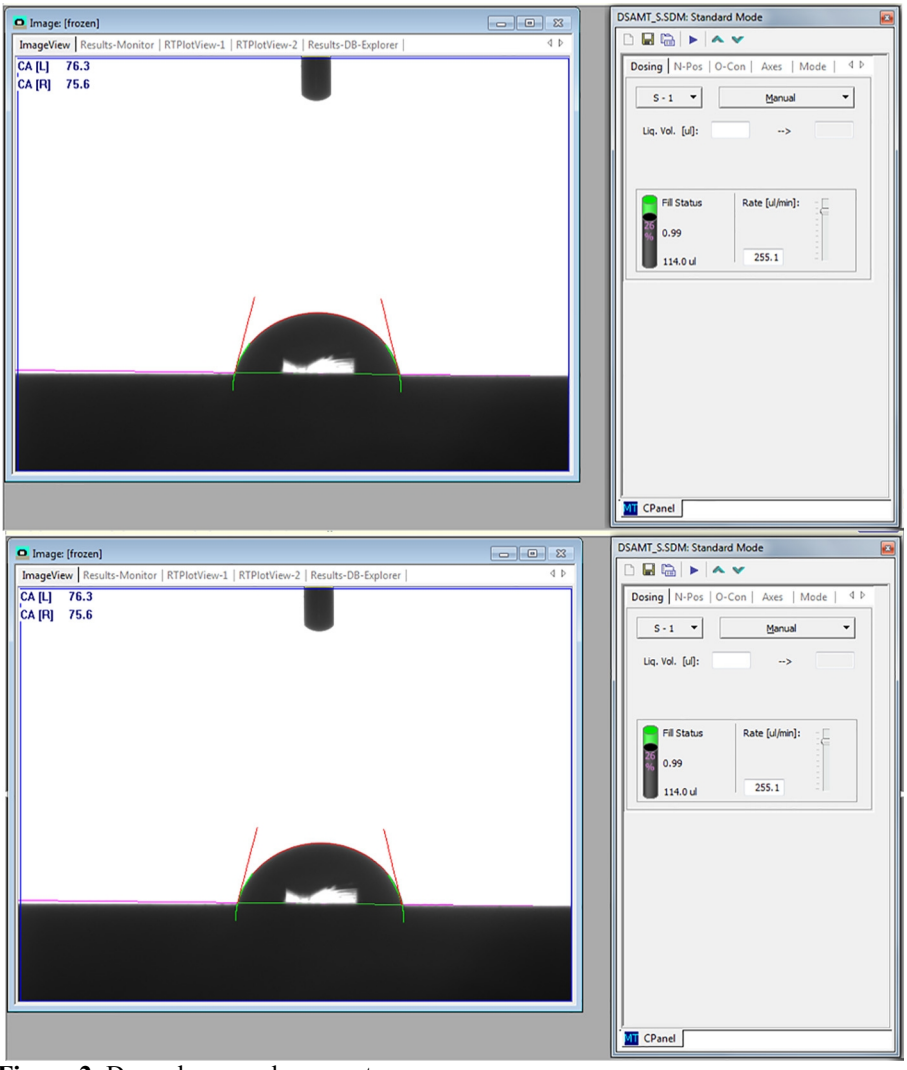

Figure 2. Drop shape analyzer system

3. Results

The mean surface roughness values (Ra, µm) of Mech P and Chem P of the studied group (I, II and III) were presented in Table 1, which was statistically significant at 5% ($p<0.001$, with $F=220.013$ and 117.434). ANOVA test with post hoc test was used for comparing the surface roughness values between three groups, revealed a statistical significant difference between them ($p_1<0.001$). Heat-Cured denture base material of (Group I) in both the Mech P and Chem P showed the highest mean surface roughness value while CAD\CAM denture base material (group III) showed the least mean value. Our study revealed no significant correlation of surface roughness of the three studied groups in mechanical polishing versus chemical polishing (Table 2). The mean values and standard deviations of contact angles measurement in mechanical and chemical polishing for group (I, II and III) were presented in Table 3, which were statistically significant at 5% level ($p=0.034$ and <0.001). ANOVA test with post hoc test was used for comparing the mean values of contact angles between the three groups using Mech P and Chem P, yield a statistical significant difference between them ($F=3.850$ and 30.186). In Mech P and Chem P, Heat-cured denture base material of (Group I) showed the highest mean contact angle value, while CAD\CAM denture base material of (group III) showed the least mean value. Significant difference was found between group (II) and group (III), ($p_2=0.012$) in mechanical polishing. Statistical significant difference was found in Chem P between group (II) and group (I) and group (II) and group (III). Table 4 shows a significant correlation of contact angles in group (I) and group (III) in mechanical polishing versus chemical polishing. No significant correlation was observed in contact angles of group (II) in mechanical polishing versus chemical polishing.

Table 1. Comparison between the mean surface roughness values (Ra, µm) \ according to mechanical polishing and chemical polishing methods in each group

Parameter	Group I: Heat cure PMMA	Group II: Thermoplastic resin (Breflex)	Group III: CAD\CAM (CC) acrylic resin	F-value	p-value
Mechanical polishing (Mech P)					
Mean±SD	2.44±0.07	1.77±0.06	1.08±0.23	220.013*	<0.001*
Sig.	p_1<0.001*, p_2<0.001*,p_3<0.001*				
Chemical polishing (Chem P)					
Mean±SD	2.72±0.09	2.18± 0.10	1.39±0.31	117.434*	<0.001*
Sig.	p_1<0.001*, p_2<0.001*, p_3<0.001*				

F: values for ANOVA test, P: values for significance between groups using post hoc test (LSD); p_1: between group II and group I; p_2: between group II and group III; p_3: between group I and group III; *: Statistically significant at p≤0.05

Table 2. Correlation of surface roughness values (Ra, µm) between mechanical and chemical polishing in the three studied groups

Parameter		Mechanical polishing (Mech P)		
		Group I: Heat cure PMMA	Group II: Thermoplastic resin Breflex	Group III: CAD\CAM (CC) acrylic resin
Chemical Polishing (Chem P)	r	0.114	0.371	0.578
	p	0.754	0.292	0.080

r: Pearson coefficient

Table 3. Comparison of contact angles between the three studied groups according to mechanical (MP) and chemical polishing (CP)

Parameter	Group I: Heat cure PMMA	Group II: Thermoplastic resin (Breflex)	Group III: CAD\CAM acrylic resin	F-value	p-value
Mechanical polishing (Mech P)					
Mean±SD	70.41±4.18	67.90±2.56	66.86±1.38	3.850*	0.034*
Sig.	p_1=0.067, p_2=0.012*, p_3=0.436				
Chemical polishing (Chem P)					
Mean±SD	79.69±4.52	71.40±2.50	69.60 ± 1.43	30.186*	<0.001*
Sig.	p_1<0.001*, p_2<0.001*, p_3= 0.205				

F: values for ANOVA test, P: values for significance between groups using post hoc test (LSD); p_1: between group II and group I; p_2: between group II and group III; p_3: between group I and group III; *: Statistically significant at p≤0.05

Table 4. Correlation between contact angles in mechanical and chemical polishing in the three studied groups

		Mechanical polishing (Mech P)		
		Group I: Heat cure PMMA	Group II: Thermoplastic resin (Breflex)	Group III: CAM\CAM acrylic resin
Chemical polishing (Chem P)	r	0.799*	0.593	0.775*
	p	0.006*	0.071	0.008*

r: Pearson coefficient; *: Statistically significant at p≤0.05

4. Discussion

Hygiene is a crucial factor for patients who wear removable prosthodontic appliances. One of the most vital features of successful dental prosthesis is having a well-polished and smooth surface in order to attain perfect esthetics and oral hygiene. The polishing procedure involves gradual elimination of rough layers. The polished surface affects the oral health of tissues that are in direct contact. Polishing of the three different denture base materials used in this study intended to eliminate any surface roughness that may have acted as stress concentrator zones (1, 18, 19). With

the introduction of commercially available CAD/CAM denture systems; the era of digital complete dentures has arrived with all the positive benefits for both the patient and practitioner, and the ability to reduce the time required to provide patients with dentures and the potential to reduce the cost of care for patients while still providing quality dentures using state of the art dental materials is encouraging. For that reason, CAD/CAM denture base resin was selected in this study to evaluate the effect of different polishing techniques on the surface roughness because the smooth surface of removable denture bases of prosthodontic appliance may vary in the different resin materials which depend upon the techniques used for finishing and polishing (20, 21). Results revealed a significant lower surface roughness in group (III) for both mechanical and chemical polishing which may be attributed to the nature of CAD\CAM polymer material and processing technique. Since it polymerizes under high temperature and pressure; it promotes the formation of longer polymer chains and leads to a higher degree of monomer conversion with lower values of residual monomer which undergoes no polymerization shrinkage. (14, 16, 22, 23). The Mech P of CAD\CAM denture base specimens' material produced surface abrasion, leaving surface irregularities not noticeable to the naked eye, and is more effective in getting smooth surfaces. Whereas in chemical polishing, the polishing liquid contains methyl-methacrylate monomer molecules, penetrates through the superficial polymeric chain of acrylic resin promoting an ultimate plasticizing influence of the acrylic resin surface. This outer layer has an influence on the under-lying irregularities caused by the finishing procedure (5, 19, 21). In the present study, the contact angle or the wettability of the denture base materials was measured as it gives information about surface energies, surface roughness and surface heterogeneity and it indicates the saliva's ability to flow over the surface of a material. A drop shape analysis system was used for measuring the contact angle since it is an innovative optical high-quality system, enabling a time saving automatic image setup and measurement of extremely fast wetting processes and also allowing measurement to be made on microscopically small samples. The small drops appear with optimum width in the video image (20, 24, 25). Our results reported that polymerized CAD\CAM acrylic resin denture base of (group III) showed a low contact angle indicating that these materials are easily wetted by water and the surface assumed as hydrophobic which represents resistance to water and any liquid. These results may be attributed to the surface tension of the liquid and the surface energy of the solid material that allowing the spreading of water over the surface and the saliva had the ability to flow over the surface of a material (26). Significant correlations were found in contact angles of group (I) and group (III) in both polishing methods but no significant correlation was found in group (II) due to a different resin brand with different physical properties of the materials.

5. Conclusions

Within the limitations of this study, and the following conclusions based on the obtained results, it may be concluded that mechanical polishing produces lower surface roughness of PMMA and CAD\CAM denture base resin with a superior smooth surface compared to chemical polishing. Mechanical polishing is considered the most effective polishing technique. Significant decrease of the contact angle was observed in CAD\CAM denture base material subjected to both polishing techniques compared to heat-cured or thermoplastic denture base material. CAD/CAM denture base material should be considered as the material of choice for complete denture construction, especially for older dental patients with changed salivary functions.

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Conflict of Interest:

There is no conflict of interest to be declared.

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