

Comparison between Heat Cured Polymethylmethacrylate, Thermoplastic Polyamide and Thermoplastic Acetal in Regarding to their Surface Roughness: *In Vitro* Study

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Abstract

Introduction: A direct link was found between surface roughness, the accumulation of plaque and the adherence of microorganisms concerning acrylic resins. However, the surface properties of the new thermoplastic materials remain questionable especially after using the conventional finishing and polishing techniques. Studying surface properties of each material makes the recommendation of the proper techniques easier.

Objectives: This *in vitro* study intended to compare three types of denture base materials in regarding to the effect of different polishing techniques on their surface roughness.

Methodology: 36 specimens were incorporated in this study. 12 specimens were in each group. 3 groups were formed: Group A: Heat cured Polymethylmethacrylate (PMMA). Group B: Thermoplastic Polyamides. Group C: Thermoplastic Acetal. Dimensions of specimens were (20 × 20 × 3 mm) with projection at the side. Statistical analysis was carried out using one-way analysis of variance (ANOVA). Statistical significance was defined at $P \leq 0.05$.

Results: A significant difference was found between the 4 polishing techniques used with technique no. 3 showing the highest significant value 0.0002 ($P < 0.05$).

Conclusion: Polymethylmethacrylate acrylic resin was the highest affected group then thermoplastic acetal and the last affected group was thermoplastic polyamides. Pre-polishing rubberizing with rubber bur improves the polishing procedure.

Keywords: Heat Cured Polymethylmethacrylate; Thermoplastic Polyamides; Thermoplastic Acetal; Surface Roughness; Conventional Finishing and Polishing Techniques; *Candida albicans* Adherence

Introduction

Due to the presence of direct link between surface roughness, the accumulation of plaque and the adherence of *Candida albicans*, surface properties of any denture base material becomes a point of particular concern to study [1,2]. In cases of denture related stomatitis an increased number of *Candida* species is found [3].

The main theory behind, is that materials with the roughest surface may serve as reservoir [4], with surface irregularities such as voids and micro cracks [5], providing an increase microorganism retention, candida adhesion and protection from shear forces [4]. Hence the utmost importance for patient comfort and denture longevity is smooth and highly polished denture surface [6]. It enhances good aesthetical results, oral hygiene and low plaque retention [7].

Surface roughness presents clinical relevance since it can affect the biofilm formation or makes its removal difficult [8]. A clinically acceptable threshold level of surface roughness (Ra) of 0.2 μm where no further reduction in plaque accumulation is expected in prosthetic and dental restorative materials has been discussed in the literature [9-11].

The surface roughness of dental materials including acrylic denture base materials is influenced by the two frequently used polishing methods; either mechanical or chemical [12-15]. Mechanical polishing uses abrasive drills and aluminum oxide sandpapers in decreasing granulations, pumice slurry with felt cone and chalk powder with a soft brush [14,15]. These abrasives of finest grit sizes promotes surface abrasion by material removal, generating traces or notches with progressively lower dimensions which increases surface smoothness [16].

Based on the conclusion of Al-Rifaiy's [17] study about surface roughness values of heat-polymerized acrylic resin in which, he confirmed, influenced by polishing method (mechanical or chemical). He also concluded that mechanical polishing promoted smoother surfaces than chemical polishing.

In evaluation of their surface roughness, a comparison between a polyamide denture base material (Flexiplast) and polymethylmethacrylate PMMA (Vertex RS) was established by Abuzar, *et al* [18]. They found that polyamide specimens produced a rougher surface than PMMA, both before and after the polishing process. When visually inspected, the surface gloss of polyamides appears less compared to the PMMA counterpart.

Polyamides have low melting point, so it is difficult to provide a satisfactory polish. Wax-up of the denture had to be performed carefully to avoid excessive trimming by burs [19]. Polishing causes overheating of polyamides' surface, exposure of their fibers and fraying at the margins, so using pumice solution during polishing procedure helps to reduce the problem of overheating [18].

Moreover, the rate of cooling of processed polyamide affects the surface properties as very slow cooling produces a strong and relatively stiff material but still with a rough surface [20].

A recent study of Bio Dentaplast [21] revealed that acetal resin showed the highest mean value of surface roughness after polishing among materials tested, but within the accepted threshold level. Although the high crystalline feature of acetal resins, which provides excellent properties as it increases the hardness. However, it might be the cause of the increased surface roughness value [22].

Dentures in (Bio Dentaplast) have many advantages: the insertion and removing of the prosthesis is done without harming the teeth offering a very good elasticity, it shows high biocompatibility, as referred by its name (Bio Dentaplast), and currently best accepted by tissues; the white color of the clasps is highly esthetics and finally it is chemically stable in oral fluids [23].

Aim

The aim of this study was to compare the surface roughness of three types of denture base materials after application of four polishing techniques upon them.

Materials and Methods

Thirty six specimens that were prepared for this study were divided into three groups. Each group contained twelve specimens, three specimens for each of the four techniques:

Group A: Heat cured polymethylmethacrylate PMMA: Acrostone.

Group B: Thermoplastic polyamide: NEWULTRA.

Group C: Thermoplastic acetal: Bio Dentaplast.

Specimen preparation

Specimens were produced from heavy body condensation silicone mold which was prepared from stainless steel pattern [24]. Stainless steel pattern was constructed in dimensions (20 × 20 × 3 mm) with projection at the side. Base plate wax (Cavex Set Up Regular Modelling wax) was melted and poured inside the mold and hence specimens were ready to be flasked. Specimens preparation was carefully standardized [24], and were polished by the same examiner in order to standardize the pressure exerted [25].

Group A: Heat cured polymethylmethacrylate specimens

Every flask contained four wax specimens. Wax specimens were invested in the conventional molding technique. After complete setting of the dental stone, wax elimination was made by placing the flask in boiling water for 10 minutes, then removed from the water and the flask was opened. All excess wax was washed out with a stream of boiling water, and then the mold washed again with boiling water. A separating medium was used to coat the surface of the mold [25].

Heat cure acrylic resin (Acrostone, Heat Cure Denture Base Material) powder and liquid was mixed according to manufacturer's instructions, then left till reaching the dough stage, when the mixture separate from the wall of the container as admitted by ADA specification no 12 for denture base resin. In the dough stage, the mixture was packed into the mold, covered with polyethylene sheet; the two halves of the flask were closed together. Flask assembly was positioned into hydraulic press; pressure was applied incrementally to allow resin dough to flow evenly throughout the mold [25].

The flask was opened, the over flow material and polyethylene separating sheet was removed. Two halves of the flask were closed together, pressed metal to metal contact and held for 5 minute before clamping, then transfer to a thermostatically controlled water bath used the conventional cycle of curing 70°C for one hour, and then brought to boil for half an hour [25].

Group B and C: Thermoplastic specimens

Every flask contained four wax specimens. A sufficient width of sprue is important (4 mm in diameter). Every specimen had one sprue attached to it at one corner, and then the four sprues were united to form one sprue coming out through the orifice of the flask at one side [26-28] (Figure 1).



Figure 1: Each wax specimen was attached to sprue then the four sprues were united to form one common sprue. The surface of the wax and dental stone was coated by separating medium.

A special dental flask designed for injection molding technique was used. Wax specimens were positioned inside the lower half of dental flask after application of petroleum jelly as a separating medium inside the flask. Dental stone (SHERA extra hard dental stone) was mixed according to manufacturer's instructions and poured into the lower half of the flask in which the level of the stone was slightly below the level of the wax specimens. After hardening of the dental stone, it was coated with separating medium as well as the surface of the base plate wax, Figure 1 then the upper half was positioned on the lower half and the dental stone was poured through the orifice of the flask.

After investing in a special flask, wax elimination was made as the conventional technique. Flask margin were checked to ensure that both flask halves fit together with intimate metal contact [28]. A thin coat of separating medium was added to the mold and allowed to dry completely (Acrylic Sep. brendent) (Figure 2).

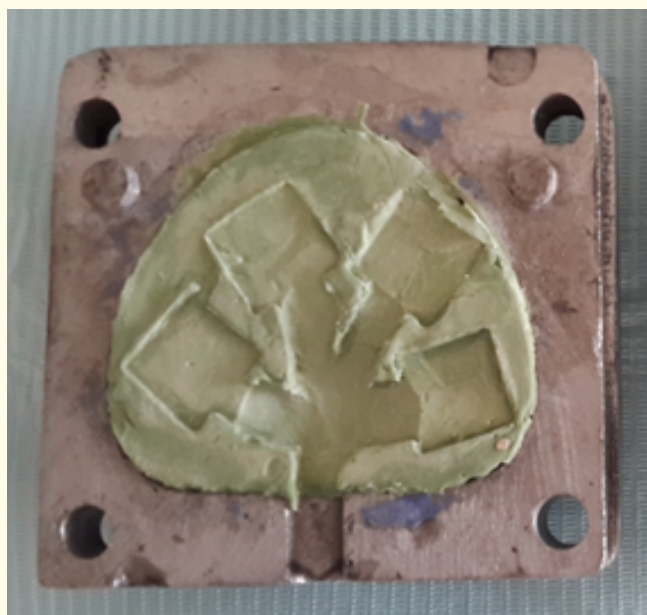


Figure 2: After wax elimination, surface of the dental stone was coated by thin separating medium and left to dry completely.

A medium size cartridge was used and petroleum jelly was applied on its outer surface. A cartridge was then placed in electric cartridge furnace (Sabilex BIOSTRONG 400) (Figure 3). The thermoplastic denture base granules are thermoplastic in nature and needed to be converted into fluid form before pouring into mold under pressure [26]. Thermoplastic polyamide (NEWULTRA) was plasticized for 15 minutes at 280°C and thermoplastic acetal (Bio Dentaplast) was plasticized for 15 minutes at 280°C according to manufacturer's instructions under pressure 7.5 bars. By using heat resistant gloves, the cartridge was inserted into the cartridge sleeve with the nozzle of the cartridge facing inwards [26-28].



Figure 3: An electric cartridge furnace (Sabilex BIOSTRONG 400). The cartridge is aligned with the flask opening.

The special dental flask was bench cooled for 15 to 20 minutes before opening [26] and not be opened immediately to prevent distortion of the specimens [29]. Sprue formers were cut with special type of knife or disk [29] (Figure 4).

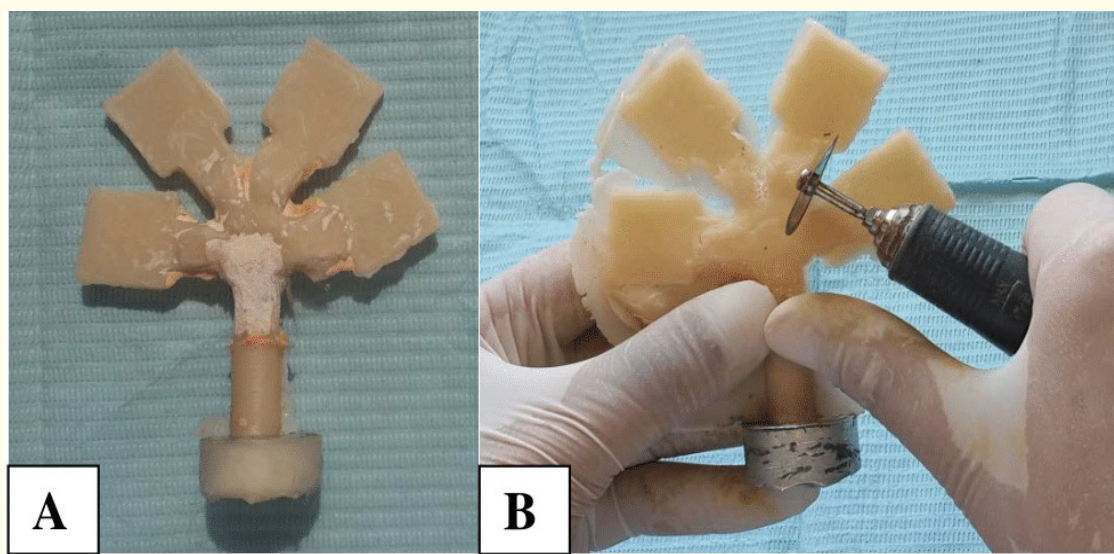


Figure 4: A: The processed specimens. B: Specimens were cut by with a disk.

Finishing of the specimens

Specimens were finished according to the method suggested by Ulusoy [14]. Acrylic stone for two minutes with low speed then tungsten carbide bur for two minutes and finally sand paper (Figure 5) for one minute. The direction of movements on the sandpaper was random.



Figure 5: Finishing with tungsten carbide bur and then by sand paper.

Conventional polishing of the specimens: (Figure 6)

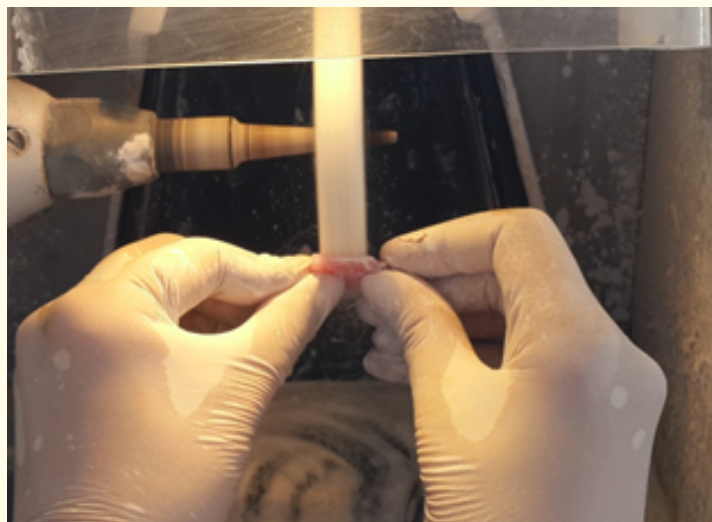


Figure 6: Conventional polishing techniques.

Four techniques were used:

- Technique No.1: fine pumice with wet rag wheel, 1500 rpm, two minutes.
- Technique No. 2: fine pumice with wet rag wheel, 1500 rpm, two minutes followed by Tripoli compound with wet rag wheel, 1500 rpm, two minutes [30].
- Technique No. 3: pre-polishing rubberizing with brown rubber disc (1500 rpm, for one minute, low pressure) followed by fine pumice with wet rag wheel, 1500 rpm, two minutes [25].
- Technique No.4: pre-polishing rubberizing with brown rubber disc 1500 rpm, for one minute, followed by fine pumice with wet rag wheel, 1500 rpm, two minutes, then with Tripoli compound with dry rag wheel, 1500 rpm, two minutes [25].

Finished specimens were all polished in the same orientation, and they were evaluated for surface roughness along the same orientation. After polishing, each specimen was rinsed in distilled water and placed in an ultrasonic bath for 10 minutes [31].

Surface roughness evaluation: [32]

Surface roughness values were measured using a profilometer. (Surtronic 2 roughness meter). Surtronic 2 was used to measure the average roughness (Ra), which is defined as the average vertical deviation along the surface of the specimen measured in micrometer (µm). A diamond stylus was moved perpendicular to the surface along the diameter of specimens. The vertical movement of the stylus, as it ascended or descended over the irregularities of the polished surface of each test specimen, was converted into digital readings. The cut off length of each tracing was 0.25 mm. Three measurements of surface roughness were performed for every specimen, and mean average Ra values were used for the statistical analysis [33]. All measurements were carried out by the same researcher [18].

Results

The mean values of surface roughness for group A: Polymethylmethacrylate: Acrostone, Group B: Thermoplastic polyamide: NEWULTRA and Group C: Thermoplastic acetal: Bio Dentaplast after polishing with polishing techniques number 1,2,3 and 4 on 3 specimens of each group are presented in (Table 1).

		Gp. A: PMMA	Gp. B: Thermo. Polyamides	Gp. C: Thermo. Acetal	P value
Before	Mean	3	4.1	4.4	0.169996
	SD	0.91	1.89	1.61	
After Technique 1	Mean	0.79	1.13	0.99	0.059319
	SD	0.11	0.13	0.08	
After Technique 2	Mean	0.21	1.11	1.03	0.0084879
	SD	0.11	0.28	0.22	
After Technique 3	Mean	0.24	1.78	0.91	0.0002644
	SD	0.13	0.20	0.11	
After Technique 4	Mean	0.40	1.43	0.93	0.0046296
	SD	0.09	0.09	0.28	

Table 1: Surface roughness mean values and standard deviation (SD) for Group A: (PMMA), Group B: Thermoplastic polyamide and Group C: Thermoplastic acetal before and after polishing with 4 techniques and their p value.

Results of the Ra mean values before polishing for PMMA, thermoplastic polyamide and thermoplastic acetal specimens as follows: 3, 4.1 and 4.4 µm. Theses mean values after polishing techniques were ranged between, for PMMA: 0.2 - 0.7 µm, for thermoplastic polyamides: 1.1 - 1.7 µm, for thermoplastic acetal: 0.9 - 1 µm.

One-way ANOVA test for specimens was used with the least significant difference (LSD) showed that surface roughness was significantly influenced by the technique used in polishing ($P \leq 0.05$). Significant differences were found between all groups after polishing techniques no. 3,4 and 2 with the highest significant value after polishing with technique number 3 ($P = 0.00026$).

Discussion

Generally, the objective of the polishing procedure of dental materials is to produce an adequately smooth and glossy surface and thereby prevent bacterial plaque formation by gradual removal of rough layers from the surface incrementally [13,33].

There is also consensus on the role of surface roughness and the initial adherence process, i.e. surface roughness is positively correlated to the rate of bacterial/ fungal colonization of biomaterials. If such rougher surfaces become exposed to the oral environment, they may be more susceptible to micro-organisms adhesion and biofilm formation and lead to infections [34].

In this study, it was difficult to make direct comparisons of surface roughness (Ra) values with other studies because of variations in the experimental procedure, methodology used for polishing as well as measuring the surface roughness, and differences in the type of PMMA materials used compared to other types of thermoplastic materials [13,34]. Due to the presence of these difficulties, a difference in Ra values maybe expected [18].

Selection of the cartridge containing thermoplastic material is very important to avoid any deficiency, which is possible but difficult to be corrected [29]. Oversized cartridges may also causes leaching out of the material between the flask and cartridge orifice. It was selected on the basis of type and size of the prosthesis or specimens.

The outer surface of the cartridge of the thermoplastic materials was coated with a separating medium to prevent the adhesion of cartridge with cartridge carrier and allows smooth separation [29].

In this study injection molding technique was the molding technique of the thermoplastic materials. One of its main disadvantages is the high cost of the equipment required for fabrication of specimens such as: special flask, cartridges of different size, thermoplastic resins and electric furnace [29].

Finishing of all the specimens were made by acrylic stone bur and sand paper which made the acrylic denture reach to the final form before polishing [16,36,37], but the adjustments which were made by tungsten carbide bur caused a rough surface and polishing procedure was necessary [17].

The finishing procedure used for thermoplastic materials was the same as finishing of acrylic resin specimens to decrease variables in this study. However, A study by Kunwarjeet [29] claimed that finishing procedures of thermoplastic materials shouldn't be the same as acrylic resin materials. Because acrylic instruments, when used, generate heat and cause fiber formation and roughness of the prosthesis. Due to the nature of thermoplastic material, the high heat generated while finishing with acrylic trimmers may soften and distort the prosthesis [29].

This study intended to use locally available polishing materials. A pumice solution was used as a first step of polishing. The pumice paste was made by mixing pumice paste with running water, placed on specimen and polished with the help of rag wheel [29]. Pumice mixed with water is the most commonly used polishing medium [33].

The combination of Tripoli compound with wet rag wheel; after using a pumice solution in polishing caused specimens to be shiny and also little heat generated during polishing sealed the surface to resist discoloration and staining. The prosthesis was dipped into cool water while polishing with Tripoli to avoid warping of the surface. The Tripoli oil residue was removed from the prosthesis with soft bristle denture brush [29].

Kunwarjeet [29] used a brown Tripoli compound which is also used for polishing of gold and acrylic but in this study white Tripoli compound was used as it was more common for polishing acrylic resins material.

Time recommended for each polishing materials was standardized in this study (two minutes). The recommended speed and maximum allowable pressure of instruments used in polishing are not easy to control and therefore, highly operator dependent. Therefore, when comparing the effectiveness of polishing technique by various investigators, a reasonable variability value for surface roughness should be expected [17].

In this study, the difference in results of the Ra mean values before and after polishing techniques for PMMA specimens showed decrease in the roughness of the specimens' surface. The value reported in this study for PMMA specimens after different polishing techniques ranged between (0.2- 0.7 μm) which is not consistent with some studies [7,14,15] that reported the characteristic value of smooth acrylic resin is 0.12 μm .

Polymethylmethacrylate surface roughness values were in accord in many aspects with other studies [15,37] which claimed that surface roughness of polished acrylic resin may vary between 0.03 and 0.75 μm . Significant bacterial colonization would occur if the surface roughness is more than 2 μm [15]. Moreover, the surface roughness of acrylic resin polished with prophylactic pastes, various rubber polishers, abrasive stones, and pumices still exceeds the threshold at Ra of 0.2 μm in other studies [1,34].

Considering thermoplastic polyamides specimens, the difference in results of the Ra mean values before and after polishing techniques also showed decrease in the roughness of the surface of specimens. This was confirmed by Abuzar, *et al.* [18] who showed that polyamide denture base material when polished with conventional laboratory technique became more than 7 times smoother whereas PMMA when polished became more than 20 times smoother using the same polishing technique. In this study mean values were not below the accepted norm of 0.2 μm Ra as it was claimed that polyamides have rougher surface than other resin materials, and it causes more bacterial and fungal colonization [38]. When compared with PMMA, the highest *Candida* species biofilm growth was shown to occur on polyamide resin [39].

Difference in results of Ra mean values for thermoplastic acetal specimens, before and after polishing techniques also showed decrease in the roughness of the surface of specimens but still above the accepted norm 0.2 Ra. The results of *in vitro* research revealed that the smallest adhesion to the materials under study was shown by *candida albicans*. Almost 10 times smaller in relation to all bacterial strains evaluated, with the smallest adhesion being to acetal. Three times smaller adhesion of *Candida albicans* to acetal resin than to acrylic material [40].

In study by MA Al-Akhali, *et al.* [41] proved that the mucosa under the acetal denture base retained more micro-organisms than the mucosa under the metallic denture base, and the colonization of micro-organisms increased by time on mucosa and on a denture base made either by metal or acetal resin.

The last three polishing techniques showed a significant difference in lowering surface roughness mean values. Technique no. 3 showed the highest significant value among the three denture base materials followed by technique no. 4 then technique no. 2. Using a pre-polishing rubber bur or disc may promote removing of course grooves and notches in the surface of acrylic specimens. This effect is more obvious on the flexible acrylic specimens than heat cured PMMA specimens due to the special nature of the thermoplastic material - mainly polyamide (Nylon)- which is more wear resistant than heat cured (Polymethylmethacrylate) [24].

Conclusions

Within the limitation of this study, the profilometric evaluations showed that pre-polishing rubberizing by rubber bur and then polishing by fine pumice with wet rag wheel either with or without Tripoli compound; improved the surface roughness of different denture base materials. Polymethylmethacrylate acrylic resin was the highest affected group followed by thermoplastic acetal and the last affected group was thermoplastic polyamides.

Conflict of Interest

The authors declare that they have no conflicts of interest in this work.

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