Comparative study of surface roughness between polyamide, thermoplastic polymethyl methacrylate and acetal resins flexible denture base materials before and after polishing

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Abstract: The aim of this study was to compare the surface roughness of different types of flexible thermoplastic materials (polyamide, polymethyl methacrylate and acetal resins) before & after polishing. ***Materials and methods:*** seven specimens were made for each group. One surface was polished using the conventional laboratory polishing technique, while the other surface remain unpolished. A profilometer was used to measure the surface roughness. ***Results:*** one way anova was used to compare surface roughness of the three materials before and after polishing. The test revealed that the surface roughness was decreased in all materials after polishing with a statistical difference, and Polyamide (Breflex) exhibited the least surface roughness values. **Conclusion:** All tested materials exhibited a little degree of roughness, below the threshold Ra=0. 2 µm. The surface smoothness of all resin specimens, was produced successfully by conventional laboratory polishing.
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Key Words: Flexible denture base material, surface roughness, polyamide, thermoplastic acrylic resin, acetal resins, conventional laboratory polishing.

Flexible dentures are excellent alternatives to conventionally used methyl methacrylate dentures, which not only provide excellent aesthetics and comfort, but also adapt to the constant movement and flexibility in partially edentulous patients. (1)

The development of polymer chemistry produced alternative materials to PMMA such as polyamides (nylon plastics), acetal resins (polyoxymethylen based materials), epoxy resins, polystyrene, polycarbonate resins, etc. All of these new types of resins are suited for thermoplastic processin. (2)

The prosthesis fabricated from these materials requires a minimum /no mouth preparation, and provides a good retention. It is thin and light in weight so it is comfortable for the patient. As well as, its good aesthetic because of the translucent and pink shade that matches the natural tissues.. Being flexible, the denture bases adapt well in the undercut areas and not cause sore spots. They also have almost no porosity and lower elastic modulus. (3)

A flexible denture base material generally is not used for long term restorations and is intended only for provisional or temporary applications, because of various problems, including fractures of the resin clasp, roughening of the polished surface of the denture base, or discoloration of denture base resin.(4)

Introduction:

However, it can be used in combination with a cast partial metal framework where clasp and saddle can be made of flexible material, thereby improving the aesthetic. While the major connector and the rest can be made from metal.(5)

A major addition to the metal-free RPD market has been **polyamide (nylon)**. In general, Polyamide resins used in dentistry exhibit high flexibility, physical strength, heat and chemical resistance and the exceedingly rare allergy response. They are used primarily for tissue supported removable dentures because the stiffness is not enough for usage as occlusal rests or prostheses parts that need to be rigid.(6)

On the other hand, all nylons demonstrate higher water sorption and creep than most dental polymers.(7) Because of their flexibility, they can't maintain vertical dimension when used in direct occlusal forces. Nylon resin can be semi-translucent and provides excellent esthetics but it is a little more difficult to adjust and polish. (8)

Thermoplastic acrylic was introduced into flexible dental material. It has adequate tensile and flexural strength. It is easy to adjust, handle and polish. As well as, the material is available in both tooth and gingival colors, providing excellent esthetics. (6, 7)

Another addition to the metal-free RPD market is **polyoxymethlene (acetal resins).** All acetal resins limit water sorption, exhibit lower creep and superior abrasion resistance with higher surface luster than nylons. The higher stiffness of acetal resinsupports conventional clasp designs, connectors and other components with some compensation required. [9]

Turner et al,[10] examined flexural properties of acetal resin to determine the appropriate design for an acetal resin removable partial denture clasp, and suggested acetal clasp dimensions should be 30% shorter with 40% greater cross-sectional area versus cast metal to have stiffness similar to a cast cobalt-chromium clasp.

Acetal resins (polyoxymethylene based materials) are very strong and flexible, resist wear and fracturing. They are indicated for partial denture frameworks. pre-formed clasps for partial dentures, occlusal splints and implant abutments. Acetal resins resist occlusal wear and maintain the vertical dimension during provisional restorative therapy. However, they lack the natural translucency of thermoplastic acrylic and polycarbonate resins.[7]

One of the most important properties of successful dental prostheses is having a well-polished and smooth surface in order to achieve ideal esthetics and oral hygiene. The polishing procedure involves gradual elimination of rough layers.[11]

Many studies have shown that there is a direct link between surface roughness, accumulation of dental plaque and adherence of candida albicans. Therefore, the effect of different polishing systems on surface roughness of denture base acrylic resins is important.[12,13]

Gungor et al,[14] evaluated the effects of chairside polishing kits and conventional laboratory polishing techniques, on the surface roughness of denture base and repair materials (polyamide resin PR, heat-polymerized acrylic resin HR and autopolymerizing resin AP) using profilometry. They found that conventional laboratory polishing was the most effective polishing technique.

The aim of this study was to evaluate the surface roughness of different types of flexible thermoplastic materials (Polyamide, polymethyl methacrylate and acetal resins) using a profiler after conventional polishing technique.

Material & Methods:

The three flexible denture materials [Breflex, polyan IC (brecrystal) and Biodentplast] (Bredent, Senden, Germany) were evaluated & compared. They were divided into 3 groups:

Group A: Breflex is pink in color, belong to the **polyamides (Nylon).** It is indicated for partial prosthetic restoration with a highly esthetic appearance and extremely flexible.

Group B: polyan IC (Bre-crystal) is a transparent glass-like thermoplastic material based on a **polymethyl methacrylate**, it is indicated for partial and full dentures.

Group C: Biodentplast is tooth colored A2. It is a techno-polymer based on **polyoxymethylene (acetal resin**) - it is indicated for preformed clasps, metal-free removable dentures and contraindicated as denture base.,

The materials are available in the form of granules in cartridges of varying sizes. The metallic cartridges containing thermoplastic grains are heated to plasticize the resin.

All materials are suited for thermoplastic processing by injection molding technique (Thermopress 400, Bredent GmbH & Co.KG, ·Germany). The resin materials are injected into a hollow mold under very high pressure. Their plasticizing temperature is 220-265°C and a preheat time of 15 min.

Preparation of samples:

Total samples were twenty one. Seven samples of each material were prepared in the form of disks; 20 mm in diameter and 3 mm in thickness, following the manufacturers' instructions.[15] **[fig 1]**

Conventional laboratory polishing: [16]

The specimens of each material were polished from one surface using the conventional laboratory polishing technique, while the other surface remain unpolished**.** An abrasive paper was used on all specimens with light manual pressure. A slurry of medium grit pumice mixed in a 1:1 ratio of water was used. A cloth wheel of 12.5 µm for 60 s at 3,000 RPM on the polishing lathe. This was repeated with fine grit pumice. A second cloth wheel, high shine buff was then used with polishing brown Tripoli (Grobet, Carlstadt, NJ, USA) for 60s. The Polishing machine, (**jean Wirtz** GMBH& Co. KG, WEST GERMANY. 700).

Measurements of surface roughness:

The surface roughness of flexible materials were analyzed with a **3D optical non-contact surface profile [fig 2]** (Contour Gt-K1 optical profiler, Bruker Nano, Inc, Tucson, Arizona, USA) based on non-contact scanning white light interferometry to evaluate the 3D surface configuration and roughness of each surface. The objective standard camera 1.0x has a magnification 5x, The machine was placed on a vibration isolation table in a super-silent room. The profile meter scanned all sample area approximately (1.3X1. 0) μm^2. **[fig 3]** The scanning area was situated at the center part of the surface. Vision 64 application software was used to control the precision and the measurements of surface roughness parameters. [**fig 4].**

Statistical analysis

Surface roughness mean values and the standard errors (SE) around the mean were calculated. One - way analysis of variance (ANOVA) and Scheffé test for post hoc comparisons, at a significance level of

0.05 were performed to evaluate and compare the two surfaces of the three materials (Breflex, Polyan and Biodentoplast). The All data analysis was carried out using SPSS Statistical Package (Version 18, Chicago, IL, USA).

Fig 1: Flexible acrylic resin samples of groups A, B, C

Fig 2: 3D optical noncontact surface profiler

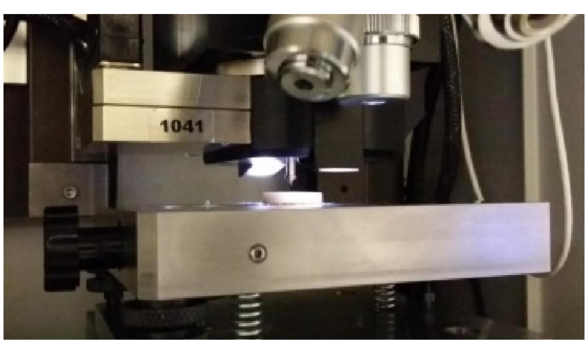

Fig 3: Non contact profilometer during surface roughness measurement

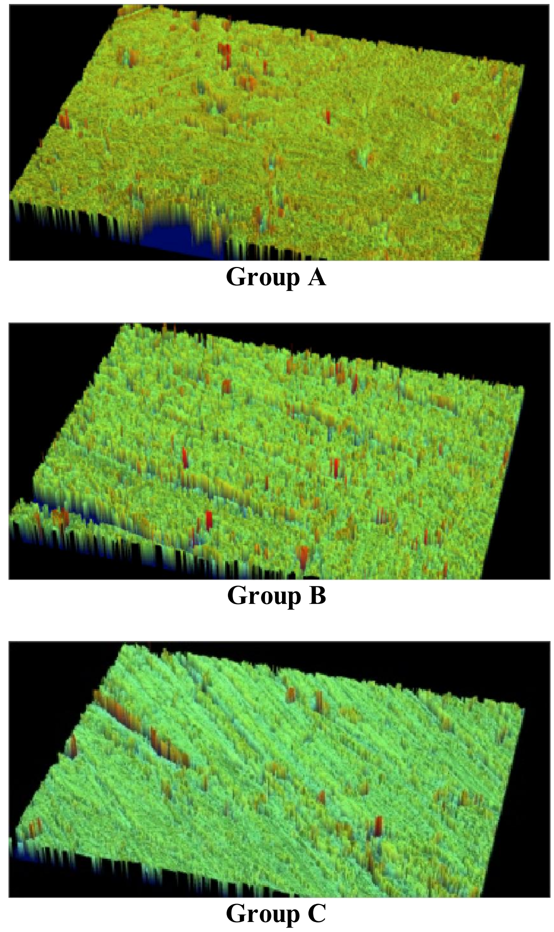

Fig 4: 3D profiler picture of surface configuration of study groups

Results:

Table 1: showing the surface roughness mean standard deviation of three groups of flexible denture materials before & after polishing

Descriptives					
		N	Mean	Std. Deviation	Std. Error
Before.Polishing µm	A	7	0.7986	0.34391	0.15380
	B	7	2.2471	0.30731	0.13743
	C	7	1.6647	0.45072	0.20157
	Total	21	1.5701	0.70592	0.18227
After.Polishing µm	A	7	0.1196	0.01708	0.00764
	B	7	0.1639	0.01256	0.00562
	C	7	0.1791	0.02163	0.00967
	Total	21	0.1542	0.03073	0.00794

Table I, showed an increase in the mean surface roughness of group B before polishing (2.24±0.30) (mean±SD), followed by group C (1.66± 0.70). While group A has a reduced surface roughness mean (0.79 ±0.34).

Table 2: showing Anova test for surface roughness before & after polishing

F	Sig.
19.164	**0.000**
15.621	**0.000**

Table 3: showing Post Hoc Test of surface roughness of all groups before & after polishing

Multiple Comparisons					
Scheffe					
Dependent Variable	(I) Material	(J) Material	Mean Difference (I-J)	Std. Error	Sig.
Before Polishing µm	A dimension2	m B	-1.44859*	.23547	**0.000**
		C	-.86619*	.23547	**0.011**
	B mension	di A	1.44859*	.23547	**0.000**
		3C	.58239	.23547	0.084
	C mension3	dbi A	.86619*	.23547	**0.011**
		B	-.58239	.23547	0.084
After Polishing µm	di A mensio	d B	-.04432*	.01106	**0.006**
		C	-.05948*	.01106	**0.001**
	B mension2	di A	.04432*	.01106	**0.006**
		C	-.01517	.01106	0.417
	C mension3	di A	.05948*	.01106	**0.001**
		B	.01517	.01106	0.417
*. The mean difference is significant at the 0.05 level.					

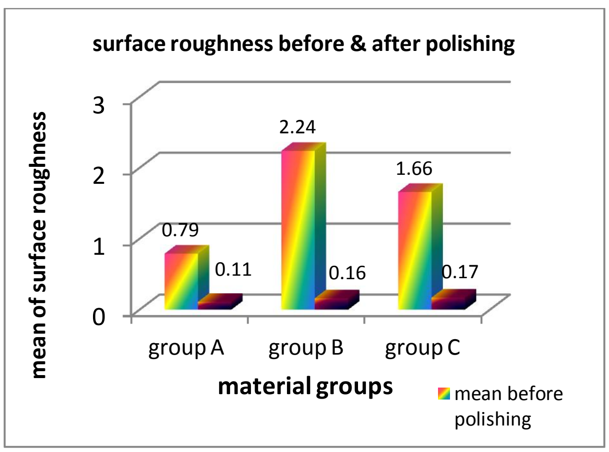

Fig 5: shows the mean of surface roughness of three flexible group materials before & after polishing.

The surface roughness was influenced greatly by polishing. There was a decrease in surface roughness mean of three groups, its range from (0.11 to 0.17), as group C exhibited the highest mean. **[fig 5]**

Anova revealed a statistical difference in surface roughness between three groups before and after polishing at $P<0.05$ (Table 2).

Discussion:

The surface roughness of denture bases promote adhesion of microorganisms and plaque accumulation. It is mainly affected by inherent material features, the polishing technique, and the operator's manual skills. Therefore, highly polished surfaces have been shown to accumulate less plaque.[12,17]

Some in vivo studies suggested a threshold surface roughness for bacterial retention (Ra = 0.2 µm) below which no further reduction in bacterial accumulation can be expected.[18,19] While other studies have indicated the plaque accumulation is expected to be reduced on materials with a surface roughness below the threshold level.[11, 18]

Several studies have revealed that injection molding techniques result in fewer dimensional inaccuracies and more accurate denture base than conventional processing techniques. [20, 21]

The injection molding system was used in this study, its advantages are that the resin is delivered in a cartridge which eliminates dosage errors, ensuring long-term stability of the shape, reduced contraction, as well as mechanical resistance with aging. Having superior physical properties, thermoplastic materials processed by injection represent esthetic alternatives to metal frames, being at the same time comfortable for the patient. [22]

The results of the current study revealed that the least rough material was polyamide Breflex (group A) before & after polishing. This suggested that polishing of polyamide with conventional laboratory method was satisfactory to eliminate any surface roughness that may act as stress concentrator zones. In addition, it could be due to the recent modification attributed to polyamide denture base materials which improved the physical properties. Fiberglass or other different fillers are added to contribute in increasing stiffness, flextural and wear resistance. [7,16]

Moreover, the statistical results in the present study showed that PMMA- Brecrystal (group B) had a highest rough surface before polishing (more than the accepted threshold level of 0.2 µm Ra). This might be due to processing procedures of the "human factors" (e.g., skills of the technician, level of attention, etc.) or due to the properties of the material. However, the rough surface was reduced after polishing to be within the accepted threshold level. It could be considered that this material is easy to adjust, handle and polish.

On the other hand, this study revealed that the highest mean value of surface roughness after polishing was (group C) among the materials tested, but within the accepted threshold level. This might be due to the high crystallinity of the acetal resins (Bio Dentaplast) material which provide excellent material properties (the higher the crystallinity in a plastic, the harder it will be). [23]

The results of the current study were in agreement with Abuzar, et al, [16] who evaluated surface roughness of a polyamide denture base material in comparison with polymethyl methacrylate and found that the surface roughness of polyamide is within the accepted threshold level of 0.2 µm Ra. Polyamide produces a clinically acceptable smoothness after conventional polishing by lathe.

However, this wasn't in accordance with the very low Ra values (0.02 µm) reported by Murray [24] for Trevalon heat-cured acrylic resin. This might be because of the mirror like finish of the specimens used in that study. Also, the same low Ra values (0.02 to 0.16 µm) reported by Ma et al [25] for heat- and autopolymerized resins might be because the measurements were taken across the surface reproduced by processing against a glass plate in a gypsum mold., and Kuhar M [11] reported that lowest surface roughness values (Ra = 0.02 µm) were determined for acrylic resin specimens which might be attributed to the use of aluminum oxide–based polishing paste after conventional lathe polishing. Therefore, these results are much lower than those presented in the present study**.**

Zissis et al,[26] reported Ra levels of acrylic resins as 3.4 µm; and Ulusoy et al,[27] reported 2.53 µm. These results are much higher than those presented in the present study. This difference might be due to the specimens in the studies by Zissis et al and Ulusoy et al were not exposed to any process of finishing or polishing to smooth the specimens.

According to the current study, all tested materials demonstrated that high values for roughness were found before polishing to be more than the accepted threshold level of 0.2 µm Ra. On the other hand, Ra of all groups after polishing was ranged from 0.11 - 0.17 (within the accepted threshold level) concluding that laboratory polishing produced the smoothest surfaces.

Conclusion:

1. Breflex (group A) exhibited the least the least surface roughness value among the tested groups.
2. No significant difference between Brecrystal & Biodentplast in surface roughness (Ra values).
3. Surface smoothness of all resin specimens, was produced successfully by conventional laboratory polishing.
4. All tested materials exhibited a little degree of roughness, below the threshold Ra=0.2µm, which doesn't allow bacterial accumulation.

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