EFFECT OF TWO POLISHING TECHNIQUES ON SURFACE ROUGHNESS OF THREE DIFFERENT DENTURE BASE MATERIALS (AN 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.
MATERIALS AND METHODS: 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 two way analysis of variance (ANOVA).
Statistical significance was defined at P≤0.05. RESULTS: Technique no. 1 showed a high significant value in compared to technique no.2 for polishing the tested materials. CONCLUSIONS: PMMA was the highest affected group followed by thermoplastic acetal and the last affected group was thermoplastic polyamide. Prepolishing rubberizing with rubber bur improves the polishing procedure.
RESULTS: Remarkable improvement in the histology and the ultrastructure of the alveolar bone of rats in Group III was observed. Moreover, hematological values revealed significant decrease in the inflammatory condition of rats with induced RA after fish oil treatment.
CONCLUSIONS: Rheumatoid arthritis is an important risk factor for alveolar bone loss. The treatment of the RA induced rats with fish oil not only prevented the alveolar bone resorption and stimulated new bone formation, but also reduced relatively the level of rheumatoid factor in the blood.
KEYWORDS: Polymethylmethacrylate. Polyamides. Acetal. Surface roughness. Finishing. Polishing.
Abbreviations: Polymethylmethacrylate: PMMA.

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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 this link 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 PMMA 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 and PMMA 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, (20) 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).

Thermoplastic acetal (Bio Dentaplast) shows many advantages: the insertion and removing of the dentures is done without harming the teeth which offers a very good elasticity. As referred by its name (Bio Dentaplast) shows high biocompatibility 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).

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

MATERIALS AND METHODS

Groups

Group A: Heat cured PMMA: Acrostone (Acrostone, Heat Cure Denture Base Material).

Group B: Thermoplastic Polyamide: NEWULTRA (Sabilex).

Group C: Thermoplastic Acetal: Bio Dentaplast (Bredent. Welsenchomer. str.2.Germany.www. Bredent.com. info@bredent.com).

-Heat cured PMMA and thermoplastic polyamide used in this study were in the shade of “pink” and thermoplastic acetal’s shade was “white”.

-For each evaluation, Thirty-Six specimens were prepared, twelve of PMMA, twelve of thermoplastic polyamide and twelve of thermoplastic acetal.

-Specimens’ preparation was carefully standardized (24). All specimens were produced from a silicone putty mold prepared from a stainless steel pattern with dimensions (20×20×3mm) with projection at the side. Base plate dental wax (Cavex Set Up Regular Modelling wax) was melted and then poured into this mold. When setting, wax specimens were separated from the mold so specimens were ready to be flasked.

Molding technique:

<u>Group A: Heat cured PMMA specimens:</u>

In case of surface roughness and adaptation specimens, every flask contained four wax specimens. The lower portion of the dental flask was filled with dental stone after mixing - according to the manufacturer’s instructions - in the dental vacuum mixer machine. Wax specimens were placed and stone was allowed to harden for 20 minutes (25).

A separating medium (Vaseline: 100% Petroleum Jelly. Skin protectant) was applied to the wax and to the surface of the stone. The upper portion of the flask was then positioned on top of lower portion and filled with stone. Stone was allowed to harden again for 20 minutes before the flask was opened (25).

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 (26).

Heat cured acrylic resins (Acrostone), was mixed following the manufacturer's instructions. A dry and clean cup was used for mixing. The powder was slowly added to the liquid and was then stirred with clean wax knife. The mixing cup was covered by glass slab at room temperature till reaching the dough stage which is obtained when the mixture separate from the wall of the container as admitted by ADA specification no 12 for denture base resin (27).

For performing a packing procedure, reaching the dough stage of the acrylic resin is mandatory. A separating medium (AINSWORTH separating medium: Sodium Alginate) was used to coat the mold. The acrylic resin was removed from its mixing cup, rolled and then packed into the mold. A polyethylene sheet was used between the two halves of the flask which were then closed together and placed under the hydraulic press. The pressure was then released for opening the flask and removing the over flowed material (flash) surrounding the mold space with wax knife. (27).

For polymerization the specimens in short cycle fasting technique involves 74ºC for 1.5 hours and then increases the temperature of water bath to boiling 100 ºC for 1hour (27).

After completing the polymerization, the flask was allowed to cool slowly at room temperature for 30 minutes, followed by complete cooling of the flask with tap water for 15 minutes before deflasking. The acrylic specimens were then removed from the mold (27).

<u>Group B&C: Thermoplastic denture base materials: Polyamide & Acetal:</u>

Every flask contained four wax specimens. A sufficient width of sprue is important (4 mm in diameter), which was attached to each specimen in the one corner then the three sprues were attached together as one sprue when reaching the orifice in the center of side part of the flask (29,30,31). (Figure 1)

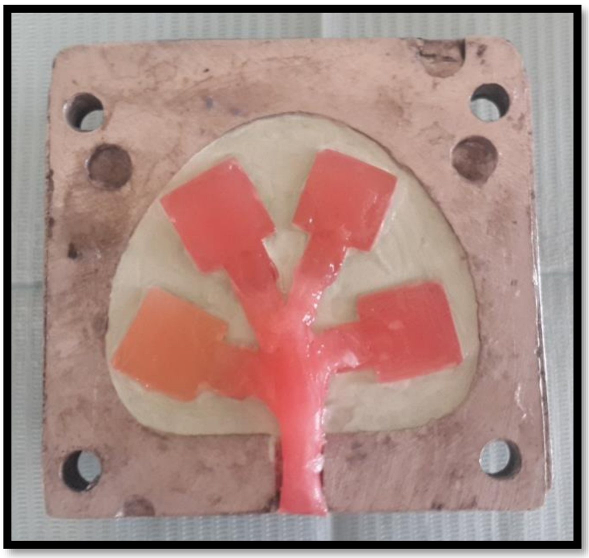

Figure 1: Showing -Each wax specimen was attached to sprue then the four sprues were united to form one common sprue.

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 STONE: Extra hard dental stone. SHERA WERKSTOFF TECHNOLOGIE. info@shear.de www.shera.de. Made in Germany) 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, 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. The bolts were loosened on the flask to remove the metal flask brackets and flask was opened. The stone around the sprue was beveled with a knife. Flask margins were checked to ensure that both flask halves fit together with intimate metal contact (31).

Thin coat of separating medium (Acrylic Sep. Plaster acrylic insulating liquid. Welsenchomer. str.2.Germany.www. Bredent.com. info@bredent.com.) was added to the mold and allowed to dry completely. (Figure 2)

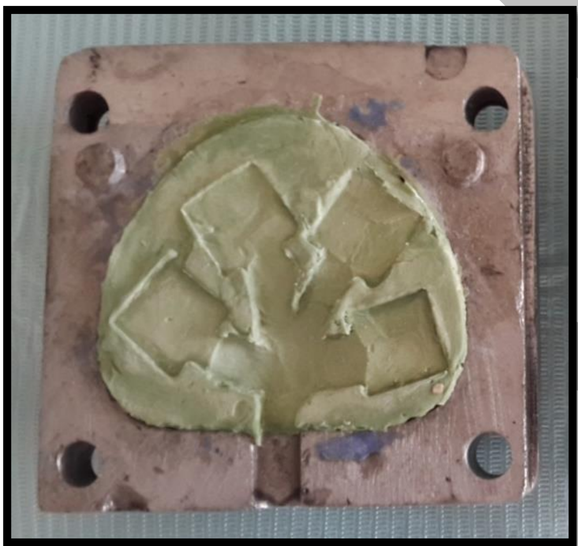

Figure 2: Showing After wax elimination, surface of the dental stone was coated by thin separating medium and left to dry completely.

The thermoplastic denture base materials were available in the form of granules in cartridges of different sizes (32). A medium size cartridge was used and petroleum jelly was applied on its outer surface. While injecting, the cartridge was aligned with the flask opening. A cartridge was then placed in electric cartridge furnace (Sabilex BIOSTRONG 400. Microinjection machine). (Figure 3)

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

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. Using heat resistant gloves, the cartridge was inserted into the cartridge sleeve with the nozzle of the cartridge facing inwards (29,30,31).

The special dental flask was bench cooled for 15 to 20 minutes before opening (29). Sprue formers were cut with special type of knife or disk (32).

<u>Finishing of the specimens:</u>

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 (150) grit (Figure 4) for one minute. The direction of movements on the sandpaper was random. All burs used for finishing procedure were cylindrical in shape to ensure parallel cutting or grinding of the bur to the surface of the sample (to minimize irregularities and equalized the pressure) (24).

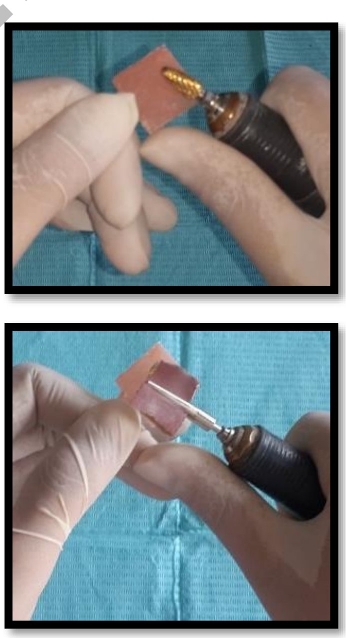

Figure 4: Showing Finishing with tungsten carbide bur and then by sand paper.

Polishing of the specimens:

Conventional polishing: Two techniques were used: (Figure 5)

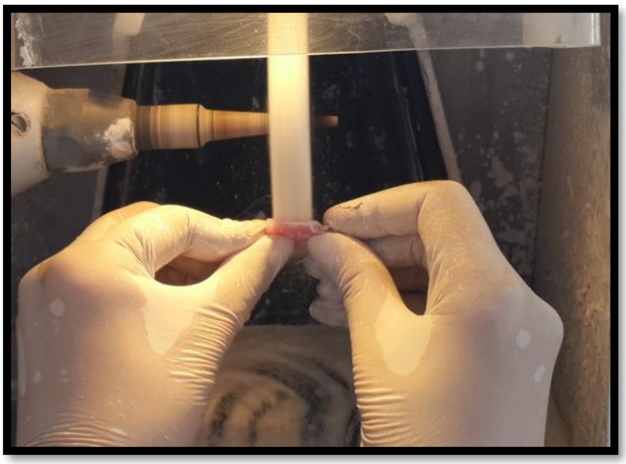

Figure 5: Showing Conventional polishing techniques.

-Technique No.1: pre polishing rubberizing with brown rubber disc (1500 rpm, for one minute) followed by fine pumice with wet rag wheel, 1500 rpm, two minutes (24).

-Technique No.2: 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 (24).

Finished specimens were all polished in the same orientation. After polishing, each specimen was rinsed in distilled water and placed in an ultrasonic bath for 10 minutes (33). All specimens were finished and polished by the same operater at the same time to avoid any variation in the pressure applied.

Surface roughness evaluation:

Specimens were evaluated for surface roughness along the same orientation. Surface roughness values were measured using a profilometer. Surtronic 2 (Taylor Hobson Surtronic 2 meter unit) 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). Each of the specimens per material under study was placed on the platform provided and was positioned in such a way that the stylus is just in contact with their surface (34).

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 (35). All measurements were carried out by the same researcher (18).

Statistical analysis:

-Data presented as mean and standard deviation (SD). Data explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests. Data showed a parametric distribution, so one-way ANAOV used to compare between materials and polishing techniques for surface roughness evaluation followed by posthocc test with Bonferroni correction.

-The significance level was set at $P \leq 0.05$.

-Statistical analysis was performed with IBM® SPSS® (SPSS Inc., IBM Corporation, NY, USA) Statistics Version 24 for Windows.

RESULTS

Mean and standard deviation (SD) for Surface Roughness (μm) for Different tested materials within other variables were presented in table (1):

A- Effect of different Material Type within other variables:

Mean and standard deviation (SD) for Surface Roughness (μm) for Different tested materials within other variables were presented in table (1).

Table 1: Mean and standard deviation (SD) for Surface Roughness (μm) for Different tested materials within other variables:

		Groups						p-value
		PMMA		Polyamide thermoplastics		Acetal resin		
		Mean	SD	Mean	SD	Mean	SD	
Surface Roughness (μm)	Before polishing	3.00[b]	.91	4.10[a]	1.89	4.44[a]	1.61	≤0.001*
	Technique 1	.24[b]	.13	1.78[a]	.20	.91[a]	.11	≤0.001*
	Technique 2	.40[b]	.09	1.43[a]	.09	.93[a]	.28	0.016*

Means with the different letter within each row are significant
**= Significant, NS=Non-significant*

It showed that there was a significant difference between the tested materials before polishing and after polishing with both technique When polished with both techniques, PMMA showed a significant difference in compared to thermoplastic polyamide and thermoplastic acetal, but there was no significant difference between thermoplastic polyamide and thermoplastic acetal.

Technique no. 1 showed a high significant value in compared to technique no.2 for polishing the tested materials.

Mean and standard deviation (SD) for Surface Roughness (μm) for Different Polishing technique within other variables were presented in table (2):

Effect of different Polishing technique within other variables:

Mean and standard deviation (SD) for Surface Roughness (μm) for Different Polishing technique within other variables were presented in table (2).

Table 2: Mean and standard deviation (SD) for Surface Roughness (μm) for Different Polishing technique within other variables.

		Polishing techniques						p-value
		Before polishing		Technique 1		Technique 2		
		Mean	SD	Mean	SD	Mean	SD	
Surface Roughness (μm)	PMMA	3.00[a]	.91	.24[d]	.13	.40[c]	.09	≤0.001*
	Polyamide thermoplastics	4.10[a]	1.89	1.78[c]	.20	1.43[b]	.09	≤0.001*
	Acetal resin	4.44[a]	1.61	.91[b]	.11	.93[b]	.28	≤0.001*

It showed that there was a significant difference between tested materials before and after polishing.
It also showed that there was a significant difference between technique no. 1 and technique no.2 for both PMMA and thermoplastic polyamide but there was no significant difference between technique no. 1 and technique no.2 for thermoplastic acetal.

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 (13,35).

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 (36).

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 (13,36). 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 (32). 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 (32).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 (32).

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 (16,37,38), 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 (32) 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 (32). 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 powder with running water, placed on specimen and polished with the help of rag wheel (32). Pumice mixed with water is the most commonly used polishing medium (35). 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 (32).

Kunwarjeet (32) 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 0.12µm. PMMA surface roughness values were in accord in many aspects with other studies (15,38) 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 (1,36).

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 (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).

CONCLUSION

Within the limitation of this study, the profilometric evaluations showed that prepolishing 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. PMMA was the highest affected group followed by thermoplastic acetal and the last affected group was thermoplastic polyamide.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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