Chemical Structure Versus Surface Structure of Polymethyl Methacrylate Processed by Two Different Methods

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Finishing and rigorous polishing of acrylate reduces adherence of the bacterial plaque to the denture. Objective: This study was conducted to compare two methods of polishing dentures (micromotor, horizontal motor) on experimental acrylic plates. Material and method: we fabricated 64 acrylic plates, half of them were polished with a micromotor and the other half with a horizontal motor. For each on them we measured and averaged 3 rugosity values before and after polishing. Results: We found that after polishing, both motors reduced the rugosity with an overall average of 0.32 ($p<0.001$), with no statistically significant difference between methods. Conclusion: Comparing the statistical results of the two polishing methods applied in the study, we have found that both methods can be applied in current practice.

Keywords: acrylic resin, polishing, roughness, SEM image

One of the materials that brought a great change in dentistry is polymethyl methacrylate, which in the nineteenth century replaced the vulcanized rubber used until that time to manufacture complete dentures.

Polymethil methacrylate (PMMA) with chemical formula: $(C_5O_2H_8)_n$ is a polymer that has been widely used as a denture base material due to its desirable properties of excellent aesthestics, low water sorbtion and solubility, relative lack of toxicity, ability to repair, and simple processing techniques. Polymers exist in different forms of aggregation, depending on their chemical structure, their preparation and processing and the influence of external factors. In dentistry they are used in an amorphous phase. In this state, the polymeric chains interconnect with each other either through physical links (physical nodes), or through chemical links (cross links), with the apparence of tridimensional structures similar to crystalline networks [1].

Studies refereeing to the mechanical properties of polymeric material and other materials with medical applications were reported previously [2,3].

Acrylic resins dominated dentures technology for several decades, being used for denture and removable orthodontic bases, artificial teeth, veneering materials, dental restorations [4].

Acrylic resins are known as polymethyl methacrylate or PMMA, which are synthetically obtained and can be modeled, packed or injected into molds during an initial plastic phase which solidify through a chemical reaction of polymerization [5].

Popularity of acrylics accrues from the fact that the material exhibits favorable working characteristics, has acceptable physical, mechanical, aesthetic properties and is easy to fabricate with inexpensive equipment [6]. It has low water sorbtion and solubility, relative lack of toxicity, ability to repair, and simple processing techniques [7].

This material has notable advantages that could be diminished by insufficient polishing of the denture. Remnant roughness after improper processing is a cause of bacterial plaque retention, colonies of microorganisms and Candida Albicans responsible of inducing the stomatitis. Candida Albicans is an opportunistic pathogen in humans and some predisposing factors such as immunosuppressive drugs, xerostomia, systemic diseases assosciated or not with poorly fited and porous dentures result in fungal infections [8].

The finishing and polishing of restorative dental materials are important steps in the fabrication of clinically successful restorations. This procedure is mandatory in order to enhance oral health, function, and aesthetics [6]. It is generally performed with polishing wheels, felt cones, and slurry of pumice and water [9].

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Denture care is indispensable for general health, especially in elderly patients who cannot adequately brush their dentures because of disease, dementia and poor dexterity. Beyond the concern for esthetics, the lack of adequate denture hygiene can cause biofilm accumulation and oral infections such as denture stomatitis [10].

Bacterial plaque retention directly affects oral hygiene even if the patient achieves an appropriate prosthesis cleaning. Ideally, denture base materials should be smooth so plaque adherence is reduced or even avoided [11].

The purpose of this study was to investigate the efficacy of polishing an acrylic resin with two different laboratory devices: micromotor and horizontal motor.

Experimental part

An experimental study was conducted in the Department of Prosthodontics, Faculty of Dental Medicine, “Iuliu Hațieganu” University, Cluj-Napoca, Romania.

We fabricated 64 experimental plates from an acrylic resin widely used in current activity (Superacryl Plus, SpofaDental). The pads were 3 cm diameter round shape, 1mm thickness and a flat surface.

The surface of each acrylic plate was analyzed and measured using a contact profilometer (Mitutoyo SJ-201, Japan) to highlight the surface changes produced by each polishing method. Surface roughness (Ra), measured in µm, was determined by the instrument’s diamond stylus as it moved across the specimen surface under constant pressure. Three measurements of surface roughness were performed for each specimen, and mean average Ra values were used for the statistical analysis.

After the initial surface roughness readings, specimens were submitted to polishing.Half of them (32 plates) were polished with a micromotor and the other half with a horizontal motor.

For polishing with the micromotor the samples were mechanically polished with SiC sandpaper (220–2000 grit) and for horizontal motor we used diamond paste (DP Paste, Struers) under continuous water cooling.

For highlighting the microscopic aspect we used scanning electron microscopy (SEM) which produces high-resolution images of sample surfaces.

Each sample was placed in an ultrasonic bath for five minutes and dried using a high-pressure air hose prior to measuring surface roughness.

Acrylic surfaces were examined under a SEM (HitachiS-2600N) at 15 kV and photomicrographs at a magnification of ×2000 at working distance of 11.1 were made.

Results and discussions

Starting from the network arrangement of the polymer chains of PMMA, we looked for an analogy between the schematic image (fig. 1) of the network and the microscopic surface image.

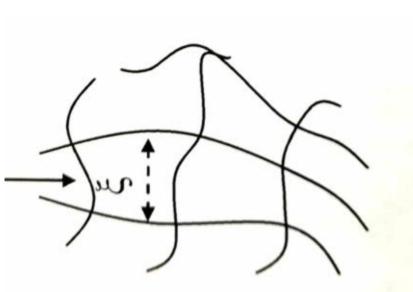

Fig. 1. Schematic representation of the network interconnected by polymeric chains

At original magnification x2000, were observed on the surface of all resin specimens longitudinal traces, parallel to each other, resulted from the initial milling process, denoting an increased roughness of the surface (fig. 2). After polishing, these surface details were attenuated, both after polishing with the micromotor and with the horizontal motor. In the polished specimens with the micromotor and sandpaper, the traces caused by the granulation persist, because this is larger than the diamond granules included in the polishing paste (fig. 3, fig. 4). Even if some small differences between the images of the polished specimens are visible, the statistical analysis does not reveal significant differences between the results obtained by the two polishing techniques.

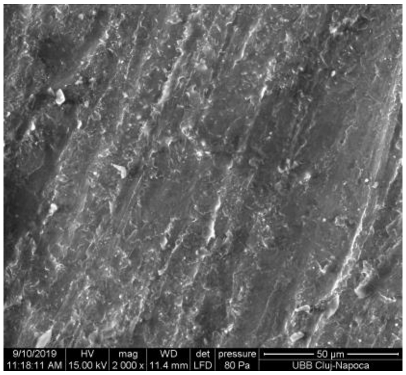

Fig. 2. Initial SEM image of acrylic sample

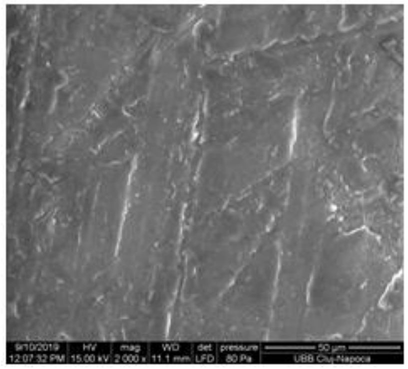

Fig. 3. SEM image of acrylic sample polished with micromotor

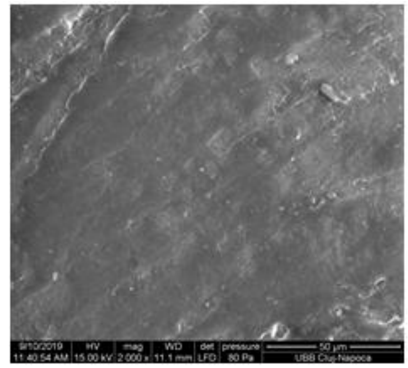

Fig. 4. SEM image of acrylic sample polished with horizontal motor

The measurements that were averaged to obtain the initial and final rugosity values had high intraclass correlation coefficients (initial: ICC3=0.677, p<0.001, final: ICC3=0.657, p<0.001). Summary statistics for all transformations are calculated in tables 1 and 2. Regardless of motor, we noticed a statistically significant reduction in average rugosity of 0.318 (0.242 to 0.394, p<0.001). Before polishing, average rugosity values ranged from 0.53 to 3.73, with an average (SD) of 1.17 (0.63) and no significant difference between plates that would be polished with the respective motors (p=0.787, post-hoc comparison of least-squares means). After polishing, average rugosity values ranged from 0.39 to 2.61, with an average (SD) of 0.85 (0.43) and no significant difference between plates that would be polished with the respective motors (p=0.732, post-hoc comparison of least-squares means).

The intercept row is shown only for completeness but it will not take part in any discussion. The 3 models performed similarly. No sphericity correction was necessary for any of the models. The main result from this table is that there is a significant difference in rugosity after treatment but both motors are similar. The interaction is not significant, therefore motors were similar at both measurements.

Table 1

TWO REPEATED MEASURES ANOVA MODELS: LINEAR, WITH RAW DATA AND LOG, WITH log-TRANSFORMED DATA. INTERPRET Eta^2 AS for R^2. A RULE OF THUMB (COHEN): 0.01-> SMALL; 0.06-> MEDIUM; >0.14-> LARGE

Transformation:	**None (Raw rugosity):**			**Log base 2:**			**Inv ('Smoothness'):**		
Effect	**F (DF)**	**Partial Eta^2**	**p-value**	**F (DF)**	**Partial Eta^2**	**p-value**	**F (DF)**	**Partial Eta^2**	**p-value**
(Intercept)	*F(1, 62) = 239.16*	*0.79*	*<0.001*	*F(1, 62) = 4.05*	*0.06*	*0.048*	*F(1, 62) = 495.34*	*0.89*	*<0.001*
Motor	F(1, 62) = 0.10	<0.01	0.749	F(1, 62) = 0.04	<0.01	0.852	F(1, 62) = 0.49	<0.01	0.489
Measurement	F(1, 62) = 68.76	0.53	<0.001	F(1, 62) = 127.08	0.67	<0.001	F(1, 62) = 111.68	0.64	<0.001
Motor:Measurement	F(1, 62) = 0.02	<0.01	0.898	F(1, 62) = 0.60	<0.01	0.442	F(1, 62) = 2.87	0.04	0.095

The next tables are just different arrangements of the same averages. We provided

-regular means (with SDs) best used in combination with untransformed data models,

-geometric means (with geometric SDs) best used in combination with log-transformed data models,

-regular means (with SDs) for inverted data (smoothness) models,

-medians (with ranges) for completeness; no nonparametric model was computed.

The first one emphasizes the differences of the motors separately for both initial (baseline) and final measurements. The second one emphasized the differences from baseline to final measurements separately for both motors. P-values were computed using post-hoc tests on least-square estimated marginal means.

Table 2
AVERAGE RUGOSITY VALUES FOR EACH TYPE OF MOTORS, AT BOTH INITIAL AND FINAL MEASUREMENTS. WE PRIVIDED REGULAR MEANS AND SDs (WITH p-VALUES FROM THE RAW DATA MODEL), GEOMETRIC MEANS AND SDS (WITH p-VALUES FROM THE log-TRANSFOMED DATA MODEL) AND MEDIANS WITH RANGES

Measurement	Motor	Mean (SD)	Geometric mean (Geometric SD)	Smoothness Mean (SD)	Median (Range)
Initial		1.17 (0.63)	1.04 (1.57)	1.05 (0.42)	0.96 (0.53, 3.73)
	micromotor	1.19 (0.73)	1.04 (1.63)	1.06 (0.44)	0.90 (0.53, 3.73)
	horizontal motor	1.14 (0.53)	1.04 (1.53)	1.04 (0.40)	1.01 (0.57, 2.76)
	p-value:	*0.787*	*0.712*	*0.257*	
Final		0.85 (0.43)	0.78 (1.50)	1.39 (0.49)	0.75 (0.39, 2.61)
	micromotor	0.87 (0.54)	0.76 (1.63)	1.45 (0.58)	0.73 (0.39, 2.61)
	horizontal motor	0.83 (0.28)	0.79 (1.36)	1.32 (0.38)	0.75 (0.50, 1.62)
	p-value:	*0.732*	*0.995*	*0.846*	
P-values are computed from the raw data model for the means and from log-transformed data model for the geometric means.					

The basic box-plots show the medians (vertical lines), IQR (boxes), outlier-free range and eventual outliers. The chart shows that both motors decrease rugosity by the same amount (fig. 5).

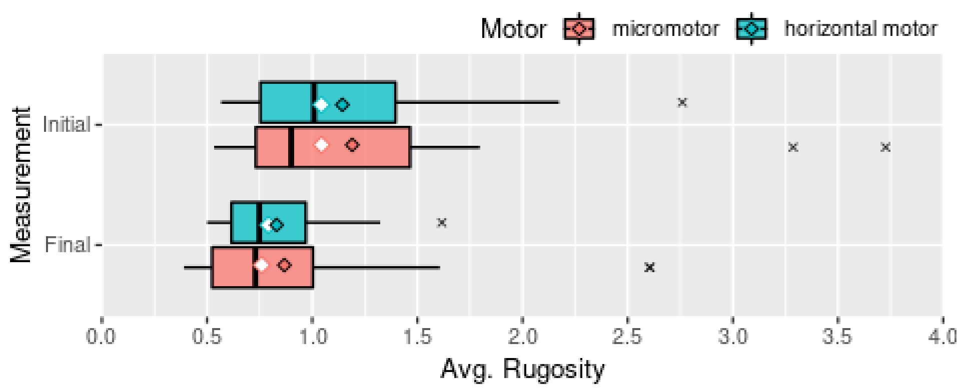

Fig. 5. Average rugosity distributions, at both measurements, with both motors (white diamonds: geometric means, black diamonds: regular means)

Dental technicians use effective techniques for polishing denture base acrylic resin [12,13].

Based on previous research, Quirynen et al. showed the surface roughness threshold for acrylic resins to be 0.2 µm, under which no significant decrease in bacterial colonization would occur. Dramatic colonization would occur beginning at 2 µm [12].

Mechanical polishing produces surface abrasion with material removal, generating surface irregularities with progressively lower dimensions as finer grits are used. Eventually, no further material is removed, leaving only surface irregularities not visible to the naked eye, and the surface appears shiny [9].

The surface roughness of dental materials including acrylic base materials is influenced by either mechanical or chemical polishing techniques [7]. In our study we have recourse to the lab conventional polishing method: micromotor and horizontal motor. Ideally, a surface with the lowest possible roughness is recommended to reduce microorganism retention and to prevent local infections and early denture deterioration [9].

For example, polishing is not always performed on completely flat surfaces and the recommended speed and the pressure of a rotating polisher are difficult to standardize [7].

The surface roughness was influenced to the greatest extent by the finishing and polishing procedures and to a lesser extent by the acrylic resin material. Depending on the grit of the abrasive used in the finishing process, surface roughness of polished acrylic resins vary between 0.03 and 0.75μm [12]. In our study, the rugosity vary between 0.39 to 2.61 μm.The different results obtained in our study were probably because of the speed and the pressure of a rotating polisher different than in the mentioned studies.

Proper finishing and polishing of dental materials are important aspects of clinical restorative procedures. Most microorganisms that are present intraorally, especially those responsible for caries, periodontal disease, and denture-related stomatitis, can only survive in the mouth if they adhere to nonshedding oral surfaces and start forming colonies [11].

Conclusions

The statistical analysis shows that there are no statistically significant differences between the acrylate polishing methods. As a result, it is possible to use any method of polishing the prosthesis, depending on the concrete clinical situation. However, it is recommended to apply conventional polishing procedures, using the horizontal micromotor.

In certain cases, as the case of a non-movable patient, the classic horizontal motor method can be replaced with the use of the micromotor at the patient's home.

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