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Effect of Polishing Technique and Brushing on Surface Roughness of Acrylic Resins

Luciana Valadares Oliveira, MS,[1] Marcelo Ferraz Mesquita, PhD,[2] Guilherme Elias Pessanha Henriques, PhD,[2] Rafael Leonardo Xediek Consani, DDS,[3] & Wagner Sotero Fragoso, PhD[1]

[1] Graduate student, Department of Prosthodontics and Periodontology, Piracicaba Dental School, University of Campinas, São Paulo, Brazil
[2] Associate Professor, Department of Prosthodontics and Periodontology, Piracicaba Dental School, University of Campinas, São Paulo, Brazil
[3] Assistant Professor, Department of Prosthodontics and Periodontology, Piracicaba Dental School, University of Campinas, São Paulo, Brazil

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Correspondence
Marcelo Ferraz Mesquita, Department of Prosthodontics and Periodontology, Piracicaba School of Dentistry, UNICAMP, Av. Limeira, 901 Bairro Areiao Peracicaba, SP CEP: 13.414-018, Brazil. E-mail: mesquita@fop.unicamp.br

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Abstract

Purpose: This study evaluated the abrasion resistance of acrylic resin to routine dental brushing procedures using different dentifrices after the resin surface had been chemically or mechanically polished.
Materials and Methods: Eighty specimens were prepared using heat-polymerizing (HP) and autopolymerizing (AP) acrylic resin, and immediately submitted to grinding with abrasive stones and disks. The specimens were divided into two groups: the first group was mechanically polished (MP) using pumice slurry, and the second group was chemically polished (CP) using heated monomer. After polishing, the specimens were submitted to 30,000 brushing cycles. Surface roughness was measured after polishing and brushing procedures, using a Surfcorder SE 1700 rugosimeter. Data were statistically analyzed by ANOVA ($\alpha = 0.05$).
Results: There were significant differences in surface roughness between polishing with MP and CP ($p < 0.05$). Significant differences in surface roughness were also found between brushing with MFP dentifrice and Tartar Control dentifrice ($p < 0.05$).
Conclusion: MP produced smoother surfaces than CP, and surface roughness as a result of polishing technique was not influenced by acrylic resin type. Even though MP resulted in smoother surfaces initially, subjecting the acrylic resin to dentifrice brushing negated this advantage.

Surface roughness of denture materials is important, as it affects the oral health of tissues in direct contact with a denture. 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.[1] Several studies have demonstrated that rough acrylic surfaces are significantly more prone to bacterial accumulation and plaque formation than smooth surfaces.[1–3] Research has indicated that a decrease in the roughness of intraoral surfaces may result in reduced plaque formation.[2] In an attempt to achieve smooth exposed surfaces that contribute to oral hygiene and low plaque retention, prosthodontic appliances made of acrylic resin must be finished and polished appropriately.

Polishing procedures for acrylic resins are performed either mechanically or chemically. Mechanical polishing (MP) promotes surface abrasion with material removal, generating traces or notches with progressively lower dimensions as finer grits are used.[4,5] It is generally performed with polishing wheels, felt cones, and slurry of pumice and water.[6] Soft brushes with chalk powder can also be used. Because all MP phases should be done sequentially without neglecting any step,[7] it is laborious and time-consuming. An alternative to this traditional method of MP was presented by Gotusso.[8] This acrylic resin polishing method, called chemical polishing (CP), consists of immersing the denture in heated monomer for 1 minute. The advantages of CP over MP are its cleanliness, ease of use, and the possibility of smoothing intaglio surfaces.[9]

The surface roughness threshold for acrylic resin is 0.2 μm, under which no significant decrease in bacterial colonization would occur. Dramatic colonization would occur beginning at 2 μm.[2] The value cited as characteristic of smooth acrylic resin is 0.12 μm,[2] but surface roughness of polished acrylic resins may vary between 0.03 and 0.75 μm.[10] An important factor in the clinical performance of a material is how it responds to hygiene procedures. The mechanical removal of debris via the use of toothbrush, dentifrice, and water is a popular alternative cleansing technique employed by many denture patients.[11]

This procedure, however, promotes the abrasion of the acrylic resin.[12] The magnitude of surface abrasion caused by toothbrushing depends on such factors as the abrasiveness of the dentifrice used, bristle stiffness, brushing technique, brushing force, the frequency of brushing, and the hardness of the denture base material.[13]

Denture bases may be constructed of heat-polymerizing (HP) or autopolymerizing (AP) acrylic resin. In addition, HP bases may subsequently be repaired with AP resins. It was therefore considered important to incorporate representatives of both types of material in the present study. A review of the literature does not show any study that compares the effect of brushing on acrylic surfaces polished using different techniques. The purpose of this study was to investigate the abrasion resistance of AP and HP acrylic resin to routine brushing procedures using different dentifrices, after the acrylic resin surface had been chemically or mechanically polished.

Materials and methods

The materials used in the present study, their manufacturers, and batch numbers are shown in Table 1.

Specimen preparation was carefully standardized. Eighty rectangular acrylic resin specimens ($25 \times 14 \times 3$ mm^3) were fabricated, according to the manufacturer's directions. Forty HP acrylic resin specimens were processed by heating the flask in a water bath at 165°F for 9 hours, and 40 AP acrylic resin specimens were processed at room temperature. After completion of processing, the specimens were immediately submitted to grinding with abrasive stones and disks. All procedures were performed by one postgraduate student. Grinding was performed in a bench vice, with low-speed instrumentation, light pressure, and intermittent contact under a water spray. Abrasive stone (Schelble, Petrópolis, Brazil) was applied for 15 seconds. Each type of abrasive disk (Labordental, São Paulo, Brazil) (coarse abrasive disk, medium abrasive disk, and fine abrasive disk) was also applied for 15 seconds. The specimens were stored in distilled water for 24 hours and randomly divided into two groups: 40 specimens were submitted to MP, and the remaining 40 specimens were submitted to CP. MP was performed using a rotating soft brush with pumice (Herjos, Vigodent, Rio de Janeiro, Brazil) slurry followed by a rotating felt cone with chalk powder (Herjos, Vigodent). CP was performed in a chemical polisher, PQ 9000 (Termotron, Piracicaba, São Paulo, Brazil), with monomer (Clássico Dental Materials Ltda, São Paulo, Brazil) heated to approximately 75°C.

Table 1 Commercial name, manufacturers, and batch number of the materials

Material	Manufacturer	Batch number
Heat-cured acrylic resin	Clássico Dental Materials Ltda, São Paulo, Brazil	99/3040
Cold-cured acrylic resin	Clássico Dental Materials Ltda	99/3040
Oral-B toothbrush	Oral-B Products, South Boston, MA	12938A
Colgate MFP	Colgate Palmolive Company, São Bernardo do Campo, São Paulo, Brazil	R1
Colgate Tartar Control	Colgate Palmolive Company	7B

Surface roughness, Ra, was measured in micrometers (μm) with Surfcorder SE 1700 (Kozaka Industry, Kozaka, Japan) at 2.4 percussion of measure after the profilometer was calibrated with a calibration specimen (Model SS-N S94 Ra 3.0 μm no. 20138, Kosaka Lab.). The cutoff value was set at 0.8 mm and 0.5 mm/sec. Statistical calculation of surface roughness was performed using an average of three surface roughness measurements taken parallel to the long axis at the central segment of each specimen.

After surface roughness readings, specimens were submitted to brushing simulation. The mechanical brushing assay was conducted on a brushing simulating machine (Equilabor, Equipamentos de Laboratório Ltda, São Paulo, Brazil). Each test specimen was brushed for 30,000 strokes, which is equivalent to approximately 3 years of cleansing.[11] This machine is equipped with eight brush holders, and a fixed load of 200 g was applied to the toothbrush neck throughout the test.[14,15] Brushes were free to move in a vertical direction. A soft bristle toothbrush (Oral-B 30, Oral-B Products, South Boston, MA) with a round-tipped end and two dentifrices, Colgate MFP (Colgate Palmolive Company, São Bernardo do Campo, São Paulo, Brazil), and Colgate Tartar Control (Colgate Palmolive Company), were used. Dentifrice paste/water slurries were prepared by mixing 6 g paste with 6 ml distilled water.[12] At the end of the assay, the specimens were removed from the machine and thoroughly washed in tap water. Surface roughness of each specimen was measured.

The data were analyzed with an analysis of variance (ANOVA) ($\alpha = 0.05$) in a factorial scheme, using acrylic resin, polishing techniques, and dentifrice as variables.

Results

Table 2 shows surface roughness mean values between MP and CP for HP and AP materials. Table 3 shows surface roughness mean values after the brushing assay for specimens of HP and AP submitted to MP and CP.

The mean values of surface roughness and standard deviation for each material and polishing technique are shown in Table 2. Smoother surfaces were obtained on both groups of MP. The difference between MP (HP = 0.0427 μm; AP = 0.0547 μm)

Table 2 Mean surface roughness (μm) ± standard deviation of acrylic resins after mechanical and chemical polishing (n = 20)

	Polishing technique	
Material	Mechanical polishing	Chemical polishing
Heat-polymerized (n = 20)	0.0427 ± 0.25 ^{a,A}	0.4884 ± 0.20 ^{a,B}
Autopolymerized (n = 20)	0.0547 ± 0.12 ^{a,A}	0.4157 ± 1.16 ^{a,B}

Means followed by the same lower case letter in a column and the same upper case letter in a row do not differ statistically by Tukey at a 5% probability level.

Table 3 Mean surface roughness (μm) ± standard deviation of acrylic resins after the polishing techniques and the brushing assay

	Dentifrice	
Polishing group	Colgate MFP	Colgate Tartar Control
AP + MP (n = 10)	$3.3848 \pm 0.5726^{a,A}$	$5.8241 \pm 0.5008^{a,B}$
AP + CP (n = 10)	$3.5217 \pm 0.3791^{a,A}$	$5.7530 \pm 0.7457^{a,B}$
HP + MP (n = 10)	$3.4985 \pm 0.4143^{a,A}$	$5.8018 \pm 0.7107^{a,B}$
HP + CP (n = 10)	$3.8527 \pm 0.4393^{a,A}$	$5.7262 \pm 0.3760^{a,B}$

Means followed by the same lower case letter in a column and the same upper case letter in a row do not differ statistically by Tukey at a 5% probability level.

and CP (HP = 0.4884 μm; AP = 0.4157 μm) were significant ($p < 0.05$). There were no significant differences between HP and AP acrylic resin submitted either to MP or CP (Table 2).

The mean values of surface roughness and standard deviation for each combination of material/polishing technique and brushing are shown in Table 3. The difference between MFP (AP + MP = 3.3848 μm; AP + CP = 3.5217 μm; HP + MP = 3.4985 μm; HP + CP = 3.8527 μm) and Tartar Control (AP + MP = 5.8241 μm; AP + CP = 5.7530 μm; HP + MP = 5.8018 μm; HP + CP = 5.7262 μm) were significant ($p < 0.05$).

Discussion

Surface roughness of denture materials is important, as it affects the oral health of tissues in direct contact with a denture. Rough surfaces on bridges, implant abutments, and denture bases accumulate and retain more dental plaque than smooth surfaces.[1,2] Once bacteria adhere to irregular surfaces and other stagnant sites, they can survive for a long period of time. A rough surface may protect bacteria from natural removal forces and even from oral hygiene methods. Ideally, a surface with the lowest possible roughness is recommended to reduce microorganism retention and to prevent local infections and early denture deterioration.[3] The threshold surface roughness for bacterial retention is 0.2 μm.[2] Surface roughness below this value does not help reduce bacterial accumulation. On the other hand, values greater than 0.2 μm lead to increased plaque accumulation.[1]

Although superior surface characteristics of the HP resin may be expected due to the higher degree of conversion of the monomeric component when compared to the AP acrylic resin, no difference in surface roughness between polymerization methods was observed in this study (Table 2); however, a significant difference between polishing techniques was observed. MP 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.[4,5] In CP, however, methyl methacrylate molecules present in the polishing fluid penetrate superficial polymeric chains of the acrylic resin, breaking the secondary bonds that join them, promoting a final plasticizing effect of acrylic resin surface. As the CP action is superficial, it supposedly has no effect on the irregularities caused by finishing procedures.[16] The results of the present study are in accordance with Ulssoy,[7] who demonstrated lower roughness values when abrasives of the finest grit sizes were employed in the final polishing step. Rahal et al[16] also observed lower surface roughness for acrylic resin specimens submitted to MP than for those submitted to CP. These results illustrate that CP acts on valleys and peaks of irregularities, mollifying and rounding these areas, reducing the distances between them, and smoothing the material surface; however, this polishing technique causes wear in both valleys and peaks, making it more difficult to decrease the distance between them. On the other hand, MP acts on peaks and is more effective in obtaining smooth surfaces.

The present study also verified the influence of brushing procedures using two different dentifrices, after the acrylic resin surface had been chemically or mechanically polished (MP). After the brushing assay, there were no significant differences between either polishing procedure or acrylic polymerization mode (Table 3); however, differences in surface roughness were observed when different dentifrices were used. Abrasive action depends on type, size, and shape of dentifrice particles, as well as the force applied during brushing. For this reason, particles of the same shape and hardness produce similar furrows.[17] The abrasion provided by a dentifrice is influenced by its abrasive properties, resulting from its chemical composition, crystalline structure, solubility, concentration, hardness, particle size and shape, and compatibility with other dentifrice ingredients.[14] The abrasive particles in Colgate Tartar Control dentifrice have a larger diameter and more irregular shape than those of Colgate MFP. Under these experimental conditions, Colgate MFP, or any other dentifrice with small diameter or regular shape is indicated for acrylic resin.

The results of the present study showed that, in spite of the low surface roughness values achieved after the finishing and polishing process, brushing with an abrasive dentifrice inevitably increases surface roughness, regardless of how the acrylic resin was initially polished. Based on the results, clinicians could recommend the use of any dentifrice with small diameter and regular shape, such as the one used in the present study. Although laboratory studies simulate clinical conditions, testing environments are never exactly the same. Polishing of denture base chairside or in the laboratory is generally done under conditions different than those used for the present study. Clinical polishing is not usually performed on completely flat surfaces, and is highly operator-dependent. Therefore, clinical studies may be necessary to confirm the long-term behavior of surface roughness after both polishing techniques and brushing.

Conclusions

Within the limitations of this study, the following conclusions were drawn:

1. Mechanical polishing produced lower surface roughness mean values than chemical polishing.
2. After brushing, there were no significant differences in surface roughness between mechanically and chemically polished acrylic resin.

3. Acrylic resin brushing with Colgate MFP resulted in lower surface roughness values than Colgate Tartar Control.

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