Original Article

Surface Roughness of Acrylic Resins after Different Curing and Polishing Techniques

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ABSTRACT

Objective: To conduct a laboratory evaluation of the surface roughness of self-curing acrylic resin after different curing and polishing techniques.

Materials and Methods: Sixty specimens were separated into four groups. The conventional curing process was followed by a second curing cycle in a microwave oven to decrease the residual monomer levels in two groups. After curing, two groups received manual polishing and the other groups underwent chemical polishing at 70°C for 10 seconds. Roughness analysis was performed in a mechanical and laser profilometer. Analyses by Bartlett, Shapiro-Wilk, and Dunnett tests were used to compare whether the mean of the response variable was the same in all groups.

Results: The results suggested greater influences from the polishing method than the curing method and showed that the chemical polishing method yielded the highest surface roughness.

Conclusions: The average pattern of roughness of the self-curing acrylic resin was statistically the same in the groups with different curing methods. However, chemical polishing increases the average pattern of roughness.

KEY WORDS: Surface roughness; Acrylic resins; Orthodontics; Appliance

INTRODUCTION

Acrylic resins with polymethyl methacrylate are widely indicated for fabrication of orthodontic appliances used for correction of malocclusions or retention. Introduced in the 1930s, these resins are easy to handle, have reduced cost, and allow satisfactory clinical outcomes.[1,2] They consist of a polymer and monomer whose mixture triggers curing, which may be chemically activated (self-curing) or require heat (heat curing).[1,3,4]

Orthodontic appliances manufactured with self-curing acrylic resin should present smooth and polished surfaces; retain less organic debris; offer less risk of microbiological imbalance, appearance of caries, periodontal disease, oral sensitivity, or stomatitis; and favor oral hygiene.[5–7] However, several factors may yield porosities during the manufacturing process of these appliances. As possible causes, the literature mentions mistaken proportions of polymer and monomer, inadequate agglutination of powder particles to the liquid, application of resin at an improper stage of the reaction, and lack of application of a long-enough curing cycle.[8]

Technical measures should address the amount of monomer recommended by the manufacturer because excesses lead to inclusion of bubbles and consequent increases in porosity. The same is true for the proper homogenization of the mixture and adequate time for application on the dental cast after the stages of polymerization of the resin.[9]

During the curing process, part of the monomer may not react and be residually maintained. Larger amounts of this are found in chemically activated resins.[2] As a consequence, it acts as a plasticizer, increasing the solubility of the resin and worsening the physical properties of the material. Some authors have suggested that conventional curing should be followed by a second cycle in a microwave oven, which is an effective method for maintaining low residual monomer

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levels.[10,11] The microwave energy acts on the monomer molecules, leading them to vibrate and collide with each other, thereby generating the heat required to cure the resin.[12–14]

After the curing process, the appliances should be finished and polished. Surface irregularities secondary to poor polishing act as niches for retention of bacteria and food debris.[14] In an attempt to eliminate the technical steps of manual polishing, Gotuso[15,16] described the process of chemical polishing. According to this author, polishing is performed in a specific machine (chemical polisher) with a methyl methacrylate solution at 70°C for 10 seconds. However, it has also been suggested that the excess monomer incorporated during chemical polishing may irritate the oral mucosa and affect the mechanical properties of the acrylic resin.[17–20]

Mesquita et al[9] investigated the influence of chemical and manual polishing on the surface roughness of acrylic resin specimens and observed that the chemical method presented higher values of surface roughness regardless of the type of activation of the resin (chemical or thermal) when compared with the manual technique. Braun et al[18] investigated the surface texture of acrylic resins submitted to chemical polishing and found that all resins displayed a smooth and polished surface yet with irregularities after chemical polishing.

Considering the physical traits of acrylic resin surfaces used as an auxiliary tool for orthodontic treatment and the hypothesis of the influence of the curing and polishing processes, this study reports on the analysis of surface roughness of acrylic resin after different curing and polishing techniques.

MATERIALS AND METHODS

Self-curing acrylic resin (Orto Clas) was used, following the proportion of 13.4 g of polymer to 7.9 mL of monomer, as indicated by the manufacturer (Artigos Odontológicos Clássico Ltda, São Paulo, Brazil, batch no. 00624). Sixty specimens were separated into four groups according to the two techniques of curing and polishing (Table 1) and were constructed with 1-cm^3 stainless steel cylinders. In all groups the monomer was placed in the cylinders and the polymer was applied in small portions until completion. When the device was filled with acrylic resin, it was placed in the Orto Clas machine (n. 2, Promeco, São Paulo, Brazil) under 25 pounds of pressure of at 18°C for 20 minutes, with a possible variation of 2°.

Afterwards, the stainless steel device was removed from the machine and the acrylic specimens were retrieved. Next, only specimens in groups 3 and 4 were submitted to the second curing cycle in the microwave oven at 540 W for 3 minutes to decrease the residual monomer levels. An attempt was made to place the specimens at the most external area of the rotary plate of the microwave oven so all specimens would receive a similar amount of radiation.

Table 1. Groups Formed According to the Curing and Polishing Methods

Group	Curing	Finishing	Polishing
1	Conventional	Wood sandpaper (grit 180)	Manual
2	Conventional	Wood sandpaper (grit 180)	Chemical
3	Conventional + 2° cycle microwave	Wood sandpaper (grit 180)	Manual
4	Conventional + 2° cycle microwave	Wood sandpaper (grit 180)	Chemical

After curing, all groups were polished with grit 180 wood sandpaper. The specimens in groups 1 and 3 received manual polishing with water sandpaper grits 400 and 600, felt discs on the lathe, and white polishing powder. The direction of the movements on the sandpaper was random so that the surface analyzed might represent the real conditions of orthodontic appliance fabrication. The time spent in the manual polishing process was the same in all groups, 5 minutes in each step. Groups 2 and 4 underwent chemical polishing in addition to the water sandpapers, always at 70°C for 10 seconds.

Roughness analysis was performed in a mechanical profilometer (Alpha Step 200, Warthman Associates, Palo Alto, Calif), which produced a reading with an instrument that touched the previously positioned specimen, and a laser profilometer (Mahr Perthometer PRK, Providence, RI). Five measurements were taken for each specimen for later statistical analysis. Data were analyzed according to the Ra (roughness—arithmetic mean value of all deviations from the roughness profile of the midline within the measurement length) and TIR (total indicated remount—maximum vertical distance between the lowest and highest points, delimited by two parallel straight lines, calculated in the graphic image transmitted after the Ra reading). Briefly, the Ra was the linear measurement of the surface relief of the self-curing acrylic resin, and the TIR was the evaluation of this relief in a vertical direction, demonstrating the depths of irregularities and surface porosity.

Because each specimen had its surface roughness evaluated at five positions on the polished side, the mean of these five evaluations was used as a response variable. Thus, there were four groups, with 15 specimens. This sample number was determined by the statistical principle of significance determination. Analyses by Bartlett, Shapiro-Wilk, and Dunnett tests

Table 2. Mean and Standard Deviation (SD) of the Pattern Roughness (Ra) and Total Indicated Remount (TIR) of the Groups Evaluated in the Mechanical Profilometer

	Ra		TIR	
Group	Mean	SD	Mean	SD
1	0.182	0.046	1.013	0.369
2	1.812	0.584	11.794	3.532
3	0.259	0.121	1.217	0.510
4	2.229	0.585	12.500	2.902

Table 3. Punctual Estimates and Confidence Intervals (CI) According to the Interval of Ratio of the Means

Ratio	Estimates	95% CI
Group 4 / group 1	12.239	9.159; 16.3540
Group 2 / group 1	9.825	7.353; 13.1290
Group 3 / group 1	1.342	1.0047; 1.7939

were used to compare whether the mean of the response variable was the same in all groups.

RESULTS

Descriptive statistical analysis revealed high values for groups 2 and 4 when compared with the others. The results of the mean Ra pattern for these groups were 1.812 and 2.229, respectively. The difference in vertical direction was greater, with mean values of the TIR pattern of 11.794 for group 2 and 12.500 for group 4, nearly 10 times greater than groups 1 and 3 (Table 2).

The assumption of homogeneity of the variances was checked by the Bartlett test, yielding a P value of .1390. The assumption of normality was assessed by the Shapiro-Wilk test, which yielded a P value of .9414, and it was not possible to reject the hypothesis of normality of residues. Evaluation of these assumptions by analysis of variance revealed a statistical F value of 236.73, with $P < .001$. Thus, at a significance level below 1%, the hypothesis that the mean of the response variable is the same for all methods of specimen fabrication is rejected.

After rejection of the hypothesis of equality of means, the test for multiple comparisons was applied, especially the Dunnett test, taking method 1 as a control group. The estimates of ratios and means and their respective confidence intervals of 95% are presented in Table 3. It is concluded that the geometric mean of the response variable for method 4 is 12.239 times the geometric mean for method 1. Method 2 is nearly 10 times the geometric mean of method 1. The mean for method 3 is approximately 1.3 times the geometric mean for method 1. It should be noticed that the confidence interval for the ratio has a lower limit of 1. At a 1% significance level, it was not possible to reject the hypothesis of equality of the means between methods 1 and 3.

The specimens were submitted to the second evaluation of roughness by a laser beam that screened the surface and emitted mean values of relief. However, it was not possible to measure groups 2 and 4 because the degree of roughness of the samples presented a higher value than possible for the machine, which may measure values of up to 250 μm. Analysis of results for groups 1 and 3 did not reveal any statistically significant difference and showed low values of surface roughness, which was in accord with the first analysis.

DISCUSSION

The pattern of surface smoothness of the specimens submitted to chemical polishing did not allow reading by the laser profilometer. The surfaces presented irregularities after this polishing method, suggesting solubilization of the most external layer during immersion in the heated solution of methyl methacrylate. Because the sensitivity of the machine is set for variations smaller than those displayed by the specimens in groups 2 and 4, only groups 1 and 3 were evaluated. Thus, this evaluation was considered as the reliability test for the data of the mechanical profilometer, because the results between groups submitted to manual polishing were compatible and very distinct from the groups receiving chemical polishing for both evaluation methods.

Analysis of the data in Tables 2 and 3 reveals a contraindication of the chemical method for polishing of orthodontic appliances fabricated with self-curing acrylic resin. The increase in surface roughness observed in the specimens in groups 2 and 4 suggests that in clinical situations the discomfort and risk to oral health would be similarly increased. These alterations corroborate the findings of Mesquita et al[9] and Braun et al.[18] Vertical variation (TIR) of the roughness in groups 2 and 4 demonstrated great differences between the maximum and minimum values, indicating both valleys and peaks on the surface of the chemically polished resin as well as a high rate of porosity.

Analysis of the results of groups with the same polishing method submitted to different curing procedures (groups 1 and 3 compared with groups 2 and 4) reveals more remarkable influences from the polishing method than from curing on the surface roughness of the self-curing acrylic resin. This study allowed the conclusion that the chemical polishing increases the mean pattern of roughness nearly 10-fold.

The correlation between groups 1 and 3, with variations in curing, demonstrated a slight increase in the mean pattern of porosity in the group submitted to a second cycle in the microwave oven but without statistical significance. The mechanical properties of the resin may be affected by this method, and lacunae may appear on the resin surface after evaporation of the monomer.[17–19]

Variations in the curing and polishing methods promote association of factors and ultimately increase the mean pattern of porosity 12-fold when the second cycle in microwave oven and chemical polishing are used.

CONCLUSIONS

a. The average pattern of roughness of the self-curing acrylic resin was statistically the same only in the groups with different curing methods (groups 1 and 3).
b. An isolated modification in the polishing method yields an increase of approximately 10-fold in the average pattern of roughness after the chemical polishing.
c. The combination of curing method with second cycle in microwave and chemical polishing increases the mean pattern of roughness 12.239-fold.

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