Influence of a Thickness and Processing Method on the Linear Dimensional Change and Water Sorption of Denture Base Resin

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Received October 9, 2003/Accepted December 26, 2003

The purpose of this study was to evaluate the influence of a thickness and processing method on linear dimension change and water sorption in a denture base resin after storage in water for 24 hours, one week, and four weeks.

Sixty wax specimens 65mm long and 10mm wide were fabricated in three thicknesses, 1.5, 3, and 4.5mm. Three dimples were made in each wax specimen. A travelling microscope was used to measure the total distance from the uppermost dimple to the lowest dimple to the nearest 0.01mm.

Acrylic resin blocks were polymerized with 2 processing cycles (short and long-cured). Immediately after processing, all samples were measured by the same investigator. They were then weighed by an electronic precision balance capable of measuring to 0.001 g.

Data were analyzed by analysis of variance. Thickness and time of storage were statistically significant on the dimensional change (linear and weight changes) of denture-base resin (p<0.01), showing the influence of the processing method.

Key words: Linear dimensional changes, Acrylic processing methods, Water sorption

INTRODUCTION

Heat-cured acrylic resin is the most popular denture base material in clinical use1-5). However, there are dimensional changes in dental resins before, during, and after processing6). Many factors such as the size, shape, thickness of the denture and the presence of teeth can influence the dimensional change of acrylic resin dentures6-10).

The lack of dimensional stability must be accepted as one of the disadvantages of acrylic resin dentures. Linear processing shrinkage of acrylic resin dentures has been studied extensively. Reported linear shrinkage values range from 0.26 to 1.20%, but they are considered to be approximately 0.50% for wet heat-processed acrylic resins11-15).

Polymerization shrinkage was compensated by thermal expansion during processing with a conventional method16). Slow cooling after processing has also been recommended to avoid high residual stresses generated by thermal expansion differences between the plaster mold and denture base17).

The changes in dimension will vary according to the thickness of the resin that undergoes polymerization and will depend on its location within the flask18). The increase of linear dimensional expansion and the amount of water sorption in thick resin specimens were greater than those in thin samples14).

The thin, heat-cured acrylic resin specimens had more residual monomer than the thick ones18). Therefore, the difference in magnitude of shrinkage might be more than the difference in thickness14).

Acrylic resin dentures are also notable for their tendency to absorb water, which causes a corresponding dimensional change. Low water sorption of finished dentures has been considered desirable for dimensional stability19,20).

Acceptable methods of measuring dimensional change include calipers, gauges, comparators, micrometers or radiographs13). For example, a caliper and outside micrometer were used by McCartney21) to measure the cross-arch distance of processed dentures to the nearest 0.001 inch. Also, some investigators used a microscope to determine the dimensional change of acrylic resin tray materials and complete dentures22-24).

The aim in this study was to compare the water sorption and linear dimensional changes of denture base resin of different thicknesses which occurred during processing and storage in water for 24 hours, 1 week and 4 weeks.

MATERIAL AND METHODS

A stainless steel mold 65 mm long and 10 mm wide was fabricated in three thicknesses, 1.5, 3 and 4.5 mm. With the use of a silicone impression material (Colténé speedex, Polysiloxane condensation type, Whaledent Inc. 750 corporate drive, Mahwah, NJ 07430, USA) in a custom tray, master wax specimens were made these impressions.

**Linear dimensional change:**
Sixty similar working specimens were divided into six groups of ten. Three dimples were made in each wax specimen with a round bur (fig.no.801 008 1/10
mm, NTI-Kahla GmbH rotary dental instruments, Germany). The distance between three points on the specimens was measured before and after curing, placement in water, and drying on the laboratory bench. A binocular microscope (Olympus, Tokyo) was used to measure the total distance from the uppermost dimple to the lowest dimple to the nearest 0.01 mm. Because of the inability of the microscope to measure distances over 10 mm, it was necessary to measure distance AB (the lowest point of the uppermost dimple to the highest point of the middle dimple), then distance BC (the highest point of the lower most dimple to the highest point of the middle dimple), and finally to add both measurements to obtain the total linear distance value AC (Fig. 1). Linear dimensional measurements were made of each wax specimen, i.e. preprocessed specimens by one investigator.

The wax specimens were then invested in denture flasks and processed with heat-cured acrylic resin (QC-20 De Trey, Dentsply, England) using long and short processing methods.

Processing Methods:
1. Long polymerization cycle: Immerse the flasks in the compress in cold water, slowly bring the temperature of the water to 71.1°C, the constant temperature, and leave them for about 8 hours, after which the water is brought to boiling temperature and the assembly is boiled for 30 minutes.
2. Short polymerization cycle: Immerse the assembly in water at 71.1°C, the constant temperature, for 1.5 hours, then transfer it to boiling water and leave it for 30 minutes.

After processing, all specimens were measured by the same investigator using the methods described above. To determine and compare the effect of water sorption, acrylic resin specimens were stored in distilled water at 37°C and remeasured 24 hours, one week and four weeks later.

Water Sorption:
The water sorption of specimens was measured at the same time (after storing in water for 24 hours, 1 week and 4 weeks) as the measurements of linear dimensional change.

Immediately after processing, all samples were weighed by an electronic precision balance (Sartorius AG, Gottingen, Germany) capable of measuring to 0.001 g. The specimens were then immersed in distilled water at 37±1°C, and then removed from the water after different storage times (24 hours, 1 week and 4 weeks). Excess water on specimens was removed before weighing the blotting with a filter paper and transferring it to a dessicator with silica gel at 37°C. They were weighed regularly until a constant mass was reached. The water sorption was indicated in terms of weight loss.

A repeated measures ANOVA model with groups as a between-specimen factor, time as a within-specimen factor, and the linear dimensional percent changes with the preprocessed or the processed lengths as the base value showed significant differences (p<0.01).

Table 1  Linear dimensions of acrylic resin specimens (means and Standard deviations)

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Processing Methods</th>
<th>Long-cured method</th>
<th>Short-cured method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1.5 mm</td>
<td>3 mm</td>
</tr>
<tr>
<td>Preprocessed (Wax specimen) (mm)</td>
<td>18.25±0.48</td>
<td>18.22±0.25</td>
<td>18.31±0.59</td>
</tr>
<tr>
<td>Processed (mm)</td>
<td>17.99±0.46</td>
<td>17.97±0.26</td>
<td>18.05±0.58</td>
</tr>
<tr>
<td>24 hours (mm)</td>
<td>17.98±0.46</td>
<td>17.95±0.27</td>
<td>18.03±0.57</td>
</tr>
<tr>
<td>7 days (mm)</td>
<td>17.94±0.48</td>
<td>17.89±0.28</td>
<td>17.96±0.57</td>
</tr>
<tr>
<td>30 days (mm)</td>
<td>17.97±0.51</td>
<td>17.92±0.25</td>
<td>17.96±0.61</td>
</tr>
</tbody>
</table>
RESULTS

The means and standard deviations for the linear dimensions are presented in Table 1. The mean linear dimensional change in millimeters and the mean percentage change during each time period was calculated for two polymerization techniques (Table 2).

The time of storage and processing method were statistically significant on the linear dimensional change of acrylic resin specimens (p<0.01). There is a lower relative dispersion in the linear dimensions after 30 days. Based on these data, the short-cured acrylic resin specimens showed a higher linear dimensional change than long-cured specimens. Immediately following processing a significant difference in the linear dimensional change was shown.

According to the Duncan’s multiple range test, the thickness of acrylic resin specimens had no effect

<table>
<thead>
<tr>
<th>Processing Methods</th>
<th>Thickness</th>
<th>Variable</th>
<th>Mean Change (mm)</th>
<th>Mean Change (%)</th>
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<tr>
<td></td>
<td>1.5 mm</td>
<td>Wax-processed samples</td>
<td>-.26</td>
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<tr>
<td></td>
<td></td>
<td>Wax-24-Hour samples</td>
<td>-.27</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Wax-7-Day samples</td>
<td>-.31</td>
<td>-1.68</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wax-30-Day samples</td>
<td>-.28</td>
<td>-1.56</td>
</tr>
<tr>
<td>Long curing 3 mm</td>
<td>Wax-processed samples</td>
<td>-.25</td>
<td>-1.40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wax-24-Hour samples</td>
<td>-.27</td>
<td>-1.49</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wax-7-Day samples</td>
<td>-.27</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Wax-30-Day samples</td>
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<td>-1.65</td>
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<tr>
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<td>4.5 mm</td>
<td>Wax-processed samples</td>
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<td>Wax-7-Day samples</td>
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<td></td>
<td>Wax-30-Day samples</td>
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<td>Short curing 3 mm</td>
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<td>Wax-24-Hour samples</td>
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<td>3 mm</td>
<td>Wax-processed samples</td>
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<td>Wax-7-Day samples</td>
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<td></td>
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<tr>
<td></td>
<td>Wax-30-Day samples</td>
<td>-.51</td>
<td>-2.84</td>
<td></td>
</tr>
</tbody>
</table>
on linear dimensional change.

The weight changes of acrylic resin specimens with a different thickness during storage in water (24 hours, 1 week and 4 weeks) were shown in Fig. 3. The processing methods and thickness of acrylic resin were statistically significant on water sorption (p<0.01). The water sorption of the 4.5-mm acrylic resin specimens just after processing was greater than that of the 1.5-mm and 3-mm specimens.

**DISCUSSION**

The dimensional changes of the denture base resin were examined in the rectangular specimens with different thicknesses using two processing methods. The degree of contraction of specimens was not affected by the depth and diameter of dimples on samples. These small dimples were also made in each wax block to provide for measurement orientation and block identification later.

Several investigations reported that there was no significant difference between conventional and microwave curing methods on dimensional change of acrylic resins. Light-cured resin had the least amount of dimensional change, particularly after storage in water. The injection-processed resin exhibited far less polymerization shrinkage than the compression-processed resin. McCrory concluded that a short curing cycle produced more processing shrinkage. These results are in agreement with the study of O'Toole et al., which demonstrated the effect of a polymerization technique on dimensional stability using a rectangular acrylic resin plate that represented a two-dimensional measurement.

Kawara et al. suggested that the shrinkage of heat-activated acrylic denture-base resin was mainly thermal shrinkage and demonstrated the advantage of the low-temperature method in reducing thermal shrinkage.

Temperature changes in wet-processed denture bases have been shown to closely follow the water bath temperature. The duration of the terminal "boil" in the dry heat-processing cycle was, therefore, extended to 2.5 hours to allow sufficient heating at 100°C. This prolonged duration may have facilitated the diffusion of water into the hot resin. During water saturation, all resultant dimensions of the specimens showed shrinkage when compared with the stone casts. The belief that processing shrinkage may be wholly compensated by water sorption may not be true for air oven- or water bath-processed dentures.

In this study, the short-cured acrylic specimens exhibited a greater mean percent of water sorption than did the other specimens. The higher expansion of short-cured acrylic resins was not the result of higher water absorption, but the result, perhaps, of the plasticizing effect of water allowing stress to be released. The mean of the linear dimensional change of short-cured acrylic specimens was higher than the other specimens.

After approximately 40 days of immersion in water, the overall dimensions of all the dentures showed similar shrinkage. Dimensional changes during water immersion are closely related to water uptake.

Anderson et al. reported that there was a trend toward increased dimensions in both sample groups (compression-and-injection-processed resin) after 30 days of storage in water, but it was not significant. Dixon et al. showed that the linear dimension of acrylic resins due to processing and storage in water up to 90 days were not statistically significant.

In this study, the means of linear dimensions for the short-cured acrylic specimens were 17.89 mm, 17.87 mm and 17.84 mm after 1, 7 and 30 days, respectively. For the long-cured acrylic specimens, these means were 17.98, 17.93 and 17.95 mm, after 1, 7 and 30 days, respectively. From processing to 30 days in water storage, 4.5 mm acrylic specimens exhibited shrinkage in linear dimensions.

On the first day, the weight change of acrylic specimens was higher. On a given day, sorption has different values from other days because the water sorption of an acrylic specimen can not be more than a specific point.

The thickness of acrylic resin dentures is believed to be a significant factor in determining the magnitude of the shrinkage that occurs during processing. Wolfaad et al. suggested that the changes in dimension will vary according to the thickness of resin undergoing polymerization and will depend on the location within the flask.

The linear expansion and water sorption for specimens of the same thickness tended to be greater for microwave-activated resins than for heat-polymerized samples. The time required to obtain the maximum value of linear dimensional expansion and the water uptake in thick resin specimens is longer than for thin ones.

In this study, the water sorption of 4.5-mm acrylic resin specimens after 30 days was slightly higher than that of 1.5-mm acrylic resin specimens. The specimens exhibited shrinkage in linear dimensions at the same time. Linear dimensional changes in thin specimens tended to be smaller than those in thick samples. The increase of the amount of water sorption in thick resin specimens was greater than that in thin samples.

A thicker denture has greater dimensional change after deflasking and requires longer to become dimensionally stable. A thinner denture has greater warpage after deflasking, but becomes dimensionally stable more quickly. Such findings are in
agreement with others that found that thicker dentures had more dimensional change in the posterior palatal area than thinner dentures\(^{10}\).

Sadamori et al.\(^{14}\) suggested that the changes in linear dimension and water uptake of acrylic resin denture bases were influenced by the processing method and thickness. A thicker denture has a greater dimensional change after deflasking and requires longer to become dimensionally stable.

The dimensional accuracy and stability of acrylic resin dentures might be influenced by the processing method, the thickness of the bases, and the shape and size of the dentures. Furthermore, these differences might affect the properties of dentures during processing and functioning\(^{10}\).

CONCLUSION

The processing methods and thickness were effective on the water sorption of denture base resin. The short-cured acrylic resin had higher water sorption than the long-cured acrylic resin. The water sorption of 4.5 mm specimens was higher than that of 1.5 mm acrylic resin. The different times of storage and processing methods were effective on the linear dimensional change of denture base resin. The linear dimensional change for short-cured acrylic specimens were higher than that for long-cured specimens after 30 days.

ACKNOWLEDGMENTS

Presented as a poster at the 27th Annual Conference of the European Prosthodontic Association, Geneva, Switzerland, 4-6 September 2003.

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