Controlled polymerization system for fabricating precise dentures

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Statement of problem. Most processed resin denture bases do not fit the cast accurately because of polymerization changes in the resin. The fit is more noticeable in the palate between the denture base and the cast. Therefore, development of a polymerization system that will improve the fit of a denture base to the cast is of worth considering to improve the fit and retention of the denture.

Purpose. A newly developed polymerization system for dentures is presented that results in excellent adaptability of the denture base to the cast when compared with 2 other polymerization systems.

Material and methods. Forty-five maxillary dentures were made with 3 resins and 3 polymerization systems (a new polymerization system, SR-Ivocap system, original microwave polymerization system). Each denture and cast was sectioned through the second molar area parallel to the posterior border. Discrepancies between denture base and stone cast were measured at several points immediately after polymerization and after 30 days of immersion in water. In addition, disks of 3 materials processed in each system were examined for absorption of water and hardness at 2 measurement stages. Data were analyzed with the split-plot or 2-way ANOVA test.

Results. Dentures made with the new polymerization system had significantly smaller discrepancies, compared with dentures processed with the SR-Ivocap system and the microwave method. The amount of water absorption of the resin disks processed by the new system was less than the disks made by the other 2 systems. Dentures made with the new system exhibited significantly better adaption to the cast than those made with the other 2 systems.

Conclusion. The new polymerization system produced a more accurate method of processing dentures when fit was compared with the fit of dentures made with the other 2 denture base resins. (J Prosthet Dent 2000;83:514-20.)

Clinical Implications
In this study, the new polymerization system provided an effective method of fabricating well-adapted denture bases.

It is important clinically that a denture base precisely contact the oral mucosa. Numerous studies1-11 have reported on the dimensional accuracy and stability of acrylic resin dentures made by various polymerizing procedures.12-16 These studies have demonstrated that the accuracy of the fit of dentures to the mucosa is dependent on these processes. In these studies, the heat sources for polymerization of the resin was hot water, a hot metal plate, and microwave radiation. A previously described microwave polymerization method,4,5 which used a fiber-reinforced polyester flask showed that dentures polymerized in the microwave oven fit the casts better than those polymerized in a hot water bath.

To fabricate dentures with closer adaptation to the cast and thus to the mucosal surface in the mouth, the polymerization system must have the following 5 properties at the same time: (1) reduced amount of free water in the stone cast and gypsum mold in which they are processed; (2) resin dough must be injected rapidly and held under a pressure of about 3.5 MPa until polymerization is complete; (3) use of the minimum required temperature to completely polymerize the monomer in the resin dough; (4) initiate polymerization evenly and uniformly from the surface of the cast upward so the resin in the injection sprue is the last to harden; and (5) initiate polymerization immediately after the resin dough is injected into the mold space.

The purpose of this article is to provide a step-by-step procedure for processing denture bases by the new polymerization system and statistically compare the new procedure with the SR-Ivocap system and the original microwave method.

Material and methods
Forty-five edentulous maxillary stone casts were prepared by pouring mixes of dental stone (Plaston L, GC
Corp, Tokyo, Japan) into a negative rubber mold (H3-402U, Nissin Dental Products Inc, Tokyo, Japan). By following conventional dental laboratory procedures, plastic artificial denture teeth (Endure HS S30, Shofu Corp, Tokyo, Japan) were set in wax on the stone cast to make a maxillary trial denture. A silicone impression material (TSE 3455T, Toshiba Silicone Corp, Tokyo, Japan) was used to make a negative mold of the trial denture.

The original trial denture and cast were removed from the silicone mold. A new set of artificial teeth was placed in the mold, and a new cast was placed in the mold. This left a void where the original wax denture base had been. The cast and mold were held together while molten wax was poured through a hole in the mold. After the wax hardened, the mold was removed leaving a new trial denture on the cast.

Forty-five nearly identical trial dentures were fabricated in this manner. The trial dentures were randomly divided into 3 groups of 15 dentures. Each group was processed by 1 of the 3 systems and each system used its own unique formulation of acrylic resin: (I) new polymerization system, (II) SR-Ivocap system, and (III) original microwave system.

**PROCEDURES**

**Denture fabrication—New polymerization system (I)**

1. Attach a sprue to each of the 15 trial dentures in this group.
2. Use conventional dental laboratory procedures to flask each trial denture using the double-pour procedure.
3. After the stone has set, heat the flask in boiling water, open it and flush out the wax.
4. Allow the flask to cool to room temperature.
5. Coat the stone in each section with irreversible hydrocolloid separating medium.
6. Place the upper half of the flask that contains the denture teeth in the bottom part of the oven set at 55°C (131°F) and the lower half of the flask containing the cast in the top part of the control unit set at 98°C (208.4°F) (Fig. 1).
7. Allow the flasks to remain in the computer-controlled oven (Okamoto Dental Corp, Shiga, Japan) until the inside of the flask halves reach 55°C (131°F) and 98°C (208.4°F), respectively.
8. Mix the resin and allow enough time for the resin to reach the injectable state before removing the flasks from the oven. Use DS resin (Okamoto Dental Corp) precisely proportioned to a ratio of 2.8 polymer:1 monomer by weight.
9. When the flasks are heated and the mix is ready to pack, rapidly remove the flasks from the oven and bolt the halves together. Immediately attach the automatic injector.
10. Inject the resin mix into the mold space of the denture at the rate of 120 g/min and hold the resin under a pressure of 3.5 MPa (Fig. 2).
11. Allow the pressure to remain on the resin for 5 minutes, then disconnect the flask from the injector, and permit the flask to bench cool for 1 hour.

12. Open the flask and recover the denture.

**Denture fabrication—SR-Ivocap system (II)**

The 15 trial dentures made by this system were made into resin dentures by following the manufacturer’s directions exactly. A capsule that contained the recommended Ivocap resin (Ivoclar North America, Inc, Amherst, N.Y.) was used, and the ratio was 20 g of powder:30 mL of liquid.

**Denture fabrication—Original microwave method (III)**

Fifteen trial dentures were invested in a fiber-reinforced polyester (FRP) flask (GC Dental Industrial Corp, Tokyo, Japan). Conventional dental laboratory procedures were followed to invest, boil out, coat the stone with irreversible hydrocolloid separating material, and pack the resin. The mixture of microwaveable resin (MC resin, GC Corp) was proportioned 2.5 polymer:1 monomer by weight.

After the resin was packed, the flask was placed on its base on the turn table in a microwave oven (RE-Z2, Sharp Corp, Osaka, Japan) that was set at 500 W and irradiated for 1.5 minutes. The flask was then placed on its top and irradiated for another 1.5 minutes. The flask was allowed to cool to room temperature before recovering the cast and denture.

As each polymerized denture was recovered, it was kept on its respective cast and sectioned parallel to its posterior border through the center of the mesial-distal width of the second molars (Fig. 3). The machine used for the sectioning was a low-speed cutter (U-32, Luxo Corp, Tokyo, Japan).

**Discrepancy measurement**

Discrepancy between the denture base and the stone cast, as viewed from the distal of the cross section, was measured with a reading microscope (0.001, Nikon Corp). The points measured were at the right and left denture borders, the crest of the residual ridge on the right and left, and the midline of the palate (Fig. 3). Measurements were made immediately after sectioning and after immersion in water at 37°C (98.6°F) for 30 days.

**Water adsorption and hardness**

Resin disks 60 mm in diameter and 2 mm thick were made for use in water adsorption and hardness tests. Fifteen disks were made, and 5 disks of each resin were processed by the 3 polymerizing systems used for the matching denture bases. Flash was removed from each disk as it was recovered from the investment. To determine the amount of water absorbed during polymerization (A), disks were weighed immediately after removing the flash. To determine the amount of water absorbed after being desiccated then immersed for 30 days in room temperature water (B), disks were removed from the water and dried with the judicious use of blown air, then weighed.
The following formulas were used:

\[ A = \frac{(W_1 - W_2)}{W_2} \times 100 \text{ (％)} \]

\[ B = \frac{(W_3 - W_2)}{W_2} \times 100 \text{ (％)} \]

where \( W_1 \) is the weight of the disk immediately after removal of the flash; \( W_2 \) is the weight of the disk after being desiccated at 50°C for 30 days, and \( W_3 \) is the weight of the desiccated disk after being immersed in water for 30 days. Disks were weighed on an electric balance accurate to 0.1 mg (AEX-200G, Shimadzu Corp, Tokyo, Japan).

The Knoop hardness number was determined on the same disks immediately after being weighed in the water immersion test. The hardness tester was loaded with a 25 g weight (Akashi Corp, Tokyo, Japan). Statistical analyses of the discrepancy measurements and the hardness numbers were accomplished by split-plot or 2-way analysis of variance (ANOVA) procedure. Scheffe’s F-test was used for all post hoc pairwise comparisons at the 95% confidence level.

Glass transition temperature (Tg) of DS resin

The glass transition temperature (Tg) was determined only for the DS resin that was used for the new polymerization system. However, the DS resin was packed and polymerized in a water bath and this was done to compare the Tg of the water-processed DS resin to the DS resin that had been polymerized in the new system at an earlier time.

Glass transition temperature procedure

1. Make 2 disks 30 mm in diameter and 2 mm thick using the DS resin and conventional dental laboratory procedures in a water bath at 75°C (167°F) for 24 hours.

2. Recover and trim the disks. Place 1 disk in a desiccator at 50°C (122°F) to dry for 30 days.

3. Use a Differential Scanning Calorimetry (DSC) instrument (Thermoflex, Rigaku, Tokyo, Japan) to draw the curves. Use the heating rate of 10°C/min with pure aluminum oxide (Al₂O₃) as a standard.
4. Draw a tangent to each side of the first peak on each tracing to establish the reading point where the 2 lines cross, 105°C (221°F) before drying and 115°C (239°F) after drying (Fig. 4).

5. The same procedure was used on 2 disks of the same size made following the system I procedure and the results yielded the same numbers.

RESULTS

Discrepancies between the stone casts and denture bases made with the 3 polymerization systems, measured at the denture borders, residual ridges, and midline, reveal that the new polymerization system (I) had smaller discrepancies than either system II or III (Tables I and II). The mean of the discrepancies for system I after polymerization was 0.10 mm at the borders, 0.10 mm at the residual ridges, and 0.11 mm at the midline. Mean discrepancies at the borders, residual ridges, and midline for system II were 0.16 mm, 0.18 mm, and 0.21 mm, respectively; and were 0.27 mm, 0.25 mm, and 0.28, respectively, for system III. Significant differences were detected among the 3 systems at each measurement location (P < 0.0001). At 30 days of immersion in water, the dentures processed with systems I and III had small discrepancies (between 5% and 10% and 4% and 31% respectively) when compared with the before immersion discrepancies. System II exhibited large discrepancies of 40% and 110% compared with its pre-immersion discrepancies. The interaction of the polymerization method and the measurement condition was also significant at each measurement location (P < 0.0001 or P = 0.0063).

In a preparatory experiment, the temperature of 98°C was selected because it was the highest tempera-

<table>
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<th>Measurement location</th>
<th>Variable</th>
<th>Sum of squares</th>
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Tested with 2-way ANOVA.

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<td>Mean (%)</td>
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<td>After water immersion</td>
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<td>After water immersion</td>
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<td>After water immersion</td>
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Resin disks made using system I showed less water absorption and were harder than disks made using systems II and III when measured immediately after polymerization and after immersion in water for 30 days (Tables III and IV). The interaction of the polymerization method and the measurement condition was significant on water absorption and hardness (P < 0.001 and P = 0.0022). Figure 4 illustrates the DSC tracings of 2 disks processed in a water bath. One was dried in a desiccator for 30 days and the other disk was polymerized.

DISCUSSION

Dentures fabricated with system I exhibited better adaptability to the casts than those made with systems II and III (Table I). This is attributed to differences in the mechanism of polymerization inherent in the 3 systems. In system I, the resin dough was injected into the mold space that is heated to 2 temperatures. The section of the oven holding the cast was heated to 98°C (208.4°F) and the section holding the denture teeth was heated to 55°C (131°F) (Fig. 1). Polymerization began uniformly from the mucosal surface of the dried stone cast, which was at the higher temperature of 98°C (208.4°F) (Fig. 5, a). Because the sprue is in the cooler part of the mold at 55°C (131°F), the polymerization shrinkage is largely compensated for by the resin dough being fed from the sprue that is the last to harden.

In a preparatory experiment, the temperature of 98°C was selected because it was the highest tempera-
ture that would not damage the stone casts and, in combination with the 55°C temperature, would accomplish a complete polymerization reaction with better adaptation of the resin to the cast.

Almost all conventional polymerization processes, including the SR-Ivocap and microwave polymerization systems, are accomplished by heating the flask after the resin dough is packed or injected into the mold space (Fig. 5, c). Thus, polymerization is locally initiated in the resin dough at different times because the temperature of the mold and resin dough is elevated by thermal conduction. Furthermore, a denture has a complicated shape with thin and thick sections, so the conventional methods cannot always produce dentures that fit the mucosal surface of the cast more precisely. The SR-Ivocap system (II) of rapid heating at 100°C (212°F), followed by quenching in water and an excess of monomer (20 g powder:30 mL liquid) will also damage the adaptability of the denture base. Jackson et al1 reported no difference in adaptation between system II and conventional processes.

A system suggested by Craig17 uses conventional packing procedures for the resin dough, followed by heating the flask from the underside by using an electrically heated hot plate. However, this method allows the resin dough to reach the polymerization-initiating temperature locally but at different times (Fig. 5, b).17 Thus, the method fails to produce dentures that fit the cast significantly better than the other conventional polymerizing systems.

Resin disks made by the new polymerization system (I) exhibited the least water absorption (Table III). The small amount of free water in the heated stone cast resulted in a decrease in water absorption during polymerization. The large amount of water absorption during polymerization in system II is believed to be due to the presence of excess of free water in the mold. The medium amount of water absorption in system III, the microwave procedure, is most certainly because of the short polymerization time (3 minutes) that prevented water absorption. As heating time increased, the amount of water absorption tended to increase and resulted in a reduction in the hardness of resin (Table III). Furthermore, the more water there was in the resin, the greater the decrease in the glass transition temperature (Tg) (Fig. 4). This finding indicates that the water acts as a plasticizer when absorbed in the resin during polymerization or immersion in water. In addition, the presence of free water in the stone cast inhibits the polymerization of the monomer. The smaller amount of water in the denture base results in a harder resin and may actually decrease the absorption of odor or color change of dentures in clinical use.

CONCLUSIONS

Analysis of 3 polymerization systems for making complete dentures demonstrated that dentures fabricated with the new polymerization system (system I) adapted more closely to the cast than those made with systems II and III. In addition, resin disks made with system I exhibited less water absorption and were harder than disks made with systems II and III when measured immediately after polymerization and after immersion in water for 30 days. This can be explained by the unique features of the new polymerization system (I) in which the resin dough is injected into a heated dried flask, the 2 parts of which are at different temperatures, followed by immediate initiating polymerization.

REFERENCES


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