Innovative Gas Injection Technique for Closed-Hollow Obturator

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Purpose: The purpose of this study was to determine the proper prerequisite conditions for gas injection and the steps for applying gas injection for obturator fabrication. ***Materials and Methods:*** Optimal prerequisite conditions were investigated by using thermocoupling to verify exothermic changes in the resin during polymerization. Three experimental groups were designated: in the control group (C), resin was packed into the mold without argon gas injection; in the gas injection group (GI), after resin packing, gas was injected into the resin bulb in the mold; and in the plunger/gas injection group (PGI), after resin packing, the syringe plunger was drawn out before gas injection. ***Results:*** The 55°C mold temperature and addition of 0.3% DMPT to the monomer liquid caused differences in exothermic temperature increase in various parts of the resin. Without gas injection and plunger drawing, porosity was observed in the thick bulbs of groups C and PGI. In group PGI, a balloon-like elliptic hollow was observed. Compared to group C, the weight reduction in group PGI was approximately 10%. ***Conclusion:*** Proper mold temperature with secondary venting and the addition of DMPT were required before the injection of gas. The resulting prosthesis could be fabricated in one step and required no resin seal. *Int J Prosthodont 2004;17:345–349.*

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The effectiveness of an obturator depends greatly on the quality of the remaining teeth and oral structures. The weight of the obturator should be minimal; a hollow prosthesis is lighter than a solid prosthesis of equal size. Although open-hollow obturators are more common than closed-hollow obturators, difficulty in laboratory polishing and the need for frequent cleaning of the bulb's internal surface are disadvantages of this type of obturator.[1,2] In addition, patient complaints of food, fluid, and mucous accumulation in the hollow part of the open type, resulting in bad odors and altered taste sensation, have been noted. The placement of a vent to drain accumulated fluid from the hollow section and the conversion of the open type to the closed-hollow type of obturator are solutions.[2–4] A closed-hollow obturator prevents the accumulation of oral fluid. For patients requiring a combination of intra- and extraoral prostheses, a closed-hollow obturator allows the attachment of extra- to intraoral prostheses for additional retention and stability.[1–3]

The force acting on an obturator is complex (eg, vertical dislodging, rotational, lateral forces), and the important objective of prosthodontic care is to preserve the

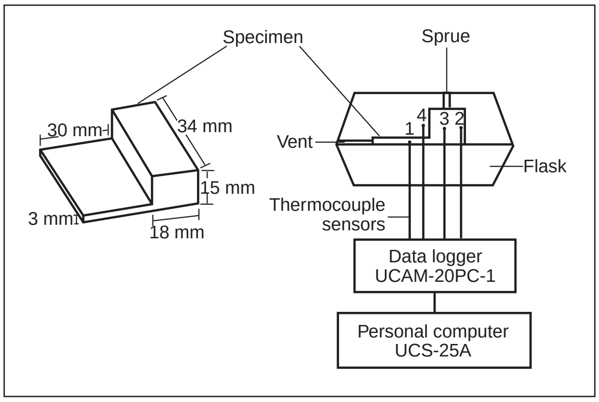

Fig 1 Specimen shape and thermocouple apparatus setup. Sensor positions: *1* = thin resin; *2* = peripheral area of bulb; *3* = bulb center; *4* = stone, 3 mm from bulb surface.

remaining structures.[5] A study on vibration analysis investigated the dynamic behavior of each component of solid, open-, and closed-hollow types.[6] All obturators move in response to excitation force; however, the displacement of the closed-hollow type is smaller and disappears rapidly. Therefore, the hollow type is suggested to transmit the least stress to the remaining abutment teeth. Moreover, hollow complete denture and hollow palatal augmentation prostheses reduce weight.[7,8]

Generally, closed-hollow obturators are separately processed in two or three parts and attached together by the use of chemically or light-polymerized resin.[3,9–12] Oral fluids could be absorbed, via porosities in the resin seal, into the inner hollow space.[4,13] Nevertheless, with a good watertight seal between obturator lid and bulb, no leakage is detected even when obturators are immersed in water for 4 weeks and/or submerged in water at 30 psi for 1 hour.[14]

To initiate uniform polymerization of acrylic resin at the mucosal surface of the heated stone cast, lower and upper halves of flasks were heated to 98°C and 55°C, respectively.[15] To compensate for polymerization shrinkage, heating of the stone mold and addition of N,N-dimethyl-p-toluidine (DMPT) in methyl methacrylate monomer (MMA), combined with the injection of argon gas, were used to fabricate a complete denture.[16] It is of interest whether this gas injection concept can be applied to the fabrication of hollow resin obturators. Heat from the mold and DMPT will hasten the polymerization propagation of resin upon contact with the mold surface. If gas injection is performed when the outer resin has hardened and the inner resin is still soft, the gas bubble will expand like a balloon inside the obturator bulb. It appears feasible to fabricate a closed-hollow obturator in one step. However, one should bear in mind that after the resin packing step, it is likely to be difficult for any space-consuming gas to expand because the mold space is fully occupied.

The aim of the present study was to fabricate a closed-hollow obturator in one step by gas injection. The hypothesis was that proper heating of the mold surface and a certain DMPT concentration would create a hard outer resin wall and soft inner resin; the preparation of an additional vent to release excess resin during gas injection would facilitate expansion of gas.

Materials and Methods

Polymer Powder and Monomer Liquid

Acrycon (Mitsubishi Rayon), a polymethyl methacrylate (PMMA) powder, was used as the raw material. Experimental powder (PEX) was prepared by heating Acrycon at 70°C in a dry-heat oven for 4 consecutive days to eliminate any benzoyl peroxide (BPO) remaining from manufacturing. Later, BPO (Nacalai Tesque) was added to the PEX to achieve 0.25 wt%. Three experimental monomer liquids (MEX) were prepared by adding DMPT at 0.0 wt%, 0.1 wt%, and 0.3 wt% to MMA monomer (Kanto Chemical).

Effect of Mold Temperature and DMPT on Temperature Changes in Resin

Thermocoupling was used to investigate temperature changes in various parts of the resin. Thermocouple sensors (TC/K type, Kyowa) were embedded in the master specimen during investment (Fig 1). After wax elimination, three flasks attached to the thermocouple sensors were heated to 55°C in a dry-heat oven. PEX and MEX were mixed in a powder:liquid ratio of 2.25:1.00 by weight. Two minutes before the beginning of resin packing, the thermocouple sensors were connected to a data logger (UCAM-20PC-1, Kyowa). The internal mold temperature was measured and monitored for 30 minutes from the start of resin packing. Investigation conditions were:

1. No flask heating and no DMPT in the MMA liquid (NH/ND)
2. No flask heating, with the addition of 0.3% DMPT in the MMA liquid (NH/0.3D)
3. 55°C flask heating, with no DMPT (H/ND)
4. 55°C flask heating, with 0.1% DMPT (H/0.1D)
5. 55°C flask heating, with 0.3% DMPT (H/0.3D)

The optimal combination of flask temperature and DMPT concentration that would induce different temperature change patterns in each part of the resin was chosen for the later experiment. This time difference indirectly implied differences in the polymerization propagation speed of the resin.

Fabrication of Closed-Hollow Obturator by Gas Injection

To simplify measurements of the obturators' size and weight, a polyvinyl siloxane master specimen was designed (Fig 1) and invested in an injection flask (Poly-Base IJ flask, Nissin). The flask's shape was modified to create a base for a syringe attachment. Before investing the upper half of the flask, an injection syringe with a modified shape, sprue, and vent was attached to the specimen (Fig 2).

After wax elimination, the flasks were heated to 55°C in a dry-heat oven. PEX and MEX (with 0.3% DMPT) manipulation was similar to that mentioned above. When the mixture reached the late fibrous stage, it was injected into the heated flask using a Preniton injection machine (Nissin) under a pressure of 20 kgf/cm^2. The syringe plunger's position was fixed at the zero point until the completion of resin injection. Three different conditions were applied:

- Group C (control): The flask was heated in 70°C water for 90 minutes and 100°C water for 30 minutes.
- Group GI (gas injection): Three minutes after resin packing, argon gas was injected into the bulb part via the inlet sprue under controlled pressure and volume.
- Group PGI (plunger and gas injection): The syringe plunger was drawn out to a designated distance. Three minutes after resin packing, argon gas was injected under controlled pressure and volume.

Group GI and PGI specimens were polymerized in the same manner as group C specimens. Three specimens were made for each group. Specimens' weight and appearance were examined. In addition, group PGI specimens were measured for hollow-space volume and cross-sectioned to enable examination of the bulb's internal portion.

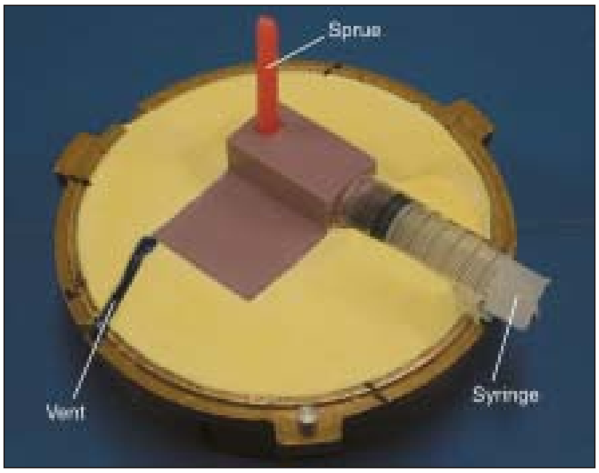

Fig 2 Lower flask investment is ground to create a base for syringe attachment.

Results

Effect of Mold Temperature and DMPT on Temperature Changes in Resin

Without mold preheating, no temperature change was observed during 30 minutes both with and without DMPT (Fig 3). In the H/ND group, temperature changes were immediately observed after resin injection. This alteration in temperature was caused by the contact of the room-temperature resin mixture with the 55°C thermocouple sensors. However, 6 to 7 minutes later, temperatures in all parts of the resin reached the same level. Under the H/0.1D condition (Fig 4), differences in temperature increase of the investigated areas were noticeable; however, the temperature peaks of the bulb periphery and bulb center were almost simultaneous. Under the H/0.3D condition, the thermal increases in three parts of the resin took place at different rates. The thin part of the resin reached its exothermic peak first (220 seconds), followed by the resin in the bulb periphery (300 seconds) and the resin in the bulb center (383 seconds). When the bulb center resin emitted exothermic heat, the temperature of the stone increased in parallel because of heat transmission.

Fabrication of Closed-Hollow Obturator by Gas Injection

In group C, an aggregation of small voids in the resin bulb center could be seen (Fig 5). After filling the mold cavity with resin, there was no space left inside the mold. Without plunger drawing before gas injection (group GI), injected gas penetrated into the resin mass and formed small voids inside the bulb. With plunger drawing and gas injection (group PGI), the gas balloon was able to expand in the resin bulb in an elliptic shape. A cross-section of the elliptic balloon revealed a hard internal surface with a slightly rough appearance but no pores. No unpolymerized layer was observed at the balloon's internal surface. The mean volume of the hollow space was 1.6 ± 0.1 mL. The mean weights of group C, GI, and PGI specimens were 15.5 g, 15.4 g, and 13.9 g, respectively. The PGI specimens were 9.6% lighter than those of group C.

Discussion

Although closed-hollow obturators have many advantages over open and solid ones, they require two to three fabrication steps and the sealing of each obturator section. The present study shows that it is possible to apply a gas injection technique to fabricate a closed-hollow obturator in one step.

Since decomposition of BPO occurs rapidly between 50 and 100°C,[17,18] heated mold surfaces, combined with the presence of DMPT in MEX, had a strong influence on the

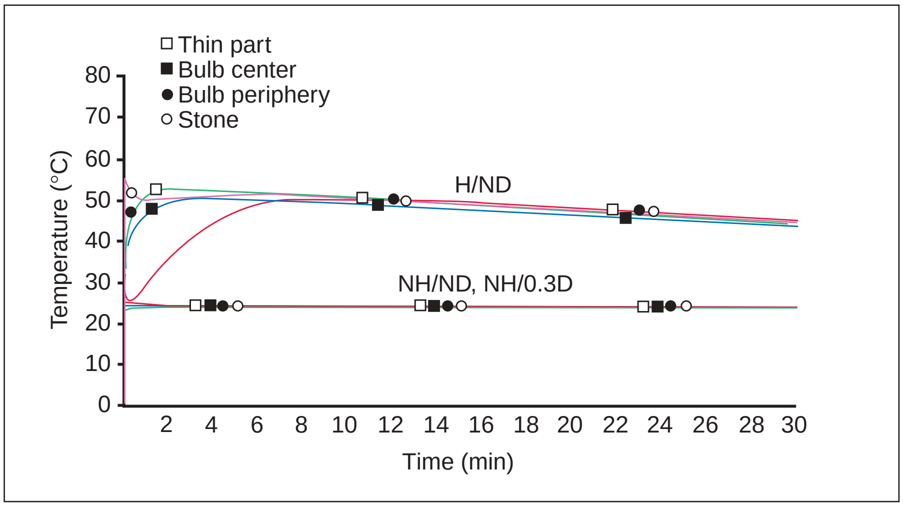

Fig 3 Except for the first 6 minutes in group H/ND (see Materials and Methods for abbreviations), no temperature changes are found in any parts of the resin in the three groups.

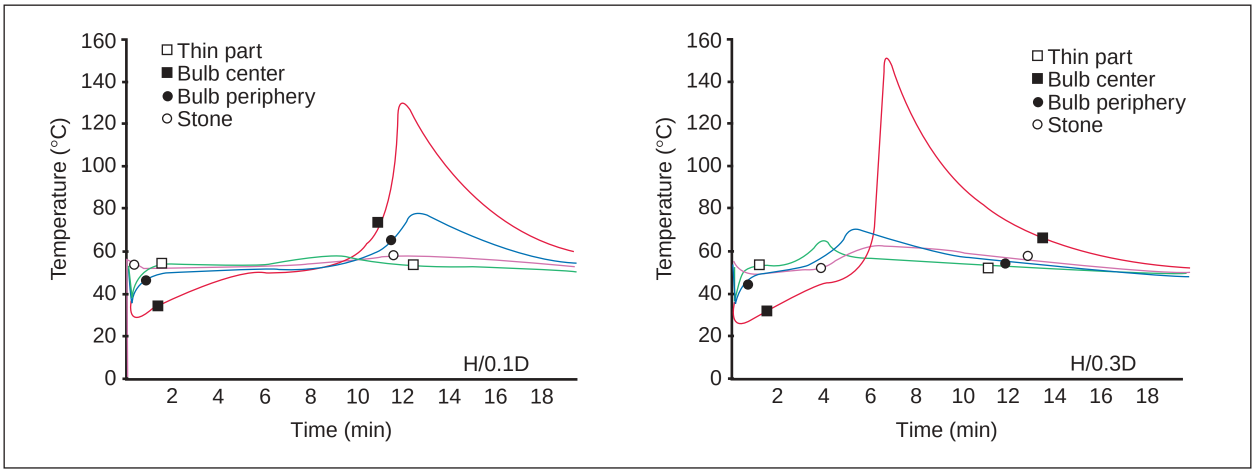

Fig 4 In group H/0.1D (see Materials and Methods for abbreviations), resin at the bulb periphery and center reaches exothermic peaks at almost the same time. In H/0.3D, peripheral bulb resin reaches its exothermic peak before the bulb center.

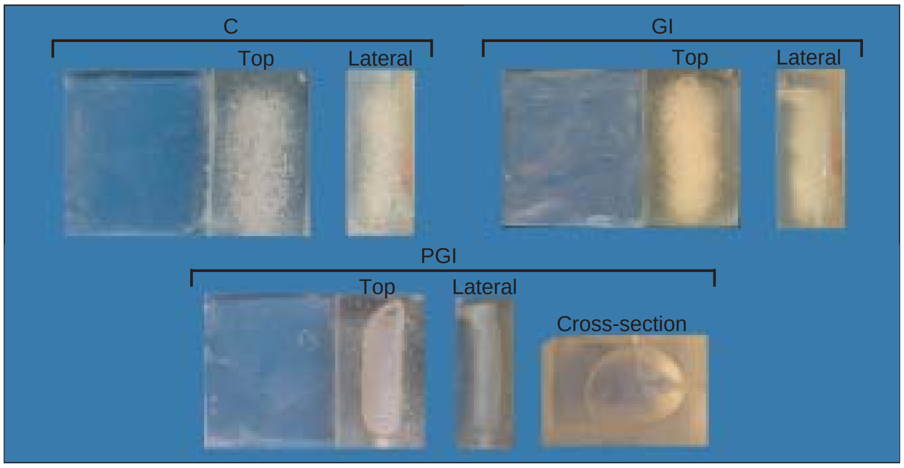

Fig 5 *Top row:* porosity in bulbs of groups C and GI. *Bottom row:* hollow space in the center of bulb and cross-sectional appearance in group PGI (see Materials and Methods for abbreviations).

polymerization reaction of acrylic resin, as did the timing of gas injection. Under the H/0.3D condition, decomposition of BPO created differences in the speed of the polymerization progress in various parts of the resin, resulting in clearly observable differences between the timing of the exothermic peak of resin at the bulb periphery and in the internal parts.

After the resin mixture flowed into the heated mold, the resin in contact with the heated stone surface further polymerized and hardened. At 2.5 minutes after resin injection, we opened the flask to test resin softness. Resin at the bulb periphery showed a hard surface, whereas the resin in the inner part retained a soft, dough-like consistency. The later the start of gas injection, the harder the outer resin wall was. However, the balance between outer wall hardness and inner resin flowability was the crucial issue in determining the timing of gas injection.

Processing thick resin specimens under a long polymerizing cycle at 74°C has been suggested.[19,20] When MMA liquid containing more than 0.1% DMPT was used, porosities were found in the resin specimens in spite of the long polymerizing cycle.[20] In the present study, 0.3% DMPT was added to the MMA monomer to induce differences in the polymerization speed in the resin. The rate of polymerization at the thick part of the resin bulb was too high. Exothermic heat could not be dissipated quickly enough, thus inducing monomer boiling and leading to porosity. The porosities in the specimens can be related to excessive polymerization rate (groups C and GI) as well as the injected gas (group GI).

The need for a secondary vent was clearly shown in group PGI. Because the secondary mold vent created by drawing out the syringe plunger functioned as a drain for the soft inner resin, the gas was able to expand in the resin bulb, creating an egg-like hollow and decreasing the amount of voids inside the bulb part. As the presence of oxygen would retard or inhibit resin polymerization,[21] argon gas or other inert gases are recommended.

Using this technique, a closed-hollow obturator can be fabricated in one polymerizing cycle, requiring no additional acrylic resin to assemble the obturator parts. The technique is also expected to be applicable to silicone elastomers, which are widely used in fabrication of maxillofacial prostheses, because of the similar polymerization process. Because of the limited size of the Poly-Base IJ flask, the specimens in the present study were relatively small compared to obturators commonly found in a clinic. Attempts to improve this technique and apply it to the fabrication of other types of prostheses are ongoing.

Conclusions

The following conclusions can be drawn from this investigation:

1. A mold temperature of 55°C and 0.3% DMPT concentration are essential prior to gas injection.
2. A secondary mold space must be created before gas injection. This can be achieved by withdrawing the syringe plunger.

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