Dimensional stability of compression and injection molding denture bases in long and short curing procedures

Noppavan Nagaviroj, Krantarat Wanitchanont, Widchaya Kanchanavasita, Amornrat Wonglamsam

Department of Prosthodontics, Faculty of Dentistry, Mahidol University, Bangkok, Thailand

Abstract

Objectives: To compare the linear dimensional change of compression molding (Probase Hot and SR Triplex Hot) and injection molding (SR Ivocap High Impact) denture base materials subjected to long and short curing procedures.

Materials and methods: Six disc-shaped specimens (40 mm in diameter, 3 mm in thickness) of each material were polymerized in long and short curing procedures according to manufacturer's instructions. The dimensional change of the disc was measured in two perpendicular directions immediately after processing, 24 hours and 48 hours after processing using a measuring microscope. Statistical analyses were performed by three-way ANOVA (α=0.05) and simple effects analysis because of the interaction among 3 independent variables (materials, curing procedures and time after processing).

Results: There was a significant difference in dimensional change among materials. The dimensional change of SR Ivocap High Impact was the least, especially with the long curing procedure ($p<0.05$). Significantly less dimensional change occurred when SR Ivocap High Impact was cured in a longer period of time (0.02-0.023%). The dimensional change of compression molding (Probase Hot and SR Triplex Hot) occurred more at 48 hours after processing (0.05-0.13%) than at 24 hours after processing (0.03-0.05%).

Conclusions: Dimensional change of the injection molding material after processing was less than the compression molding material. The curing procedures had an effect on the dimensional accuracy of the injection molding material, i.e. long curing procedure provided less dimensional change.

Keywords: dimensional stability, denture base materials, compression molding, injection molding, polymerization shrinkage

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Corresponding author:
Noppavan Nagaviroj
Department of Prothodontics,
Faculty of dentistry, Mahidol University
6 Yothi Street, Rajthevi.
Bangkok, 10400, Thailand.

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Introduction

Most of denture bases are fabricated from acrylic resins, which have been used in dentistry and mostly used in prosthodontics, especially for removable prostheses such as complete denture or partial denture.[1] Acrylic resins and their curing methods have been developed and used for fabricating denture bases in a variety of ways.[2]

There are many advantages of using acrylic resins to construct a denture such as their acceptable color appearance which matches the oral soft tissue, adequate strength and ease of repair.[1-2]

The proper fabrication process is important for achieving optimum properties of the material resulting in the favorable prostheses. A dimensional stability is the special concern in the mechanical properties[3] which provides the well-fitting denture base that adapts to the palate and produces the border seal to the peripheral tissue. This can improve the patient satisfaction.[1]

Despite the several processing methods attempting to decrease the polymerization shrinkage, the inaccuracies of a denture base material including dimensional change can happen during and after processing.[1,3]

When fabricating maxillary complete dentures from acrylic resin, polymerization shrinkage can occur depending on the material properties and processing techniques. The posterior palatal gap may not be sealed and the vertical dimension may be changed, as a result of the dimensional change. This condition can lead to an inaccurate fit of supporting structure, poor retention, and inadequate occlusal function.[4]

To decrease the dimensional change from polymerization shrinkage in the compression molding technique, the injecting molding technique has been developed. By using this technique, the unpolymerized acrylic resin can be controlled to a specific molding design which helps compensate a polymerization shrinkage. Anderson et al.[5] reported that the injection molding could improve dimensional stability when compared to the compression molding techniques. Due to the popularity of the injection molding technique, many manufacturers have provided an acrylic resin using this technique.

In a denture construction process, we commonly use the conventional curing technique which is divided into two methods, short and long curing methods. The differences between the two methods are the boiling temperature and curing duration which may affect the properties of the denture. The long curing method produces the most dimensionally stable denture while the short curing method produces quick, cheap and less energy consumption procedure.[1-3] The purpose of this study was to compare the dimensional stability of acrylic resin using different processing techniques and polymerization cycle.

Materials and methods

Three brands of commercial denture base materials were selected: Probase Hot and SR Triplex Hot (compression molding) and SR Ivocap High Impact (injection molding) (Table 1).

Circular stainless steel mold (40 mm in diameter and 3 mm in thickness; with 1 mm in depth of two crossing triangular grooves at the bottom of the mold) was used to fabricate specimens. The two grooves created two crossing projections, with two reference points 30 mm apart, in the cured specimens (Figure 1 and Figure 2). The molds were invested in the Hanau flasks (Figure 3) and flasked for injection molding techniques (Figure 4) using dental stone type III. Six specimens were prepared from six separate mixes for each group. The compression and injection process of the specimens, using long curing method and short curing method, were carried out following the manufacturers' instruction of each material (Table 2).

Table 1 Composition of commercial denture base materials

Brand of denture base materials	Powder	Monomer
ProBase HOT	-Polymethyl methacrylate > 95% -Dibenzoyl peroxide ≤ 2.5% -Softening agent -Pigments	-Methyl methacrylate 25-100% -Ethylene dimethacrylate 1-<10% -Catalyst
SR Triplex Hot	-Polymethyl methacrylate > 95% -Benzoyl peroxide 0.5 - 1.5 % -Pigments and catalysts	-Methyl methacrylate 50-100% -Ethylene dimethacrylate 3-<10%
SR Ivocap High Impact	-Polymethyl methacrylate -Dibenzoyl peroxide -Copolymer and pigments -Pigments	-Methyl methacrylate 50-100% -Ethylene dimethacrylate 3-<10% -Copolymer

Figure 1 Circular stainless mold. (40 mm in diameter, 3 mm in thickness with 2 crossing triangular grooves)

Figure 2 The specimen after removal from the mold showing two crossing triangular projections with reference points

Figure 3 Circular stainless steel mold invested in Hanau flask

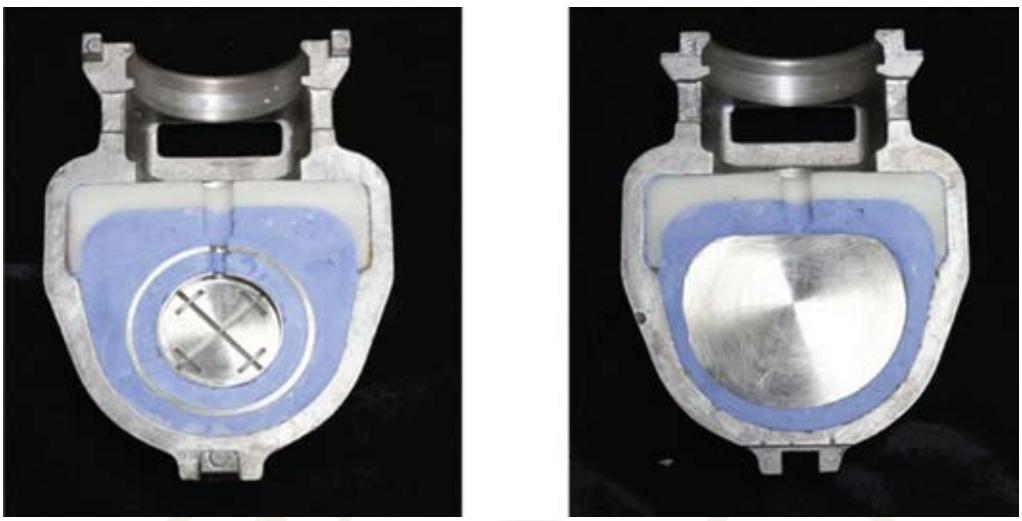

Figure 4 Circular stainless steel mold invested in flask for injection molding techniques

Table 2 Curing methods according to the manufacturer's sheet.

Brand	Processing Procedure	P:L Ratio (g:ml)	Mixing time	Working time	Curing Procedure	Curing method according to manufacturer's sheet
Probase Hot (long-cured)	Heat-cured compression molding	22.5:10	10 min	20 min	Long	Heat-polymerization in cold water, heat up to 100 °C and let boil for 45 min.
					Short	Heat-polymerization in boiling water 100 °C for 40 min.
SR Triplex Hot (long-cured)	Heat-cured compression molding	23.4:10	10 min	20 min	Long	Heat-polymerization in cold water, heat up to 100 °C and let boil for 45 min.
					Short	Heat-polymerization in boiling water 100 °C for 20 min.
SR Ivocap (long-cured)	Heat-cured injection molding	20:30	5 min	10 min	Long	Using the Ivocap flask starts to boil for 90 min. during entire polymerization
					Short	Using the Ivocap flask starts to boil for 35 min. during entire polymerization

The linear dimensional change of the specimens was determined by the changes in the distance between the reference points. The measurements were made after deflasking, and at 24 hours and at 48 hours using a measuring microscope.

The normality test of the data was carried out using the Shapiro-Wilk test, while the test for homogeneity of variances was carried out using Levene's test in SPSS for Windows (version 16). The percentage linear dimensional changes were analyzed by three-way analysis of variances (ANOVA), the 3 independent variables were material brand, processing time and time after processing. The simple effects analysis was used when there was an interaction among these. All statistical tests were performed at α=0.05.

Results

The mean values and standard deviations of the percentage linear dimensional changes are shown in Table 3. From three-way ANOVA (Table 4), a significant interaction between materials and curing procedures, as well as, between materials and times were observed.

Table 3 Mean and standard deviation of percentage linear dimensional changes after 24 and 48 hours from the initial distance (n=12)

Materials	Curing procedures	% Linear Dimensional Changes at times after processing Mean±SD	
		24 hours	48 hours
Probase Hot	Long	-0.030±0.005	-0.051±0.006
	Short	-0.030±0.005	-0.052±0.003
SR Triplex Hot	Long	-0.052±0.007	-0.131±0.009
	Short	-0.050±0.005	-0.133±0.010
SR Ivocap High Impact	Long	-0.020±0.003	-0.023±0.002
	Short	-0.037±0.004	-0.047±0.003

Table 4 Tests of between Subjects Effects (three-way ANOVA)

Source	Type III Sum of Squares	df	Mean Square	F	p-value
Materials	.098	2	.049	1.434E3	<.05
Curing procedure	.002	1	.002	49.929	<.05
Time	.048	1	.048	1.389E3	<.05
Materials * curing procedure	.003	2	.002	46.088	<.05
materials * time	.037	2	.019	547.324	<.05
Curing procedure * time	.000	1	.000	3.536	.062
materials * curing procedure * time	5.704E-5	2	2.852E-5	.834	.437

*Statistical significance at α = 0.05

The percentage linear dimensional changes in all materials were statistically significant difference in both curing procedures and times.

Linear dimensional changes of SR Triplex Hot showed the highest value in both long and short curing procedures at 24 and 48 hours after processing, while SR Ivocap High Impact showed the lowest value of linear dimensional changes. Significantly less dimensional changes occurred when SR Ivocap High Impact was cured longer (Figure 5 and Figure 6).

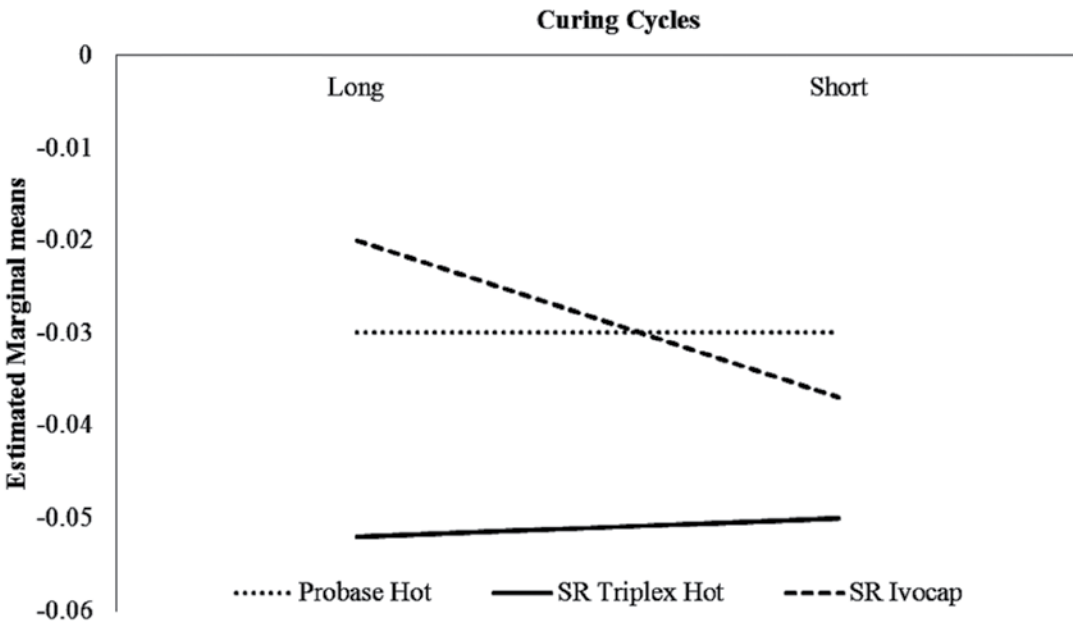

Figure 5 Estimated marginal means of linear dimensional changes of the three materials between long and short curing procedures at 24 hours after processing

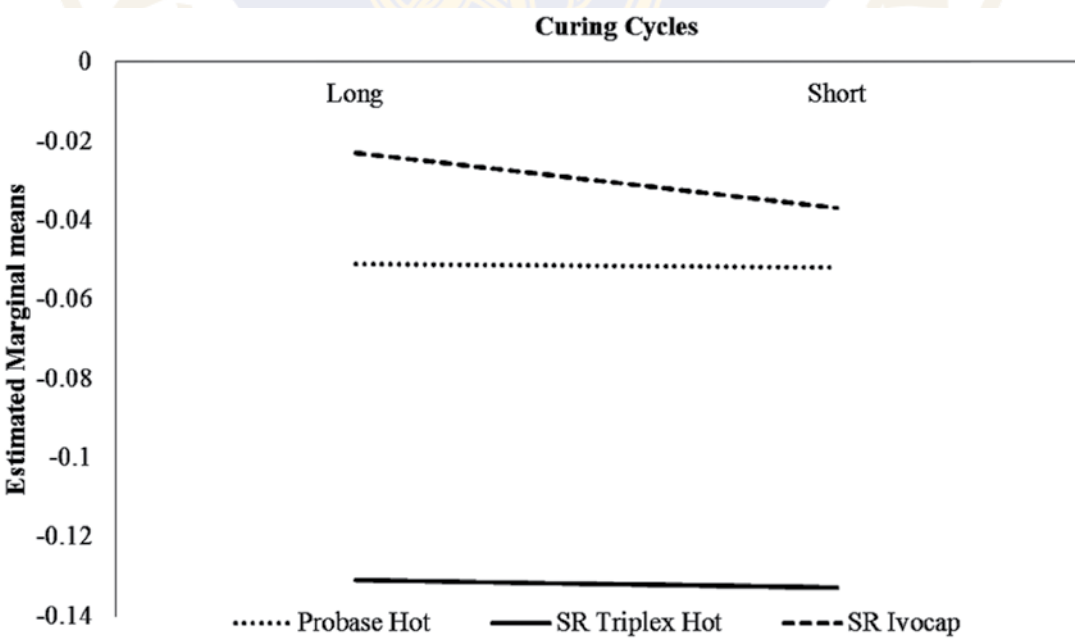

Figure 6 Estimated marginal means of linear dimensional changes of the three materials between long and short curing procedures at 48 hours after processing

Linear dimensional changes of Probase Hot and SR Triplex Hot demonstrated statistically significant difference between 24 hours from initial distance and 48 hours from initial distance in both curing procedures. Only SR Ivocap cured by short curing procedures showed statistically significant difference between 24 hours from initial distance and 48 hours from initial distance. SR Ivocap High Impact cured by long curing procedures did not show any differences between 24 and 48 hours from initial distances (Figure 7 and Figure 8).

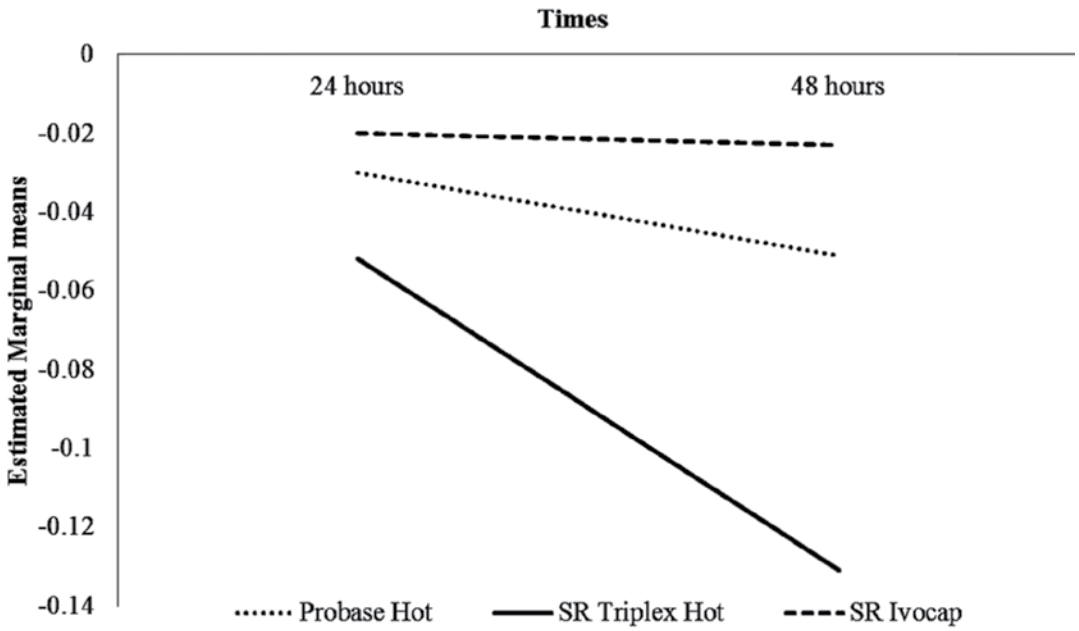

Figure 7 Estimated marginal means of linear dimensional changes of the three materials in long curing procedure between 24 and 48 hours after processing

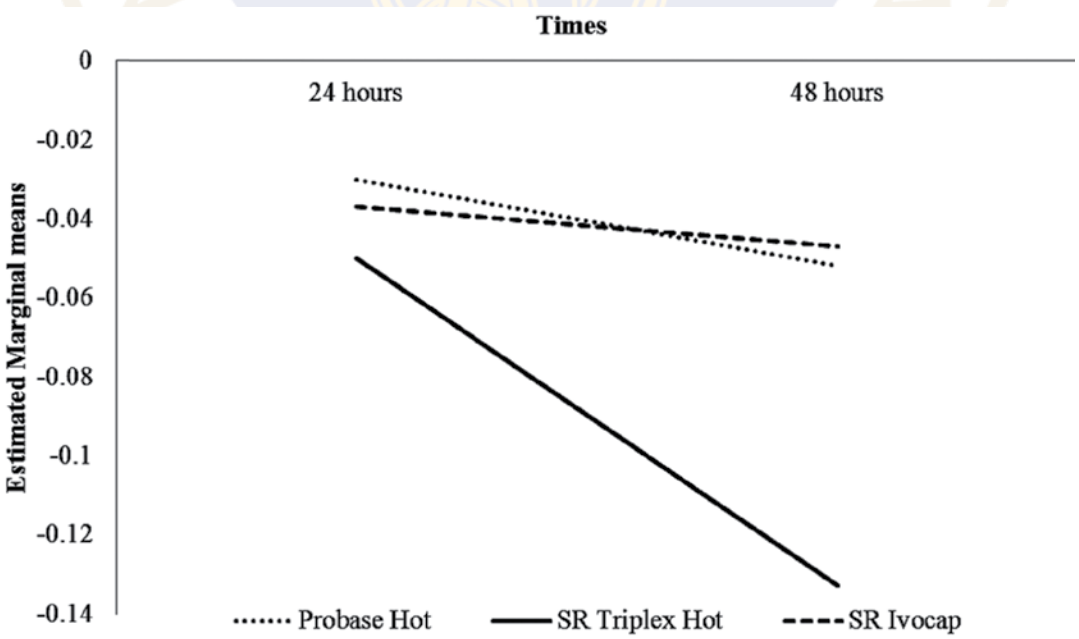

Figure 8 Estimated marginal means of linear dimensional changes of the three materials in short curing procedure between 24 and 48 hours after processing

Discussion

The dimensional change of an acrylic denture base material can be examined using various methods, such as measuring vertical dimension, measuring pin point opening in articulator and measuring linear dimensional change. In this experiment, the stainless steel mold directly invested in the flask was used. The specimens were disc-like with controlled thickness to permit a measurement of the dimensional change of the specimens, resulting from polymerization. The absence of denture teeth and different denture base thickness were the condition to avoid dimensional distortion of acrylic specimens.

The two acrylic resins fabricated by compression molding technique, Probase Hot and SR Triplex Hot showed different degrees of shrinkage that could arise from the difference in composition of the material. The manufacturer claimed that the Probase Hot formula was developed but all of the compositions have not yet been clearly stated.

The injection molding materials, SR Ivocap High Impact, showed less shrinkage than that of the compression molding materials. In a previous study, complete dentures processed by SR Ivocap system provided minimal processing error in dimensional stability. The mean increase in vertical dimension for the injection method was 0.001±0.003 inch.[6] Anderson et al.[5] reported that the injection molding can improve dimensional stability compared with the compression molding techniques. This polymerization shrinkage measured within 24 hours of processing range from 0.35% to 0.78% for the injection process. Nogueira et al.[7] concluded that the injection molding techniques produced a significantly smaller incisial pin opening, more accuracy, reduced vertical changes and decreased occlusal adjustment in laboratory over the compression molding techniques.

It can be explained by the compensation of polymerization shrinkage due to the pressure applied by injection of the resin. The resin was injected to the mold and was pressured for 5 minutes before placing in the boiling water. During the curing process, the pressure was maintained and the polymerization shrinkage was compensated to a certain extent from a reservoir of the non-polymerized material from the sprue. Another advantage of the injection molding techniques is less measuring error according to well-prepared capsule package of monomer and polymer.

Stanford and Paffenbarger[8] investigated that long curing procedures could produce more dimensional accuracy of dentures than short curing procedures. In this study, the specimens that were cured by compression molding techniques produced the same level of dimensional change between long curing and short curing procedures. Bhanodaya et al.[10] conclude that the cooling process was believed to be the cause of residual stress and distortion from induced strain. The rate of cooling of the flask after processing has an effect on the dimensional changes of acrylic resin more than the rate of heat application.[10] By the way, curing procedures affected the SR Ivocap High Impact injection molding that long curing procedures could provide more dimensional accuracy than short curing procedures because of the longer boiling time and duration of pressure application, and the higher degree of monomer conversion.

A polymerization reaction is never 100% complete as not all monomer is able to react completely.[9] Thus, vary amounts of free monomer still exist in the polymerized denture known as residual monomer.[1-2]

After polymerization, there is less than 1% residual monomer presented in heat-cured acrylic resin. It is temporarily trapped in the polymer network and dimensional change can

occur until the monomer leaches out which can take few minutes, several days, or several weeks.[1-2]

For both 24 and 48 hours after processing, residual monomer also exists.[9] The difference is amount of leaching out monomers. For the 48 hours after processing, less monomer presented as it continued leaching when the time passed by.[9]

In this research, we focused on the simple disc-like specimens. In clinical situation, however, other factors to be concerned are size, shape, thickness and the presence of artificial teeth and distortion when the denture is deflasked that influences the dimensional stability of complete denture. These should be taken into account for determinate of dimensional stability of complete denture.

The conclusions are as follows :

1. The injection molding techniques provided more dimensional accuracy than compression molding techniques.

2. The curing procedures affected SR Ivocap High Impact material; long curing procedures provided more dimensional accuracy.

3. No statistically significant differences in long and short curing procedures in compression molding technique materials.

4. The different time after processing did not affect SR Ivocap High Impact using long curing procedure. The long curing procedure could not show any differences between 24 and 48 hours from initial distances.

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