Original Article

pISSN, eISSN 0125-5614
M Dent J 2017; 37 (3) : 273-280

Flexural Strength of Three Denture Base Materials in Different Curing Procedures

Widchaya Kanchanavasita[1], Thitinon Jongtamgpiti[2], Amornrat Wonglamsam[3], Noppavan Nagaviroj[4]

[1] *D.D.S., Grad. Dip. in Clin.Sc. (Prosthodontics), M.Sc. (Dental Materials Science), Ph.D. (Biomaterials), Diplomate Thai Board of Prosthodontics, Department of Prosthodontics, Faculty of Dentistry, Mahidol University, Bangkok, Thailand*

[2] *D.D.S., M.Sc., (Prosthodontics), Department of Prosthodontics, Faculty of Dentistry, Mahidol University, Bangkok, Thailand*

[3] *D.D.S., M.Sc., (Prosthodontics), Ph.D. (Dental Materials Science), Diplomate Thai Board of Prosthodontics, Department of Prosthodontics, Faculty of Dentistry, Mahidol University, Bangkok, Thailand*

[4] *D.D.S., M.Sc.(Prosthodontics), Ph.D.(Dr.scient.med.), Department of Prosthodontics, Faculty of Dentistry, Mahidol University, Bangkok, Thailand*

Objectives: This study compared the flexural strength of three denture base materials when processed under long-curing and short-curing techniques.

Material and methods: Three denture base materials (SR Triplex Hot, Probase Hot and SR Ivocap High Impact) were polymerized in long- and short- curing procedures. Twelve rectangular specimens (10mm x 64mm x 3.3mm) of each material were prepared according to ISO 20795, and stored in distilled water at 37°C for 48 hours. The three-point bending test with a 5 mm/min crosshead speed was carried out using a universal testing machine.

Results: The mean and standard deviation values of flexural strength of SR Triplex Hot, ProBase Hot and SR Ivocap High Impact cured by long-curing procedure were 78.8±2.5, 78.9±2.8 and 73.2±4.6 MPa, respectively. Of those cured by short-curing procedure were 76.0±2.6, 77.5±3.0 and 68.1±2.8 MPa, respectively. Two-way ANOVA (α=0.05) showed that there was no interaction between the two variable – material and curing time. The flexural strengths of SR Triplex Hot and ProBase Hot were significantly higher than those of SR Ivocap High Impact ($p<0.05$). In addition, the flexural strengths of materials subjected to long-curing procedure were significantly higher than those processed by short-curing procedure ($p<0.05$).

Conclusion: Flexural strength of SR Triplex Hot and ProBase Hot were higher than that of SR Ivocap High Impact. Longer curing time resulted in higher flexural strength of the denture base materials.

Keywords: flexural strength, denture base material, compression molding technique, injection molding technique

How to cite: Kanchanavasita W, Jongtamgpiti T, Wonglamsam A, Nagaviroj N. Flexural strength of three denture base materials in different curing procedures. M Dent J 2017; 37: 273-280.

Correspondence author: Widchaya Kanchanavasita
Department of Prosthodontics, Faculty of Dentistry, Mahidol University, 6 Yothi Street, Ratchathewi, Bangkok, 10400 Thailand
Email: widchaya.kan@mahidol.ac.th
Received : 15 June 2017 Accepted : 11 September 2017

Introduction

Poly(methyl methacrylate) or PMMA has been used in manufacture industry since 1920s and in dental field as denture base material since 1930s because this material fulfills the requisites for high strength, low water sorption and dimensional stability.[1,2] The most common problem of denture base was fracture because of uneven or insufficient thickness of denture base and errors from laboratory procedures. It is important to maintain the regular thickness of the denture with comfortable feeling during denture wearing in order to avoid the thin dentures.[3] Also, improper powder/monomer mixing ratio, processing technique and curing procedure can reduce the denture mechanical properties, such as flexural strength.[4,5] The use of heat curing procedure can control the occurrence of internal porosity or gaseous porosity resulting in decreased flexural strength.[6]

The manufacturers recommended the curing procedures for their products, either or both long- and short-curing procedure. The long-curing method normally starts from room temperature, gradually increases to 100°C and maintains at this temperature for 10-12 hours. The short- or rapid-curing procedure starts at 100°C and cures at this temperature for 6-8 hours.[1,6]

Previous studies[1,2,4,7,8] revealed that the conventional long-curing procedure could prevent the appearance of internal porosity. The slow temperature increase prevents boiling of monomer and avoids the porosity. On the contrary, rapid curing at 100°C raises the exothermic reaction up to 131°C, at which the monomer boils and vapors out (boiling point temperature of monomer is 100°C).[1] As a result of internal porosity the flexural strength of denture base is reduced. Some studies[9,10], however, showed that rapid curing did not cause internal porosity because the flask was clamped with pressure of 22 atm at 100°C. The clamped pressure could increase the boiling point of monomer to 228°C, so the monomer was not vaporized off, and the gas was not produced.

The injection-molding technique has been introduced to overcome the deficiency of compression molding technique.[11-13] However, Grunewald, et al.[14] reported that the injection molding was not superior to the conventional method because the mechanical properties, including flexural strength, of these two techniques were not significantly different. The curing process is time-consuming for lab technicians and the technique requires additional equipment. The objective of this study was to compare the flexural strength of three denture base materials processed under long- and short-curing techniques.

Materials and Methods

Three commercial denture base materials used in this study were shown in Table 1 and 2.

Table 1 Composition of commercial denture base materials

Brand of denture base materials	Powder	Monomer
SR Triplex Hot®	Poly(methyl methacrylate) >95% Benzoyl peroxide 0.5-1.5% Pigment and catalyst	Methyl methacrylate 50-100% Ethylene dimethacrylate 3-<10%
ProBase Hot®	Poly(methyl methacrylate) >95% Dibenzoyl peroxide ≤ 2.5% Softening agent Pigment	Methyl methacrylate 25-100% Ethylene dimethacrylate 1-<10% Catalyst
SR Ivocap High Impact®	Poly(methyl methacrylate) Dibenzoyl peroxide Copolymer and pigment	Methyl methacrylate 50-100% Ethylene dimethacrylate 3-<10% Copolymer

Table 2 Curing methods according to manufacturer's sheet

Material	Manufacturer	Processing procedure	Powder-liquid ratio (g:ml)	Mixing time	Working time	Curing procedure
SR Triplex Hot (Batch No.R32692)	Ivoclar Vivadent Schaan, Lichtenstein	Heat-cured compression molding	2.34:1	10 min (including time for leaving mixture to mature)	20 min	**Long curing procedure** Start at room temperature, heated up to 100 °C (within 1 hr), and boiled for 45 min **Short curing procedure** Started at 100 °C and boiled for 20 min
ProBase Hot (Batch No.R48140)	Ivoclar Vivadent Schaan, Lichtenstein	Heat-cured compression molding	2.25 : 1	10 min (including time for leaving mixture to mature)	20 min	**Long curing procedure** Start at room temperature, heated up to 100 °C (within 1 hr), and boiled for 45 min **Short curing procedure** Started at 100 °C and boiled for 40 min
SR Ivocap High Impact (Batch No.R35688)	Ivoclar Vivadent Schaan, Lichtenstein	Heat-cured Injection molding	0.67 : 1	5 min	10 min	**Long curing procedure** Started at 100 °C and boiled for 90 min **Short curing procedure** Started at 100 °C and boiled for 35 min

The plastic mold was cut to size 10mm x 65mm x 5mm and invested in the Hanau flask using dental stone Type 3. Nevertheless, the SR Ivocap-flask was used for SR Ivocap High Impact. The plastic mold was then removed after the stone had set and the flask had been separated. Separating media was applied on the vacant space in both conventional dental flask and SR Ivocap flask. The specimens of the three materials were processed according to the manufacturer instruction. After being removed from the flask, the specimens were cut to size 10mm x 64mm x 3.3mm by using a low speed saw and were grinded with standard metallographic grinding papers no. P500, P1000 and P1200, respectively. The specimens were then kept in distilled water at 37C for 50±2 hours.

The three-point flexural strength $\sigma = \frac{3Fl}{2bh^2}$ (F is the load in newton, l is the distance (mm) between the supports, b and h is the width and thickness (mm) of the specimen measured immediately prior to water storage) was determined using a universal testing machine. The specimens were loaded to failure at a crosshead speed of 5 mm/min while they were immersed in a water bath at 37±1°C. For the specimens of which failure occurred beyond the flexural strain of 5.0%, the failure load at 5.0% strain was used to calculate the flexural strength (Figure 1).

The mean and standard deviations of the flexural strength of three denture base materials are presented in Table 3.

The statistical analysis done by SPSS for Windows[15] showed that data distribution of each experiment group was normal (Shapiro-Wilk $p>0.05$) and their variances were not different (Levene's test $p=0.387$). Two-way ANOVA (at $\alpha=0.05$) showed that there was no interaction between the two main factors (i.e. materials brand and curing procedure), but there was a significant difference of flexural strength among the three brands and between the two curing procedures. Multiple comparison using Tukey's HSD was carried out further to reveal which materials differed. The result showed that the flexural strength of SR Ivocap was significantly lower than that of Probase Hot and Triplex Hot ($p<0.05$), and the flexural strength of Probase Hot and Triplex Hot was at the similar level ($p>0.05$).

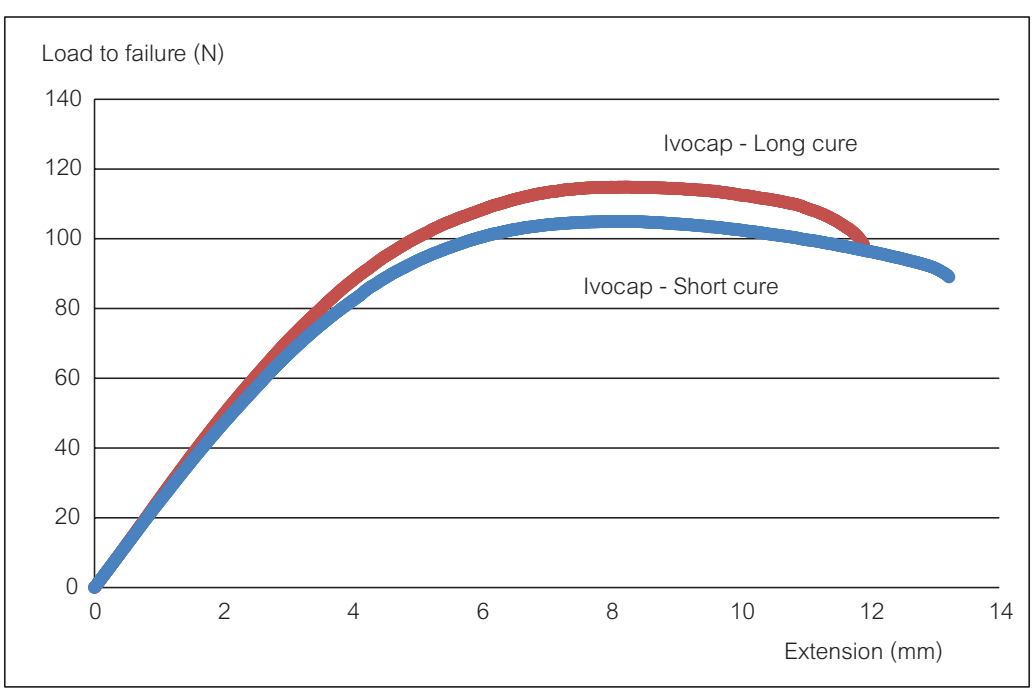

Figure 1 Load-extension plots representing failure of SR Ivocap denture base materials beyond 5% strain under both long and short curing procedures.

Table 3 Flexural strength of three denture base materials by long and short curing procedures (n=12).

Brand of materials	Curing procedures	Flexural strength (MPa)
		Mean±SD
SR Triplex Hot	Long	78.8±2.5[a]
	Short	76.0±2.6[a]
ProBase Hot	Long	78.9±2.8[a]
	Short	77.5±3.0[a]
SR Ivocap	Long	73.2±4.6[b]
	Short	68.1±2.8[c]

Flexural strength with the same superscript are not significantly different at $p<0.05$.

Table 4. Two-way ANOVA table representing 2 main factors – materials brand and curing procedure

Source	Sum of Squares	df	Mean Square	F	Sig.
brand	829.385	2	414.693	42.592	0.001*
curing	176.094	1	176.094	18.086	0.001*
brand * curing	39.392	2	19.696	2.023	0.140
Error	642.607	66	9.736		
Total	411079.320	72			

*Significance at $\alpha = 0.05$

Discussion

Poly (methyl methacrylate) or PMMA has been the material of choice for fabrication of removable denture since 1930s because it possesses suitable properties such as low water sorption, dimensional stability and easy fabrication. However, the most common problem of denture was fracture. The fracture of the denture base might occur during function because of the poor flexural strength of PMMA denture base.[16,17] Errors from laboratory technique such as improper powder and monomer ratio, processing technique and improper curing procedure can also lead to inferior properties. Conventional denture base materials were cured at initial low temperature with long curing time to prevent boiling of the MMA monomer. This process is time-consuming for the dental technician. Therefore, alternative processing techniques and curing procedures are introduced, for example, curing in boiling water for short period of time, and short curing technique which curing time is shortened.

The three-point bending test is useful for comparing physical properties of denture base materials as it simulates the stress applying to the denture during masticatory function.[18] The masticatory force may deform denture during function and may lead to its fracture.

In this study, three denture bases (two are compression molding materials and the other is an injection molding, encapsulated materials) polymerized by long and short curing procedures were loaded to failure by the three-point bending test. The compression molding materials were broken at the maximal loading force. Since SR Ivocap High Impact behaved plastically, some of them failed beyond the 5.0% flexural strain and some of them were not broken at all. This could be the effect of butadiene-styrene (SBR) rubber phase in the

material. Therefore, failure load at 5.0% strain was used to calculate the flexural strength of SR Ivocap.

Thomas et al.[19] and Barbosa et al.[20] stated that the main composition could affect the flexural strength. If the main composition is not different, the flexural strength of denture base also is not different because the flexural strength depends on the bond strength of polymer. That the flexural strength of SR Triplex Hot and ProBase Hot in each curing procedure were not significantly different, can be explained by the mentioned studies since the composition of both materials are not different; the main composition is methyl methacrylate (> 95%), benzoyl peroxide (1%) and other additive in the remaining (plasticizer and coloring substances).

In short curing procedure, the flexure strength of both SR Triplex Hot and Probase Hot were not significantly different, even though the curing time of SR Triplex Hot was two times less than ProBase Hot (20 minutes for SR Triplex and 40 minutes for ProBase Hot). It might be due to the additive composition of SR Triplex Hot acting as a chemical activator to start the polymerization immediately after mixing; however, the exact composition of material was not revealed.

Recently the rapid-cured denture base material has been cured in water at 100°C because the chemical activator, dimethy l-p-toluidine, was added to the rapid cured denture base material. Accordingly, the denture base can be cured in boiling water. SR Triplex Hot and ProBase Hot might have the same composition as the rapid cured denture base material, so they can be cured in boiling water.[21]

Sunint et al.[4] and Al Doori et al.[5] stated that there were variety of factors that caused of internal porosity in denture base; such as air entrapment during mixing, monomer contraction during polymerization, monomer vaporization associated with exothermal reaction, the presence of residual monomer, insufficient mixing of monomer and polymer, processing temperature higher than 70°C, and inadequate compression in the flask. Jerolimov et al.[21] reported that occurrence of porosity depends on the concentration of the initiator, generally benzoyl peroxide in the polymer. Eleven percentage of the porosities were associated with decreased mechanical properties, poor esthetics, potential harboring of organisms and retention of fluids. Wolffardt et al.[7] stated that the generation of porosity in PMMA denture base is apparently a complex phenomenon and is multi-factorial in origin. In this study, the factor relating to internal porosity was monomer vaporization associated with exothermic reaction and the presence of residual monomer.

In the previous studies[1,6], the denture base material processed by a conventional curing procedure, was cured from low temperature then gradually increase to 100°C to prevent the monomer vaporization. If the denture base material was cured at 100°C, the large amount of exothermic heat created a temperature spike of about 131°C, causing monomer to vaporize off at 100°C and gaseous porosity happened which could reduce the flexural strength.[8] Jadhav et al.[23] and Sunint et al.[4] reported that the denture base cured by long curing procedure had more strength than by short curing procedure. Therefore, the flexural strength of SR Triplex Hot and ProBase Hot cured by long curing procedure were higher than those cured by short curing procedure.

Moreover, residual monomer, a property of PMMA denture base material, should be as low as possible to reduce tissue sensitivity and to increase flexural strength.[23,24] It is related to flexural strength because residual monomers cause the internal or gaseous porosity in PMMA denture base materials. In the study of Harrison and Huggett[25], residual monomer was found less in the long curing procedure. The long curing procedure starts to cure in low temperature then

temperature gradually increases so the monomer could be more completely cured when compared to the short curing procedure.

The short curing procedure could create internal or gaseous porosity that decreased the flexural strength. Even though, long curing procedure took more time than the short curing procedure, the flexural strength of denture base cured by the long curing procedure was more than that of the short curing procedure.

Conclusion

1. Flexural strength of the compression molding materials (SR Triplex Hot and ProBase Hot) was not significantly different but they were significantly higher than that of the injection molding material (SR Ivocap).

2. Flexural strength of SR Ivocap High Impact cured by long curing procedure was significantly higher than that was cured by short curing procedure.

Funding: None
Competing interests: None declared
Ethical approval: None (Laboratory study)

References

1. Brauer GM. Dental applications of polymers: a review. J Am Dent Assoc. 1966;72:1151-8.
2. Darvell BW. Material sciences for Dentistry. 9th ed. Woodhead publishing; 2009. 108-77.
3. Kanchanavasita W, Kortrakulkij K. Effect of denture cleanser on color stability and flexural strength of three denture base materials. Mahidol Dent J. 2010;29:24-35.
4. Sunint S, Jayant N, Sanjeev M. Comparative evaluation of surface porosity in conventional heat polymerized acrylic resin cured by water bath and microwave energy with microwavable acrylic resin cured by microwave evergy. Comtemp Clin Dent. 2013;4:147-51.
5. Al Doori D, Huggett R, Bates JF, Brooks SC. A comparison of denture base acrylic resin polymerized by microwave irradiation and by converntional water bath curing systems. Dent Mater. 1988;4:25-32.
6. Bentaher HA, Juszczyk AS, Deb S, Clark RK, Radford DR. Flexural strength and degree of polymerization of a proprietary denture base acrylic resin designed to be cured using long or short cycles. Eur J Prosthodont Restor Dent. 2012;20:163-7.
7. Wolffaaedt FJ, Jones CP, Fatti P. The occurance of porosity in heat cured poly methyl methacrylate denture base resin. J Prosthet Dent. 1986;55: 383-400.
8. Hussain S. Textbook of Dental Materials. 1st ed. Chennai: Jaypee Brothers; 2008.
9. Yau W, Cheng Y, Clark R, Chow T. Pressure and temperature changes in heat-cured acrylic resin during processing. Dent Mater. 2002;18:622-9.
10. Maurizio S, Andrea B, Francesca M, Cecilia G, Marco F. Assessment of flexural strength and color alteration of heat-polymerized acrylic resins after simulated use of denture cleansers. J Pros Dent. 2006;8:20-6.
11. Pryos WJ. Injection molding of plastic for dentures. J Am Dent Assoc. 1942;29:1400-8.
12. Garfunkel E. Evaluation of dimensional changes in complete dentures processed by injection-pressing and the pack-and-press technique. J Prosthet Dent. 1983;80:757-61.
13. Anderson GC, Schulte JK, Arnold TG. Dimensional stability of injection and conventional processing denture base acrylic resin. J Prosthet Dent. 1988;60:394-8.
14. Grunewald AH, Paffenbarger GC, Dickson G. The effect of molding processes on some properties of denture resins. J Am Dent Assoc. 1952;44:269-84.
15. SPSS Inc. Released 2009. PASW Statistics for Windows, Version 18.0. Chicago: SPSS Inc..
16. Chitchumnong P, Brooks SC, Stafford GD. Comparison of three- and four-point flexural strength testing of denture-base polymers. Dent Mater. 1989;5:2-5.
17. Stafford GD, Bates JF, Huggett R, Handley RW. A review of the properties of some denture base polymers. J Dent. 1980;292-305.

18. Yunus N, Rashid A, Azumi L, Abu-Hassen M. Some flexural strength properties of a nylon denture base polymer. J Oral Rehabil. 2005;32: 65-71.
19. Thomas RM, Mark AL. Physical properties of four acrylic denture base resins. J Contemp Dent Prac. 2005;6:1-5.
20. Barbosa CM, Ribeiro MC. Influence of double flask investing and microwave heating on the superficial porosity surface roughness and knoop hardness of acrylic resin. J Prosthodont. 2009;18:503-6.
21. Jerolimov V, Brooks SC, Huggett R, Bates JF. rapid curing of acrylic denture-base materials. Dent Mater. 1989;5:18-22.
22. Jadhav R, Bhide SV, Prabhudesai PS. Assessment of the impact strength of the denture base resin polymerized by various processing techniques. Indian J Dent Res. 2013;24:19-25.
23. Dogan A, Bek B, Cevik N, Usanmaz A. The effect of preparation conditions of acrylic denture base materials on the level of residual monomer, mechanical properties and water absortion. J Dent. 1995;23:313-8.
24. Huang FM, Hu CC, Chang YC, Chou MY. Residual monomer releasing from acrylic denture base in water. Chin Dent J. 2000;19:17-22.
25. Hurrison A, Huggett R. Effect of th curing cycle on residual monomer levels of acrylic resin denture base polymers. J Dent. 1992;20:370-4.