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A Comparative Evaluation of the Flexural Strength of Denture Base Resins Polymerized By Compression Molding, Injection Molding and Microwave Techniques of Denture Processing- An Invitro Study

Dr.Sayali D. Kuwlekar

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ABSTRACT: Mechanical behaviour of the denture base, including flexural strength, depends on the type of the material and even on processing techniques. Denture material should have flexural strength at the proportional limit that is sufficiently high enough that permanent deformation does not result from the stress applied during mastication. The aim of the present study is to compare the flexural strength of heat cure resins cured by compression molding, injection molding and microwave technique of processing. 15 specimens were prepared for all the three curing techniques, respectively and the flexural strength was tested using Universal testing machine.The data obtained was analysed with One Way ANOVA test followed by Post Hoc Tukey Test for pairwise comparison. Microwave group showed maximum flexural strength (92.67±0.81) followed by Injection group (91.46±1.58). Compression group showed least flexural strength (78.08±2.13)

KEYWORDS: Flexural strength, Compression molding, Injection molding, Microwave curing

I. INTRODUCTION

Polymethyl methacrylate, introduced in 1937 by Dr. Walter Wright, has been successfully used for the fabrication of denture bases and artificial teeth and since then it has excellent aesthetic properties, low solubility and lack of toxicity[1].The denture base should be strong enough so that it can withstand functional and parafunctional masticatory forces. Mechanical behaviour of the denture base depends on the type of the material and even on processing techniques. Hence, heat cure resins and polymerization techniques have been modified to improve physical and chemical properties of denture bases [2]. Flexural strength is the magnitude of the elastic stress at the proportional limit above which plastic deformation occurs. Denture material should have flexural strength at the proportional limit that is sufficiently high enough that permanent deformation does not result from the stress applied during mastication[3]. The most clinically remarkable cause for denture fracture is fatigue under masticatory loads due to the repetitive flexing of the denture bases [4]. The processing technique can induce stress into the denture base during processing and finally lead to failure [5]. Incompletely polymerized acrylic resins have been shown to have lower mechanical properties as compared to products that have been subjected to complete polymerization. Thus flexural strength measurements can give an assessment of the quality of polymerization and aid in determining the resistance of denture bases to excessive forces[6]. Out of the three techniques used in this study, the conventional method for resin polymerization to process dentures is compression molding with heat activation in a water bath[4]. Polymerization shrinkage and dimensional change are common problems encountered with compression molding which lead to compromise in the fit of the denture[2]. Advances in polymer science have developed new molding and activation techniques, such as injection-molding and microwave activation[7]. Introduced in 1942 by Pryor, injection molding technique allows for directional control of the polymerization process through the flask design. A constant flow of new material under pressure compensates for the polymerization shrinkage[8]. The use of microwave energy was first reported in 1968 by Nishii as an alternative PMMA processing method[9]. The advantages of microwave polymerization technique are such that less equipment is required and it has better accuracy of fit[10].Despite the advantages of microwave polymerization, this method has still received limited clinical acceptance[11]. Mechanical properties such as impact strength, transverse strength, porosity, residual monomer content, and dimensional accuracy have been studied, but few studies have been reported of the flexural fatigue strength. Therefore, it was essential to evaluate and compare the flexural strength of denture base resins polymerized by the conventional heat cured, microwave and injection molding techniques of denture processing. The rationale of this study is to compare the flexural strength of heat cure resins cured by compression molding, injection molding and microwave techniques of processing.

II. MATERIAL AND METHOD

Fabrication of sample: An ½ inch medical grade stainless steel rod was machined to dimensions of 65X10X2.5 mm [figure 1]. Customized samples were fabricated from the following polymerization techniques.Samples were divided into three groups, each group consisting of 15 samples.

- Group A- Compression molding
- Group B- Injection molding
- Group C- Microwave technique

1) Compression molding method:

Polymethyl methacrylate (Acralyn-H) was mixed in a ratio of 3:1 by volume. Once the heat cure resin reached its dough stage, the acrylic dough was packed in the mold space in slight excess [figure 2,3]. The heat cure resin was polymerized by two different cycles. Seven samples were polymerized by short curing cycle i.e 74°C for 2 hours followed by 100° C for 1 hour and 8 samples were cured by long curing cycle i.e. 74°C for 8 hours followed by 100°C for 1 hour

2) Injection molding method:

Premeasured SR-Ivocap capsules of resin and monomer (20 g powder, 30 mL monomer) were mixed in Cap vibrator for 5 minutes before injecting into the flask. Hydraulic pressure of 6 atm at 100 degree celcius was maintained for 40 minutes for curing. After curing, the flasks were held under running water for cooling process for 10 minutes [figure 4,5].

3) Microwave processing method:

Heat-cure acrylic resin (NatureCryl-MC) was mixed in a porcelain jar in the ratio of 21 g polymer: 10 ml monomer as per manufacturer's instructions. The resin was kneaded and packed in the mold as it reached dough stage. The flasks were bench pressed and a trial closure was done at 1500 psi with removal of excess flash. Finally the flasks were bench cured for 1 hour. Curing was done in the microwave oven for 5 minutes at 540 W [figure 6,7].

Flexural strength testing: Each specimen was subjected to the 3-point bending test, at a cross head speed of 5mm/min. The flexural test was carried using a universal testing machine.[figure 8]

The specimen was positioned in the universal testing machine between the grips. The distance between the specimen support was 40 mm. Load was applied to the center of the specimen. Once the machine was started it began to load the specimen at a crosshead speed of 5 mm/min. The loading was continued till fracture occurred and the breaking load was recorded. Throughout the tests the control system and its related software recorded the load and extension or compression of the specimen.

The flexural strength (MPa) was calculated using the formula:

$FS=3WL/2(bd)^2$

FS= Flexural strength

W=load at fracture

L= distance between supporting points(40 mm)

b=width of specimens (mm)

d=specimen thickness (mm)

Data analysis plan and methods: Statistical analysis was performed using SPSS software version 19. Level of significance was kept at 5%. Descriptive statistics was performed to report mean and standard deviation. Flexural strength among three study groups was compared using One Way ANOVA test followed by Post Hoc Tukey Test for pairwise comparison.

III. RESULTS

Microwave group showed maximum flexural strength (92.67±0.81) followed by Injection group (91.46±1.58). There was no significant difference between microwave group and injection molding group. Compression group showed least flexural strength (78.08±2.13) amongst which the long curing cycle had better results than the short curing cycle. Overall difference in flexural strength among study groups was significant (p=0.001).

TABLES

Table no:1 Comparison of flexural strength among study groups

Groups	Mean	SD	F value	p value
Microwave	92.67	0.81	382.273	0.001*
Injection	91.46	1.58		
Compression	78.08	2.13		

Table no:2 Pairwise comparison of flexural strength

Pair	Difference	p value
Microwave vs. Injection	1.21	0.109 (NS)
Microwave vs. Compression	14.59	0.001*
Injection vs. Compression	13.38	0.001*

Table no: 3 Comparison of flexural strength among study groups

Groups	Mean	SD	F value	p value
Microwave	92.67	0.81	396.245	0.001*
Injection	91.46	1.58		
Compression (Long cured)	79.58	1.73		
Compression (short cured)	76.37	0.83		

Table no:4 Pairwise comparison of flexural strength

Pair	Difference	p value
Microwave vs. Injection	1.21	0.068 (NS)
Microwave vs. Compression (Long cured)	13.09	0.001*
Microwave vs. Compression (Short cured)	16.30	0.001*
Injection vs. Compression (Long cured)	11.88	0.001*
Injection vs. Compression (Short cured)	15.09	0.001*
Compression (Long cured) vs. Compression (Short cured)	3.21	0.001*

IV. DISCUSSION

The flexural strength is one of the most important mechanical tests specified by the ADA specification No:12 and ISO 12 20795-1 for denture base polymer[12]. Flexural strength of acrylic resin, processed and cured with any method, should be no less than 65 MPa according to ISO 1565. The present study measured and compared the flexural strength of denture base acrylic resin processed by three different techniques: compression molding, injection molding and microwave method of processing. In the present study, rectangular specimens were examined and thus, variables such as shape, size and thickness of the samples were controlled. The 3 point bending test has been useful in many studies that evaluate denture base acrylic resins because it simulates the stress that is applied on the prosthesis during chewing[13]. The samples were not subjected to immersion in water because it would lead to plasticization of the resin, making it more flexible and resilient. Among the three groups, microwave processing (Group C) showed the highest flexural strength (92.67±0.81 MPa) than the injection molding (Group B) (91.46±1.58 MPa) and compression molding (Group A) (78.08±2.13 MPa). Table no:1 shows that the difference in flexural strength among microwave and comparison group was significant (p=0.001). The results agree with the studies reporting highest flexural strength of microwave method of curing when compared to compression molding process of curing[14][15]. Equal heating of substance and rapid rise in temperature are the advantages of microwave heating.Microwave energy acts on the monomer which promotes an immediate and uniform heating of the polymer mass, that activates the decomposition of benzoyl peroxide, the reaction initiator, and quickly yields free radicals for the polymerization process which decreases in the same proportion as polymerization increases[16]. In Brazil, the first microwave research was reported in 1994 by Del BelCury et al, who investigated physical properties of acrylic resin processed by microwave energy compared to water bath[15]. Their results showed differences among the resins that were attributed to the composition of acrylic resins. The heat is distributed more effectively and there is lesser risk of porosity. As the temperature increases, the number of monomer molecules decrease and so residual monomer content is reduced to minimal. The residual monomer is a well-known plasticizer and affects the physical and mechanical properties of acrylic resins[5]. Table no: 2 showed that the difference in flexural strength among injection and compression group was significant (p=0.001). The results indicated that the differences observed can be attributed to the polymer constituents and to the method of polymerization[17]. Hamnakareported that all the injection molded thermoplastic resins had significantly higher impact strengths compared to the conventional compression molding[2]. Zappini et al[18]demonstrated in an in-vitro study that Ivocap had significantly higher fracture resistance and advised to use this material in complete denture fabrication. Table no:2 and 3 showed Intergroup comparison of flexural strength in which no difference was found among microwave group and injection group (p=0.069). The physical and mechanical properties of the injection molded resin may be attributed to dual polymerization and small particle sizes which led to insignificant difference between flexural strengths of microwave and injection molding method of processing[19]. As the SR-Ivocap specimens showed high flexural strength, it can be concluded that the amount of residual monomer was less than in the compression molding technique and polymerization was more complete. Compression molding specimens showed lowest flexural strength. The plasticizing effect of residual monomer affects flexural strength and consequently deformation occurs more easily under load. Therefore, this study supports the hypothesis of Kelly [20]and DeClerck[21]that the residual monomer content and porosities in denture base resins might be the reasons for lower flexural strength. The evaporations of the residual monomer produces porosities in the denture base resin and lead to formation of cracks within the acrylic that makes the denture base prone to fatigue failure. Thus, residual monomer content can be directly related to the flexural fatigue strength of acrylic resins[5]. Compression molding specimens (Group A) were subcategorized into long curing and short curing groups. Table no: 4 showed that the difference in flexural strength long cured and short cured compression group was significant (p=0.001) such that long curing cycle group showed higher flexural strength than short curing cycle group. The result is in accordance with study by Jadhav et al[23] who reported that the denture base cured by long curing procedure had more strength than by short curing procedure. The shorter curing cycles provided faster polymerization but the monomer content and porosities might be the reasons for lowest flexural strength among all the four groups.

V. CONCLUSION

- Microwave method of denture processing showed highest flexural strength followed by injection molding and compression molding showed the lowest strength.
- Statistically insignificant difference was found between microwave and injection molding method of processing.
- Based on the disadvantages associated with microwave processing, Injection molding technique may prove to be advantageous than microwave and compression molding method of processing.

REFERENCES

[1]. Francis J, Shetty R, Shenoy K, Somaraj V. Comparative evaluation on the influence of different curing cycles on the mechanical properties of three commercially available denture base resins: an in-vitro study. J Appl Dent Med Sci. 2016;3(2):23–30.

[2]. Gharechahi J, Asadzadeh N, Shahabian F, Gharechahi M. Flexural strength of acrylic resin denture bases processed by two different methods. J Dent Res Dent Clin Dent Prospects. 2014;8(3):148–52.

[3]. Hamanaka I, Iwamoto M, Lassila L, Vallittu P, Shimizu H, Takahashi Y. Influence of water sorption on mechanical properties of injection-molded thermoplastic denture base resins. ActaOdontol Scand. 2014;72(8):859–65.

[4]. Elboraey AN, Dehis WM, Mousa MK. Flexural and tensile strength of acrylic resin denture base materials processed by three different methods. Res J Pharm BiolChem Sci. 2016;7(4):2556–63.

[5]. Banerjee R, Banerjee S, Prabhudesai PS BS. Influence of the processing technique on the flexural fatigue strength of denture base resins: An in-vitro investigation. Indian J Dent Res. 2010;21(3):391–5.

[6]. .Nisar S, Moeen F HU. Effect of varying curing regimens and powder liquid ratios on the flexural strength and surface porosities of heat-cure acrylic: An in vitro experiment. Int J Dent Sci Res. 2015;3:64–71.

[7]. Machado C, Sanchez E, Azer SS, Uribe JM. Comparative study of the transverse strength of three denture base materials. J Dent. 2007;35(12):930–3.

[8]. Pryor WJ. Injection Molding of Plastics for Dentures. J Am Dent Assoc. 1942;29(11):1400–8.

[9]. M. C, BelCury AA Del, Rodrigues Garci RCM. The Use of Microwave Energy in Dental Prosthesis.Adv Induction Microw Heat Miner Org Mater.2011;(1).

[10]. Patil PS, Chowdhary R, Mandokar RB. Effect of microwave postpolymerization treatment on residual monomer content and the flexural strength of autopolymerizing reline resin. Indian J Dent Res. 2009;20(3):293– 7.

[11]. Spartalis GK, Cappelletti LK, Schoeffel AC, Michél MD, Pegoraro TA, Arrais CAG, et al. Effect of conventional water-bath and experimental microwave

International Journal Dental and Medical Sciences Research
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polymerization cycles on the flexural properties of denture base acrylic resins. Dent Mater J. 2015;34(5):623–8\
[12]. Standard 11266 I. International Standard International Standard. 61010-1 Iec2001. 2014;2014:13.
[13]. Memon MS, Yunus N, Razak AA. Some mechanical properties of a highly cross-linked, microwave-polymerized, injection-molded denture base polymer. Int J Prosthodont. 2001;14(3):214–8
[14]. Gurbuz O, Unalan F, Dikbas I. Comparative study of the fatigue strength of five acrylic denture resins. Journal of the Mechanical Behavior of Biomedical Materials. 2010;3(8):636-639.
[15]. Barbosa D, Souza R, Pero A, Marra J, Compagnoni M. Flexural strength of acrylic resins polymerized by different cycles. Journal of Applied Oral Science. 2007;15(5):424-428
[16]. Sarac YS, Sarac D, Kulunk T, Kulunk S. The effect of chemical surface treatments of different denture base resins on the shear bond strength of denture repair. J Prosthet Dent. 2005;94(3):259–66.
[17]. Raut A, Rao PL, Vikas BVJ, Ravindranath T, Paradkar A, Malakondaiah G. An in vitro study to compare the transverse strength of thermopressed and conventional compression-moldedpolymethylmethacrylate polymers. Indian J Dent Res. 2013;24(3):356–62.
[18]. Zappini G, Kammann A, Wachter W. Comparison of fracture tests of denture base materials. J Prosthet Dent. 2003;90(6):578–85.
[19]. Hamanaka I, Takahashi Y, Shimizu H. Mechanical properties of injectionmolded thermoplastic denture base resins. ActaOdontol Scand. 2011;69(2):75–9
[20]. Ellsworth K. Fatigue failure in denture base polymers. J Prosthet Dent. 1969;21(3):257–66.
[21]. De Clerck JP. Microwave polymerization dental prostheses.J Prosthet Dent. 1987;57(5):650–8.
[22]. RajashreeJadhav, SV Bhide PP. Assessment of the impact strength of the denture base resin polymerized by various processing techniques. Indian J Dent Res. 2013;24(1):19–25.

FIGURES

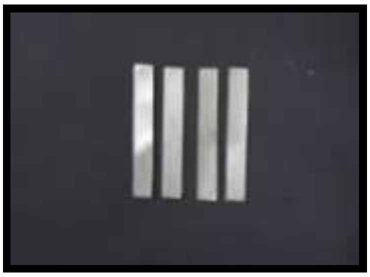

FIGURE 1

FIGURE 2

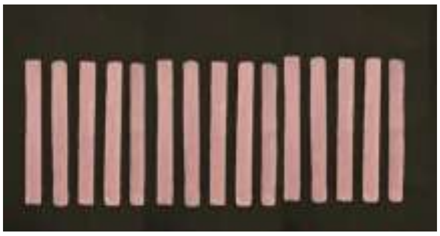

FIGURE 3

FIGURE 4

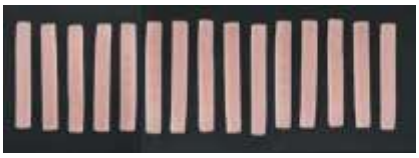

FIGURE 5

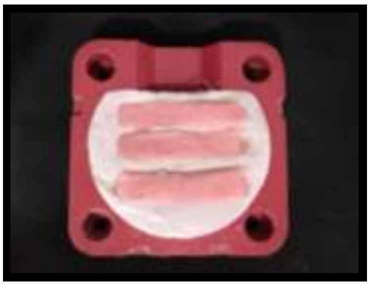

FIGURE 6

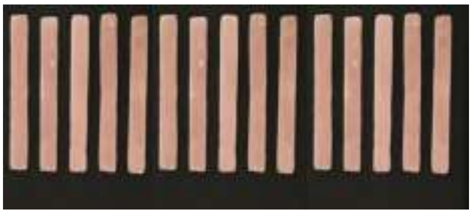

FIGURE 7

FIGURE 8