



Comparative evaluation of properties and processing time during polymerization for heat cure polymethyl methacrylate by conventional water bath technique vs automatic pressure cooker technique- an *in vitro* study

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ABSTRACT

Background: Different curing methods for polymerization have been used like Heat cured, Light cured, Chemical cured and Microwave energy. The water bath processing technique has been the most conventionally used polymerization technique. In spite of the advantages provided by this technique like ease, simplicity and cost effectiveness, a major disadvantage has been the long processing time required.

Purpose: To evaluate and compare the properties like impact strength, flexural strength, surface hardness, porosity and processing time required for polymerization of heat cure PMMA by conventional water bath technique and pressure cooker technique.

Materials and Methods: A total of 40 specimens were prepared into two groups as follows: Control group (Group A) 20 specimens containing heat cure acrylic resins processed by Conventional Water bath processing technique and Experimental group (Group B1) 20 specimens with Heat cure acrylic resins were processed by Automatic Pressure cooker which further were divided into two subgroups as B1 (10 specimens) cured for 15 minutes and B2 (10 specimens) cured for 30 minutes.

Result: Group B2 shows significantly higher impact strength, highest flexural strength (96.1 MPa), and significantly higher surface hardness compared to Group B1 and A. Group B2 shows significantly lower porosity and small size of porosity compared to Group B1 and A.

Conclusion: Group B2 was considered superior to the rest of the groups.

Keywords: automatic pressure cooker technique, heat cure polymethyl methacrylate, processing time, polymerization

INTRODUCTION

Denture base materials have remained a challenge in dentistry from the beginning of dental art. Introduction of poly methyl methacrylate (PMMA) resin for the use of denture base material dates back to the year 1937 when Dr. Walter Wright clinically evaluated PMMA and found that it fulfilled all the requirements of an ideal denture base material.⁽¹⁾ Different polymerization techniques using heat, light, chemical and microwave energy have been utilized in past to improve the physical and mechanical properties of resin materials.⁽²⁾

The water bath processing technique has been the most conventionally used polymerization technique. In spite of the advantages provided by this technique like the ease, simplicity and cost effectiveness, a major disadvantage has been the long processing time required.⁽³⁾ Boilable resins (modified resins) were introduced to reduce the processing time but did not have the same physical properties as PMMA.⁽⁴⁾ Nishii et al introduced microwave polymerization with comparable physical and mechanical properties, lesser porosity and better dimensional accuracy than conventional water bath, but required specially formulated non-metallic epoxy resin flasks and more than one formulation of acrylic resin because different combinations or particle sizes of copolymers may react differently when polymerized through microwave irradiation.^(5,6)

The pressure cooker polymerization utilizing conventional equipment was introduced by I Muley which requires less than 1 hour for polymerization.⁽⁷⁾ Undurwade JH and Sidhaye AB studied the residual monomer content using pressure cooker.⁽⁸⁾ On polymerization by a pressure cooker,

physical and mechanical properties are comparable to water bath method. A new rapid processing procedure for curing PMMA denture base resin in an automatically controlled pressure cooker was introduced by Xia Chun Ming, Shi Changxi, He Weizhou.⁽⁷⁾ The pressure cooker significantly reduced the polymerization time and was controlled automatically.

With the advent of newer methods of activation of the polymerization of denture base resins, there is a need to compare the properties of resins polymerized using different modes of activation. However not much literature is available regarding the properties of pressure cooker polymerization. Therefore, the aim of the study was to compare the automatic pressure technique of curing with conventional water bath technique by evaluating the flexural strength, impact strength, surface hardness, porosity and time of polymerization of the cured poly methyl methacrylate resins.

MATERIALS AND METHODS

There were three groups used:

Group A: Control Group cured by conventional water bath technique.

Group B1: Experimental Group cured by automatic pressure cooker technique in 15 minutes.

Group B2: Experimental Group cured by automatic pressure cooker technique in 30 minutes.

Preparation of Control Group Specimens (Group-A):

Total 20 control group specimens of $64 \times 10 \times 3$ mm were prepared as recommended by the American Dental Association specification No.12 for denture base resins⁽⁹⁾ (Figure 12). The Acrylizer (Dentcure, PUNEET, Made in India) was filled with water. The clamped flasks were placed in water at room temperature ($23 \pm 2^{\circ}\text{C}$) and temperature was raised to $73 \pm 1^{\circ}\text{C}$, held at $73 \pm 1^{\circ}\text{C}$ for one and half hours and then increased to 100°C in half an hour and processed for 30 minutes more. After the completion of the curing cycle the flask was removed from the water bath and bench cooled for 30 minutes, immersed in cool tap water for 15 minutes prior to deflasking. The acrylic specimens were then retrieved, finished, and polished. The dimension and quality of the

specimens were verified. Specimens were then measured for accurate dimensions using digital verniercaliper and stored in water at room temperature.

Preparation of Experimental Group Specimens (Group- B1):

Total 10 specimens of $64 \times 10 \times 3$ mm were prepared for experimental group B1 by automatic pressure cooker technique (Acryfam, VILMAN, Made in India). The automatic pressure cooker was filled with water at room temperature ($23 \pm 2^{\circ}\text{C}$) and the clamped flasks were placed and the lid was locked. Air pressure inside the cooker was set at 6kgf/cm^2 and the power was turned on. The temperature was increased to 100°C and it was held at this temperature and 6kgf/cm^2 pressure for 15 minutes and then the power supply was turned off. The vent of the pressure cooker was released automatically. The specimens were later recovered from the flasks.

Preparation of Experimental Group Specimens (Group- B2):

Total 10 specimens of $64 \times 10 \times 3$ mm were prepared for experimental group B2 by automatic pressure cooker technique (Acryfam, VILMAN, Made in India). The automatic pressure cooker was filled with water at room temperature ($23 \pm 2^{\circ}\text{C}$) and the clamped flask was placed and the lid was locked. Air pressure inside the cooker was set at 6kgf/cm^2 and the power was turned on. The temperature was increased to 100°C and it was held at this temperature and 6kgf/cm^2 pressure for 30 minutes and then the power supply was turned off. The vent of the pressure cooker was released automatically.

The flasks were removed from the water bath and automatic pressure cooker. They were cooled to room temperature for 30 minutes and then immersed in water at room temperature for 15 minutes. The specimens were deflasked and were carefully examined for any processing defects like porosity, deformed structures etc. if any defects were seen, they were rejected. Excess material was trimmed and polished on the lathe machine with trimming burs, stones, sandpaper mandrels & polishing buff. The specimens were checked for the appropriate size with digital vernier caliper.

Flexural (Transverse) Strength:

The total number of specimens for Flexural strength were 20: Ten Group A Specimens, Five Group B1 specimens, Five Group B2 Specimens. The test was achieved by using Universal Testing Machine (Computerized, Software Based) Company: Star Testing System, India, Model No. STS 248, each specimen was positioned on bending fixture, consisting of 2 parallel supports (50mm) apart, the full-scale load was 50kg, and the load was applied with cross head speed of 1mm/min by rod placed centrally between the supports making deflection until fracture occurred.

The transverse strength was calculated using the following formula⁽¹⁰⁾:

$$\sigma = \frac{3Pl}{2bd^2}$$

σ : Flexural strength.

l : The distance between the supports.

b : Width of the specimen.

d : Depth or thickness of the specimen.

P : The maximum load at the point of fracture.

Impact Strength:

The total number of specimens for impact strength was 20: Ten Group A Specimens, Five Group B1 specimens, Five Group B2 Specimens. Impact strength was conducted with Charpy type impact testing instrument. (CHARPY IMPACT STRENGTH{UN-NOTCHED} Machine Specification: Digital Impact Testing Machine, Company: Zwick Germany, Model No: 5102) (Figure 15). The specimen was supported horizontally at its ends and struck by a free-swinging pendulum which is released from a fixed height in the middle. A pendulum of 2 joules testing capacity was used. The scale reading gave the impact energy absorbed to fracture the specimen in joules when struck by a sudden blow. The Charpy impact strength of notched specimen was calculated in J/m.

The impact strength was calculated using the following formula⁽¹⁰⁾:

$$\text{Impact strength} = E/b.d \times 10$$

E: is the impact absorbed energy in joules.

b: is the width in millimeters of the test specimens.

d: is the thickness in millimeters of the test specimens.

Surface Hardness Test:

The total number of specimens for Surface Hardness Test was 20: Ten Group A Specimens, Five Group B1 specimens, Five Group B2 Specimens. Surface hardness was determined using Vicker's Micro hardness Tester. The instrument consists of blunt-pointed indenter 0.8mm in diameter that tapers to a cylinder 1.6mm. The instrument is designed to measure hardness of a range of rigid materials. It shows difference between the depth of indentation in relation to time in a specimen under a primary contacting load and secondary penetrating load. Indenter consists of a Vickers's pyramidal shaped diamond indenter that contacts and penetrates the specimens on load application.⁽¹¹⁾ VHN is a valid tool for evaluating the hardness and viscoelastic responses of polymers.⁽¹²⁾ The hardness testing machine used in the present study used Vickers's Micro hardness Tester, using a load of 50 gf for 30 seconds.⁽¹³⁾

Porosity Test:

The total number of specimens for Porosity Test was 20: Ten Group A Specimens, Five Group B1 specimens, Five Group B2 Specimens. Porosity was determined using Stereo Microscope (Company: WuzhouNewfound Instrument Co. Ltd, China Model No: XTL 3400E, Magnification: 10X) and the size of the porosity was analyzed using Image Analysis System (Company: Chroma Systems Pvt. Ltd, India, Model: MVIg 2005). The area of 1500 μm x 1500 μm was marked on the PMMA sample. The specified area of the sample was observed in stereo microscope and the size of the porosity was measured using the image analysis system. The respective readings were noted in numbers and microns.

All the results obtained were subjected to statistical analysis.

OBSERVATIONS AND RESULTS

Flexural Strength (Graph 1):

The flexural strength of specimens was tested by Universal Testing Machine. Table-1 shows the mean values for each specimen group obtained together with the standard deviation of coefficient of variation. To identify any significant differences between the data obtained for the groups of materials tested, a one-way analysis of variance was undertaken which is tabulated in Table-2.

Group A: The flexural load applied to the Group A specimens were in the range of 219.81-257.74 N with the mean of 239.95 ± 12.67 N. The range of flexural strength was between 82.17-93.17 MPa with the mean of 86.40 ± 3.80 .

Group B1: The flexural load applied to the Group B1 specimens were in the range of 254.89-281.06 N with the mean of 267.58 ± 11.19 N. The range of flexural strength was between 83.17-92.53 MPa with the mean of 87.89 ± 3.39 .

Group B2: The flexural load applied to the Group B2 specimens were in the range of 281.06-331.04 N with the mean of 304.68 ± 18.01 N. The range of flexural strength was between 86.80-100.27 MPa with the mean of 96.1 ± 5.57 .

The above analysis revealed that higher the load or force required to fracture the specimens, greater will be the transverse strength. Apparently, Group B2 shows the highest flexural strength (96.1 MPa) followed by Group B1 with 87.89 MPa which is closely followed by Group A with 86.40 MPa. Hence Group B2 was considered superior when compared with other two groups.

Impact Strength (Graph 2):

The impact strength of specimens was tested by Digital Impact Testing Machine. Table-3 shows the mean values of each specimen group obtained together with the standard deviation of coefficient of variation. To identify any significant differences between the data obtained

for the groups of materials tested, a one-way analysis of variance was undertaken which is tabulated in Table-4.

Group A: The energy absorbed to break the specimens were in the range of 0.728-0.984 joules with a mean of 0.824 ± 0.076 joules. ⁽¹⁰⁾ The range of impact strength was between 159.65-228.30 joules/mm with a mean of 182.64 ± 19.78 joules /mm.

Group B1: The energy absorbed to break the specimens were in the range of 0.736-1.168 joules with a mean of 0.9024 ± 0.174 joules. The range of impact strength was between 159.65-250.64 joules/mm with a mean of 196.73 ± 37.16 joules /mm.

Group B2: The energy absorbed to break the specimens which were in the range of 0.576-1.184 joules with a mean of 0.9072 ± 0.242 joules. The range of impact strength was between 130.90-245.64 joules/mm with a mean of 201.33 ± 46.49 joules /mm.

The above analysis revealed that higher the energy absorbed to fracture the specimens, greater the impact strength. The analysis of the difference in impact strength was then carried out by one way analysis of variance (ANOVA), which revealed that Group B2 had significantly higher impact strength compared to Group B1 and A. Group B2 was considered superior to the rest of the groups.

Surface Hardness (Graph 3):

The surface hardness of specimens was tested by Vickers Micro hardness Tester. Table-5 shows the mean values for each group obtained together with the standard deviation of coefficient of variation. To identify any significant differences between the data obtained for the groups of materials tested, a one-way analysis of variance was undertaken which is tabulated in Table-6.

Group A: The surface hardness of the specimens in the range of 15.01-16.70 HV with a mean of 15.872 ± 0.42 .

Group B1: The surface hardness of the specimens in the range of 15.01-16.95 HV with a mean of 16.18 ± 0.83 .

Group B2: The surface hardness of the specimens in the range of 15.01-20.05 HV with a mean of 17.22 ± 1.88 .

The analysis of the difference in surface hardness was then carried out by one-way analysis of variance (ANOVA), which revealed that Group B2 had significantly higher surface hardness compared to Group B1 and A. Group B2 was considered superior to the rest of the groups.

Porosity (Graph 4):

The porosity of specimens was analyzed by Stereo Microscope and Image Analysis System. Table-7 shows the mean values for each group obtained together with the standard deviation of coefficient of variation. To identify any significant differences between the data obtained for the groups of materials tested, a one-way analysis of variance was undertaken which is tabulated in Table-8.

Group A: The porosity observed and their size in the range of 2-4 with a mean of 3 ± 1.0 . The average size of the porosity was in the range of 26-33 μ with the mean of $29.40 \pm 2.70\mu$.

Group B1: The porosity observed and their size in the range of 2-3 with a mean of 2.40 ± 0.54 . The average size of the porosity was in the range of 24.95-31.22 μ with the mean of $28.26 \pm 2.46\mu$.

Group B2: The porosity observed and their size in the range of 1-3 with a mean of 2.0 ± 0.71 . The average size of the porosity was in the range of 19.4-29.8 μ with the mean of $24.82 \pm 4.34\mu$.

The analysis of the difference in surface hardness was then carried out by one-way analysis of variance (ANOVA), which revealed that Group B2 had significantly lesser number of

porosity and small size of porosity compared to Group B1 and A. Group B2 was considered superior to the rest of the groups.

Time of polymerization of PMMA:

The time of polymerization of PMMA resins of specimens of Group A was one and half hour, Group B1 was 15 minutes and Group B2 was 30 minutes. The results revealed that Group B1 requires less time compared to B2 followed by Group A. Group B1 was considered superior to rest of the groups.

DISCUSSION

At the time of its introduction denture base resins were cured without any scientific background which affects physical and mechanical properties for not following a standard curing program. As reported by Jerolimov et al.⁽¹⁴⁾ the choice of curing had much greater influence than mixing ratio with regard to the level of residual monomer, and flexural property of heat cure denture base material which improves with decreasing the amount of residual monomer. In a study by Honorez et al.⁽¹⁵⁾ three processing methods were used: two processing cycles recommended by the manufactures and one quick violent boiling. They stated that denture should not be polymerized by placing the flask in boiling water for quick cure as it may have a clinical significance for those patients who may be sensitive to acrylic resin residual monomer. As the clinical application in acrylics increased, many researchers have recommended different curing cycles for processing heat cure denture base resins. The techniques varied from rapid to slow measures, some continuing as long as eight hours or more.

The curing cycle employed for processing the heat cure denture base resins had influence on its physical and mechanical properties. Harrison and R. Huggett⁽¹⁶⁾ in their study determined the effect of curing cycles on residual monomer levels of acrylic denture base polymers, they showed that high level of residual monomer has a deleterious effect on the properties of denture base polymers and further concluded that short curing cycles were undesirable and its results in significantly raised levels of residual monomer. Dogan et al.⁽¹⁷⁾ reported that for heat cured resins, the longer curing time improved the tensile strength and decreased the level of residual monomer. They stated that the tolerable level of residual monomer for tissue sensitivity for each individual was hard to predict.

Villittu PK et al.⁽¹⁸⁾ studied the effect of polymerization temperature and time on residual monomer content of denture base polymers and concluded that polymerization

temperature and polymerization time significantly affects the residual monomer of denture base polymers. Polymerization depends on the monomer being attached to the polymer free radical. The more the temperature rise, the faster the molecules move and the more complete will be the polymerization reaction. With the conventional method, the temperature rises at the end of the curing cycle and some free monomer is left in the resin.

Processing technique has been found to have profound influence on the impact strength. Through years, the water bath heat processing technique has been the most widely used polymerization technique. It is an easy, simple to handle and a cost-effective procedure. The water bath heat processing technique involves the activation of the initiator, i.e. benzoyl peroxide, creating the first free radicals which start the polymerization. The temperature required to generate free radicals is above 60°C (140°F). The exothermic polymerization reaction increases as the temperature increases. At 100.8°C, the methyl methacrylate boils and creates porosities in the resin. This is because as the exothermic reaction progresses, heat is liberated which does not escape easily due to the unfavorable thermal gradient.⁽⁶⁾ As the heat cannot be directly produced in the denture base material inside the mold, heat must be produced indirectly by the heating up of the water. The heat dispersion is low and may result in voids in the denture base resin. To control this thermic gradient, it is necessary to polymerize the denture base resin at a much slower rate, approximately 8 hours for complete polymerization. The relatively longer time required for processing is a major disadvantage of the water bath polymerization technique. To compensate for this disadvantage, a faster or a short curing cycle was introduced. This research demonstrates that the impact strength, flexural strength, surface hardness and porosity of denture base resins polymerized by automatic pressure cooker technique is superior when compared to denture base resins polymerized using a long curing cycle or alternative polymerization procedures.

In 1939 Undurwade and Sidhaye studied the polymerization of denture base material in a domestic pressure cooker. The flask was placed in the domestic pressure cooker filled with hot water, and then water was heated to the boiling point. The steam inside the domestic cooker continued to rise to 1520 mm Hg, which was produced by the boiling water. This steam pressure was held for 30 minutes. The automatic control pressure cooker used to heat polymerized acrylic resin in this study is a new concept because it does not require maintaining an initial temperature at or below 70⁰ C(158⁰F). It appeared from this study that the specimens polymerized in the automatic pressure cooker (less than 6 kgf/cm² pressure with the water at 100⁰C for 15 minutes for group B1 specimens and 30 minutes for group B2 specimens) were completely polymerized.⁽⁸⁾

The boiling point of monomer at 6 kgf/cm² pressure can be calculated with the formula to calculate the boiling point of liquids above the atmospheric pressure by Maron and Prutton. The boiling point of methyl methacrylate is 168.9°C at 6kgf/cm² pressure in the automatic pressure cooker (six times atmospheric pressure). This was calculated at 168.9°C, which was 48.9°C (120°F) more than the temperature of curing (100°C) in the automatic pressure cooker. Therefore, it is not possible for the monomer to boil at this higher temperature. This supports the hypothesis that the pressure does play an important role in accelerating the initial polymerization.

The conventional water bath polymerization has been the most widely used denture base processing technique, but the residual monomer content and porosities produced have been suggested as the most significant reasons for the reduced flexural strength.^(19,20) Using a pressurized chamber to heat cure acrylic resin is a new concept, because it does not require initial maintenance of temperature at or below 70⁰ °C. The studies by Xia Chun Ming⁽²⁰⁾ in 1996 showed that there was no significant difference between new pressure cooker and conventional polymerization for surface hardness and porosity. In this study the increased

flexural strength of specimens cured by the automatic pressure cooker compared to the water bath technique may be due to increased degree of polymerization due to the steam pressure along with reduction in the residual monomer content and porosities. The results were in accordance with the studies of Gentleman L et al and Banerjee R et al that curing under pressure produces properties superior to those obtained by curing in open air alone.⁽²¹⁾

In this study the total time consumed by an automatic controlled pressure cooker was only 15 minutes and 30 minutes when compared to conventional curing method, which was one and half hours. Both time and power consumed were less for automatic controlled pressure cooker and at the same time strength is superior to the conventional method.

Flexural strength, (transverse strength / modulus of rupture) is essentially a strength test of a bar supported at each end, or a thin disk supported along a lower support circle, under a static load.⁽²²⁾ Denture base polymers may fail clinically because of flexural fatigue. A complete denture flexes many times during use. The midline fracture that occurs in complete denture is usually a flexural fatigue failure. Another cause of fracture of the denture is impact outside the mouth like accidental dropping of the denture. It is therefore appropriate that flexural strength testing and impact testing was used as a method of comparing the polymers performance.

The transverse strength (flexural strength) of a material is a measure of stiffness and resistance to fracture.⁽²³⁾ Flexural strength tests were undertaken as these were considered relevant to the loading characteristics of a denture base in a clinical situation. The flexural strength of a material is a combination of compressive, tensile, and shear strengths. As the tensile and the compressive strength increases, the force required to fracture the material also increases. Increase in mean load to fracture the specimens and corresponding mean transverse strength was highest in Group B2 followed by Group B1. The transverse strength was least in Group A which was only slightly lesser than Group B1.

Impact strength may be defined as the energy required to fracture a material under an impact force.⁽²²⁾ It is explained as a material's ability to withstand shock loading as measured by fracturing a specimen. Impact testing measures the energy required to break a specimen by dynamically applying a load. The impact property determines overall toughness of the material. Toughness is defined as the ability of the material to absorb applied energy. The area under the stress strain curve is directly proportional to the toughness of the material. The higher the impact strength of the material, the higher is its toughness. Impact properties can be modified by addition of impact modifiers like plasticizer, fillers etc, which appear to act as stress transfer agents. Factors that affect Impact strength are: (a) Orientation of polymer molecules with fillers increases the toughness of material (b) Processing of specimens, where inadequately processed specimens reduce the toughness (c) Voids act as stress concentrators created by poor processing conditions (d) High processing temperatures can also cause thermal degradation and thereby reduce the impact strength (e) High degree of crystallinity reduces the impact strength (f) a reduction in the average molecular weight decreases impact strength.^(22,24,25)

The energy absorbed to fracture the specimens and corresponding impact strength are presented in Table-4. The mean energy absorbed to fracture the specimens and corresponding impact strength was highest in Group B2 (Energy absorbed 0.9072 joules. Impact strength 201.32 joules /mm) followed by Group B1 (Energy absorbed 0.9024 joules. Impact strength 196.73joules/mm). Group A exhibits least impact strength (Energy absorbed 0.824 joules. Impact strength 182.64 joules /mm). Thus, higher the energy absorbed to fracture the specimens, greater the impact strength.

Hardness may be broadly defined as the resistance to permanent surface indentation or penetration.⁽²⁴⁾ The hardness of denture base materials may undergo changes due to continued polymerization reaction and water uptake. However, the extent to which these

processes affect the hardness of materials is still unclear. The type of processing could affect resin mechanical properties such as surface roughness and hardness. Hardness provides a possible indication of the abrasiveness of dental material. The surface properties of acrylic resin can be affected by hardness, which is characteristic of ease of finishing the material as it is resistant to in-service scratching during cleansing.⁽²⁵⁾ The data obtained from the present study shows that Group B2 (17.22) specimens have the greater surface hardness followed by Group B1 (16.18). Group A (15.87) has the minimum hardness compared to rest other groups.

Porosity in acrylic resin is a complex phenomenon of multifactorial origin. It appears to depend partly on the material polymerization method combination and the flasking technique used.⁽²⁶⁾ Various methods have been used to study porosity, including microscopic observation of a cut specimen.^(5,27) A photographic method, and mercury porosimetry is generally regarded as the best method available for the routine determination of pore size.⁽²⁶⁾ There are two major causes of porosity: polymerization shrinkage which is associated to the contraction porosity, and volatilization of the monomer which may be termed as gaseous porosity.⁽²⁸⁾ The data obtained from the present study shows that Group B2 shows least number of porosity followed by Group B1 and Group A. Also, it shows that the average size of the porosity seen in specimens was smaller in Group B2 (24.82 μ) compared to Group B1 (28.25 μ) and Group A (29.40 μ).

There has been continuous research to reduce the processing time and enhance the physical properties of denture base acrylic resins. The present study states that the time required for processing of specimens is least (15 minutes) in Group B1 cured by automatic controlled pressure cooker followed by Group B2 specimens (30 minutes). Group A specimens are cured by conventional water bath technique which required more time (one and half hour) for processing.

Conclusion:

The type of polymerization technique plays an important role in influencing the impact strength, flexural strength, surface hardness and porosity of denture base resin. Flexural strength, Impact strength and Surface hardness of automatic pressure cooker cured denture base resins Group B2 was high, followed by automatic pressure cooker cured denture base resin Group B1 and conventional water bath cured denture base resin Group A. Porosity seen and Processing time in automatic pressure cooker cured denture base Group B2 was less, followed by automatic pressure cooker cured denture base resin Group B1 and conventional water bath cured denture base resin Group A.

The main limitation of this study was that it was an in vitro study where in the in vivo properties are not taken into consideration. Hence, this study can further be improvised by a clinical study where in the properties like water absorption and its correlation on dimensional change can also be considered and evaluated intra-orally; where-in the denture will constantly be in contact with saliva and mucosa.

Conflict of interest: Conflict of interest declared none

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Table 1: Comparison of mean values of flexural load (N) and flexural strength (MPa)

	Group A(n=10)	Group B1(n=5)	Group B2 (n=5)
	Mean \pm SD	Mean \pm SD	Mean \pm SD
Flexural Load (N)	239.95 \pm 12.67	267.58 \pm 11.19	304.68 \pm 18.01
Flexural Strength (MPa)	86.40 \pm 3.80	87.89 \pm 3.39	96.1 \pm 5.57

Table 2: One Way Anova Test for Flexural Strength of PMMA

Source of variation	Degrees of freedom (d.f.)	Sum of squares	Mean square
Treatments (between columns)	5	316633	63327
Residuals (Within columns)	34	3542.9	104.20
Total	39	320176	

Value of F = 607.72, $p < 0.001$, highly significant

Table 3: Comparison of mean values of Impact Load (J) and Charpy Impact Strength (J/m)

	Group A(n=10)	Group B1(n=5)	Group B2 (n=5)
	Mean \pm SD	Mean \pm SD	Mean \pm SD
Impact Load (J)	0.824 \pm 0.076	0.9024 \pm 0.174	0.9072 \pm 0.242
Charpy Impact Strength (J/m)	182.64 \pm 19.78	196.732 \pm 37.16	201.33 \pm 46.49

Table 4: One Way Anova Test for Impact Strength Of PMMA

Source of variation	Degrees of freedom (d.f.)	Sum of squares	Mean square
Treatments (between columns)	5	362291	724.58
Residuals (within columns)	34	17688	520.24
Total	39	379979	

Value of F = 139.28, $p < 0.001$, highly significant

Table 5: Comparison of Mean values of Microhardness Test In HV

	Group A(n=10)	Group B1(n=5)	Group B2 (n=5)
	Mean \pm SD	Mean \pm SD	Mean \pm SD
Microhardness Test in HV	15.872 \pm 0.42	16.18 \pm 0.83	17.22 \pm 1.88

Table 6: One Way Anova Test for Surface Hardness of PMMA

Source of variation	Degrees of freedom (d.f.)	Sum of squares	Mean square
Treatments (between columns)	2	6.132	3.066
Residuals (within columns)	17	18.470	1.086
Total	19	24.601	

Value of F = 2.822, $p < 0.001$, highly significant

Table 7: Comparison of Mean Values of Porosity and Average Size (μ)

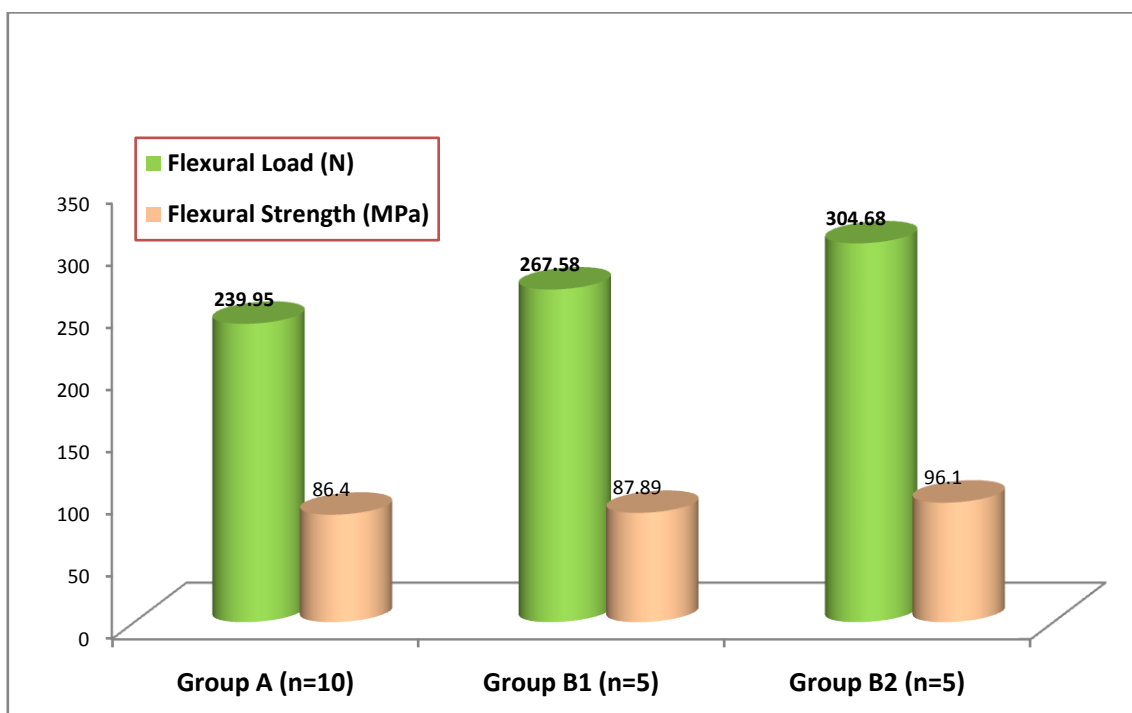
	Group A(n=5)	Group B1(n=5)	Group B2 (n=5)
	Mean \pm SD	Mean \pm SD	Mean \pm SD
No. of Porosity	3 \pm 1.0	2.40 \pm 0.54	2.0 \pm 0.71
Average size (μ)	29.40 \pm 2.70	28.26 \pm 2.46	24.82 \pm 4.34

Table 8: One Way Anova Test for Porosity Seen in PMMA

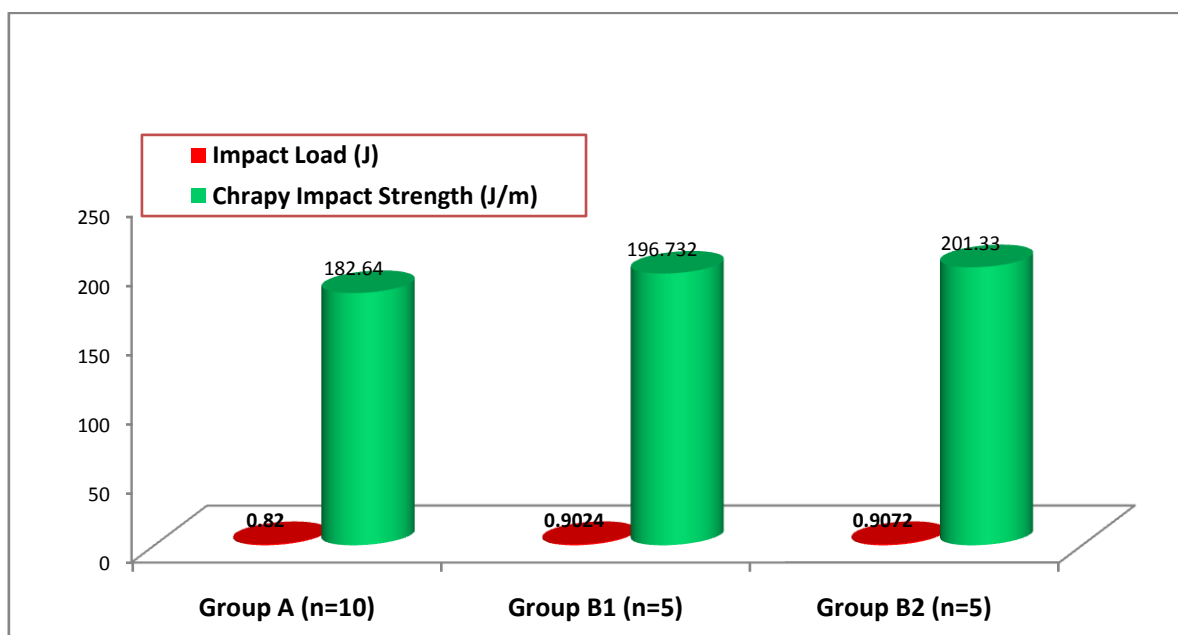
Source of variation	Degrees of freedom (d.f.)	Sum of squares	Mean square
Treatments (between columns)	2	2377.2	1188.6
Residuals (within columns)	12	34.400	2.867
Total	14	2411.6	

Value of F = 414.63, $p < 0.001$, highly significant

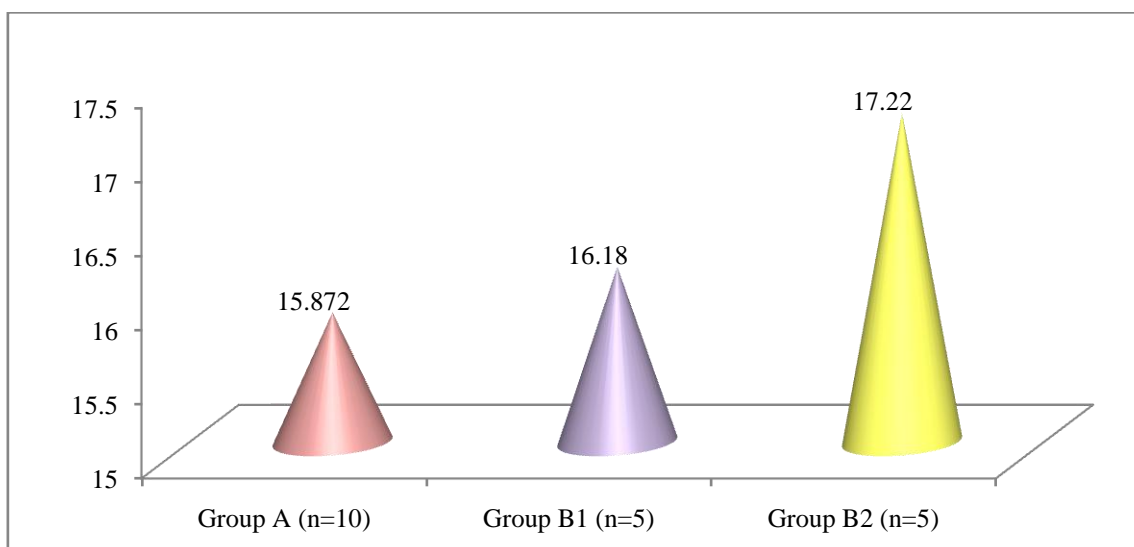
Graph 1: Comparison of mean values of Flexural Load (N) and Flexural Strength (MPa) in Group A, (n=10), Group B1 (n=5) and Group B2 (n=5)



Graph 2: Comparison of mean values of Impact Load (J) and Charpy Impact Strength (J/m) in Group A, (n=10), Group B1 (n=5) and Group B2 (n=5)



Graph 3: Comparison of mean values of Microhardness Test in HV in Group A, (n=10),
Group B1 (n=5) and Group B2 (n=5)



Graph 4: Comparison of mean values of of Porosity and Average size (μ) in Group A, (n=10),
Group B1 (n=5) and Group B2 (n=5)

