Original Article

Evaluation of the Transverse Strength and Elastic Modulus of High Impact Denture Base Material

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Abstract

Introduction: High fracture resistance of prostheses are well accepted by both patients and dentists to have a proper restoration of the dentition. The research designated assess polymerization time effect distinct and complete temperatures on mechanical properties (denture base resin) of a high strength. The research purpose is to assess and compare the procedure used in polymerization distinct effect autoclave on the elastic modulus and transverse strength of a high strength acrylic resin to the conventional heat polymerizing.
Methods: Rectangular sample of ninety-one polymarised high heat strength denture base resin were created. Polymerized sample done by hot water regarded as control group and the other groups were polymerized in autoclave at different temperatures and time lenghts. After deflasking of sample before procedure it was kept forty eight hours in water. Three parameters were used when conducting transverse strength test bending using calibrated universal testing machine with a load of 500 kg cell and a crosshead speed of 5 mm/min. One-way ANOVA was used in assessing transverse strength and elastic modulus data. And for comparison of the groups application of Tukey HSD trial has been seen appropriate ($p<0.05$). **Results:** Specimens that polymerized by autoclave at 130ºC for 20 and 30 minutes showed significantly better characteristics compared to the other groups. **Conclusion:** Upgrading of base resins transverse strength is required because the research indicated autoclave polymerization at 130℃ for 20 and 30 minutes may be an alternative polymerization method.

Keywords: Acrylic Resins, Polymerization, Elastic Modulus.

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Introduction

Since 1973 acrylic resins is the substance used for denture base due it is affordability, esthetics and ease of application (1). However, there are few clinical challenges including fracture resistance of resin bases that are subject to further research. Clinical research, it indicate that common problem face is middle fracture related to maxillary denture (2,3). Concentration of stress and increased flexing usually lead to denture fracture. Denture break happened as result of one of these ; weakining of the base substances during chewing of something or happens when denture is dropped on a hard surface. Further, water absorption by denture base material in the oral cavity make it more susceptible to fracture (4). Mechanical properties of resin bases upgrading consume much time. Mechanical improvement of PMMA has been discussed under three different topics: First PMMA subtitute substance improvement; second, modification of PMMA formula by adding a rubber graft copolymer; and third other substances like ; carbon fibers, glass fibers and ultra-high modulus polyethylene has been used to supplemented PMMA (5). High-impact resin such as; co-polymers, cross-linking agents and a rubber phase in the bead polymer have been used to bolstered the acrylic. The rubber-reinforced acrylic contains butadien styrene rubber substances grafted with methyl methacrylate, which is dispersed in a polymethyl methacrylate matrix. The involvement of rubber serve as crack progress protection (6). Different type of materials known as high strength denture base resin are available in the market. Conventional heat-cured acrylic resin can afford these subtitute substances (7). Beside efforts in improvement of resistance fracture by the addition of a stregthen sbustances, various polymerization procedures were investigated in a effort to reduce polymerization complications. Heat-cured polymerizarion, also known as a conventional method, is the most popular method. The conventional technique entailes monomer-polymer dough moulding and polymerization in a water bath (8). Different curing protocols such as pressure or hot water curing have been proposed to increase PMMA strength (9). Unfortunately, mechanical property challenges including denture fractures have not completely resolved and are still considered common incidents in patients wearing dentures (10). There is modification approach over years in polymerazation approach underwent certain process in an endeavor to upgrade physical mechanic properties of acrylic resins. Polymerization in an autoclave with higher temperature have shown to increase the transverse strength compare to conventional heat cured acrylic resin (11). PMMA producers of denture resins products mentioned that their products are of high quality,upgraded and even lay claim to have novel thou their is no any scientific evidence to prove any strength differences between contemporary versions of PMMA products. Since there is no information about the effect of high polymerization temperature in acrylic resins, further research is required to investigate the mechanical characteristics of high impact acrylic resin. The purpose of this in vitro research is to analyse different effect of temperatures and length of time in polymerization on transverse strength and elastic modulus of a high strength acrylic denture base resin. The null hypothesis was that temperature and length of time in polymerization would effect the transverse strength and elastic modulus of the resin.

Materials and Methods

High strength denture base resin (Rodex, Povere, Milano, Italy) was used in the research (In Table I). Chemical composition of the acrylic resin is been presented. From each group seven samples were drew up for the mechanical test. Ninety rectangular samples of acrylic resin, measuring 65 mm×10 mm×3.3 mm teflon rectangular matrix (ISO/FDSI 1567) were prepared for transverse strength test. Metal master model was individually supported with waxes patterns to copy the sample. Samples were supported in Type III dental stone (Gyproc, Prevest Denpro, Jammu, India) in metal dental flasks.

For control group acrylic resin was mixed base on manufacturers directives as control group. The polymerized sample that was processed in hot water at hundred degree for thirty minutes were observed as control. Test group details are shown in Table II. Then specimens were deflasked and finished using an automatic polishing machine with 200-400-600 grit waterproof carbide papers (Grin PO 2V grinder-polisher, Metkon A.Ş, Bursa, Turkey). Later, samples at period of 20 minutes were cleansed by ultrasound and then stored in distilled water at 37ºC for 48±2 hours before test. Three point bending procedure were conducted in the transverse strength test these are: Universal testing machine (Lloyd Instruments, LRX, Fareham Hant, United Kingdom) calibrated with a 500 kg load cell and a cross-head speed of 5 mm/min. The instruments use for transverse testing are two polished cylindrical support which is 3.2 mm in diameter and 10.5 mm long and a central loading plunger. The two supports has average interval of fifty millimeter which constitute maxillary molars average distance in a complete denture. To get the occurance of fracture and deviation of load deflection a penpendicular compressive force use to apply at the center of the specimen. Regulating of the transverse strength (σ) was done by calibrating the machine and computing the values automatically using the following equation:

$$\sigma=3Fl / 2bh^2$$

The latter F represent the maximum load applied (N), l represent the length between the supports (span length= 50 mm), b represent the width (10 mm) and h (3.3 mm) is the thickness of the sample. The minimum flexural strength of denture base materials (Type 1 heat-polymerized polymers) should not be below 65 MPa (ISO 1567). If the sample of result four out of five goes accordance with the requirement, the substance is consider pass. If only one or two of the sample goes accordance with the requirements the substance is considered failed. In a situation were three of the samples go accordance with the demand test of six new samples will be organised for repeatation. The substance is considered pass if five out of the second serries go accordance with the demand. Elastic modulus (E) was calculated from transverse strength test. Additionally, regulating of samples deflection in (mm) and corresponding forces (N) were done. Equation below was used to calculate. The elastic modulus :

$E= Fl^3 / 4bh^3d$ where d is the deflection (mm).

The elastic modulus of denture base materials (Type 1 heat polymerized resin) should not be below 2000 MPa (ISO 1567). In a situation were three of the sample did not tally with the demand the sample failed. In a condition that three of the transverse modulus results go with with the requirement, preparation of six new sample must be done for retest. And in situation were minimum five sample results of the second series go according with the requirement, the substance is regarded passes.

Table I. Chemical composition of the denture base resin used in this study.

Acrylic Resin	Chemical Composition		Polymerization Cycle	Manufacturer
	Powder	**Liquid**		
Rodex	Rubber-based copolymer, benzoyl peroxide	Methyl methacrylate monomer, ethylene glycol dimethacrylate (EGDMA) as crosslinking agent	Water bath 30 minute at 100℃	Povere, Milano, Italy

Table II. Test groups used in this study

Test Groups	Polymerization Methods
G I	Control, conventional water bath polymerization 9 hours at 74℃
G II	Autoclave polymerization at 60 ^{0}C for 30 min followed by: 100 ^{0}C for 10 min
G III	100 ^{0}C for 20 min
G IV	100 ^{0}C for 30 min
G V	110 ^{0}C for 10 min

G VI	110 ^{0}C for 20 min
G VII	110 ^{0}C for 30 min
G VIII	120 ^{0}C for 10 min
G IX	120 ^{0}C for 20 min
G X	120 ^{0}C for 30 min
G XI	130 ^{0}C for 10 min
G XII	130 ^{0}C for 20 min
G XIII	130 ^{0}C for 30 min

Statistical analysis

SPSS software (SPSS Institute Inc., version 9.0, Cary, NC) was used for statistical assessement with significance level at 5%.

One-way ANOVA was used in analyzing transverse strength and the elastic modulus data, while for comparing the group Tukey HSD test was used.

Results

The Table III was used for presenting results of the transverse strength. Mean values and standard deviations of transverse strength and modulus of elasticity test of each group are summarized in Figures 1-2. Groups XII and XIII showed significant differences compared to the other groups in transverse strength values *($p<0.05$)*. Group XIII showed the highest transverse strength value (124,53±16,38), followed by group XII (112,20±8,48). Group II and III showed the lowest values (90,42±7,59 and 90,82±4,21).

Table III. Mean values and standard deviations of transverse strength test.

Test groups	N	Mean	SD
G I	7	**93,3757**	**6,89434**
G II	7	**90,42**	**7,59**
G III	7	**90,82**	**4,21**
G IV	7	**96,57**	**6,84**
G V	7	**92,29**	**7,39**
G VI	7	**92,85**	**2,86**
G VII	7	**94,92**	**7,85**
G VIII	7	**95,86**	**15,98**
G IX	7	**97,79**	**7,47**
G X	7	**99,89**	**4,99**
G XI	7	**101,14**	**5,77**
G XII *	7	**112,20**	**8,48**
G XIII *	7	**124,53**	**16,38**
Total	91	**98,66**	**12,40**

* The mean difference is significant at the .05 level.

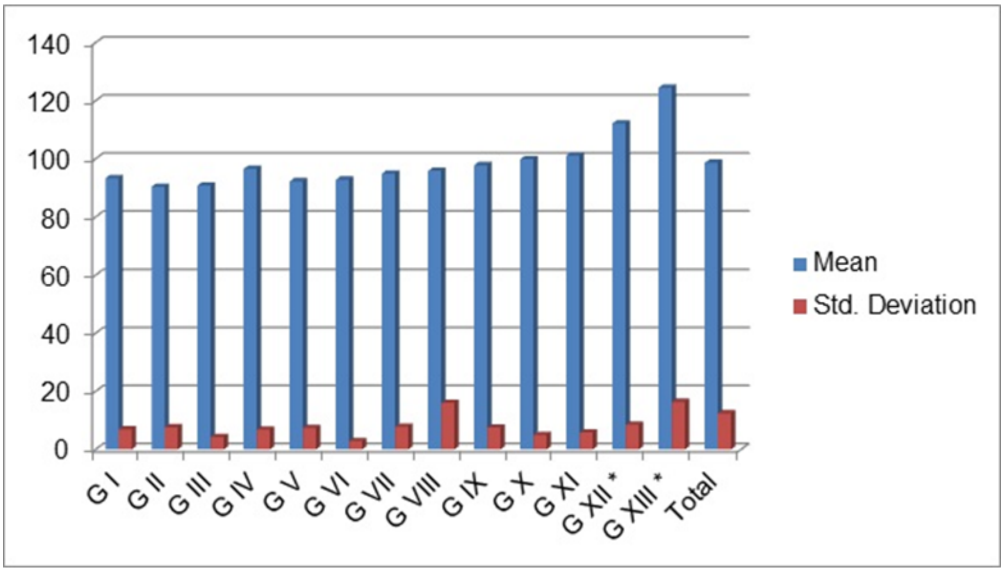

Figure 1. Transverse strength of resin in different polymerizing conditions

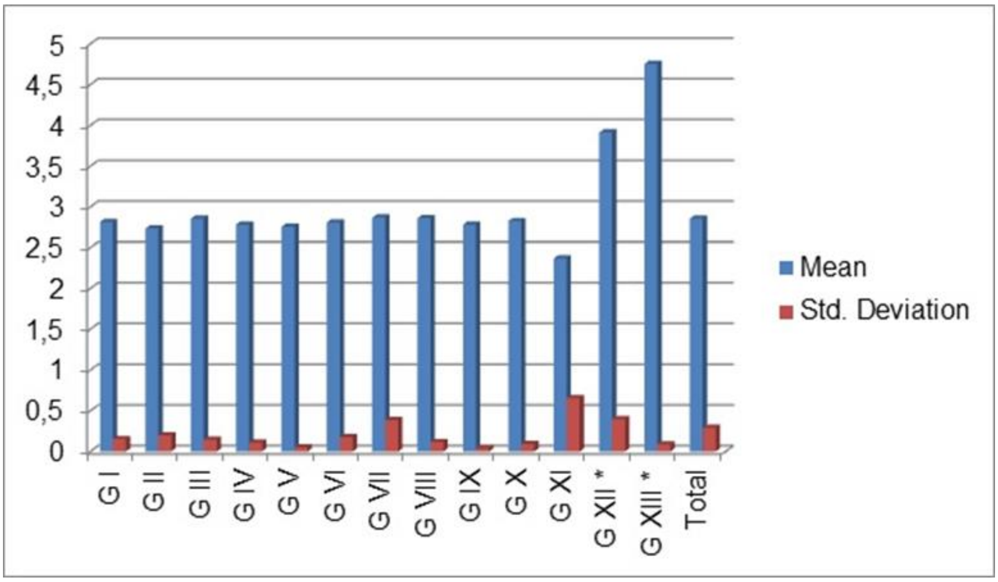

Figure 2. Modulus of elasticity results of resin in different polymerizing conditions

Table IV was used to present results of the elastic modulus test. Groups XII and XIII showed significant differences regarding the elastic modulus values (*P<0.05*) when it contrast with other group. Group XIII showed the highest elastic modulus value (4,75±0,08), followed by group XII (3,91±0,39). Group XI showed the lowest value (2,36±0,65).

Table IV. Mean values and standard deviations of elastic modulus test

Test groups	N	Mean	SD
G I	**7**	**2,81**	**,15**
G II	**7**	**2,73**	**,19**
G III	**7**	**2,85**	**,14**
G IV	**7**	**2,78**	**,10**
G V	**7**	**2,75**	**,04**
G VI	**7**	**2,81**	**,17**
G VII	**7**	**2,87**	**,38**
G VIII	**7**	**2,86**	**,11**
G IX	**7**	**2,78**	**,04**

G X	**7**	**2,82**	**,09**
G XI	**7**	**2,36**	**,65**
G XII *	**7**	**3,91**	**,39**
G XIII *	**7**	**4,75**	**,08**
Total	**91**	**2,85**	**,28**

* The mean difference is significant at the .05 level.

Discussion

The previous studies, it was stated that heat-cured acrylic resins showed high strength values at higher polymerization time and temperature during polymerization process. There are not much studies related "effect of autoclave polymerization on physical and mechanical properties of PMMA" denture base resin. In current study, autoclave polymerization was performed at higher temperature, time and pressure compared to conventional heat polymerization. Subsequently, transverse strength and elastic modulus values of high impact acrylic resin were compared.

Research purpose was to assessed transverse strength and elastic modulus of denture base using different autoclave polymerization method, temperature and time. The hypothesis of this in vitro study was that autoclave polymerization, temperature and time that effect the transverse strength and elastic modulus of denture base resin.

In our previous study, polymerization in an autoclave device with higher temperature showed to increase transverse strength of heat polymerized denture base resins when compared to conventional water bath technique. It could be beacuse in conventional water bath technique temperature could reach only up to 100ºC. However, temperature may be set up above 100ºC automatically when polymerization is performed in an autoclave device (11).

In this study, autoclave polymerization was performed at different temperatures and time lengths. In this study, polymerization temperature of 100, 110 and 120ºC and polymerization time of 10, 20, 30 minutes were selected randomly. The highest value of the transverse strength was reached in groups of 130ºC 10-20-30 minutes. Polymerization at 130 ºC for 20 and 30 minutes showed significantly higher transverse strength and elastic modulus values. Conversely, the results for the autoclave polymerization at 110 and 120ºC groups indicate statistically no different from the control group. These findings can be described due to increased pressure and increased cross-linking at 130ºC conditions. As a result of crosslinking, a 3D network formed an adequate number of bridges between macromolecules that led to the increased strength and rigidity of the resin (12,13). The study results come to conclusi and agreed with the studies doe by Gad *et al.* (13) and Abdulwahhab (14) who found significant increase of autoclave polymerization in flexural properties of PMMA denture bases.

In other studies, effect of autoclave polymerization on transverse strength of denture base polymers was done (11, 15). Indication from the results of polymerization in an autoclave showed a statistically significant increase of transverse strength when contrasted with water bath. Also autoclave curing resulted in better stability when contrasted with water bath; because autoclave provides a chance of even heat distribution through out the flask and provides complete polymerization by enhancing higher cross-linking bonds between the polymer chains (16).

There is risen in time and temperature in different polymerization, specifically in high impact resin, elastic modulus values were suddenly increase when very close between groups I and XI. This was lower for a very small variation with the polymerization time of 100 or 110 ºC. In order to achievede a good outcome, high temperature should be used for suitable handling of the substance.

During the polymerization process, providing of higher polymerized compound is been achieved as a result of activation cause by heat in chemical reactions between the monomer and polymer components of the resin. Increased polymerization by thermal stimulation give rise to complete network of polymer chain and improves mechanical properties of the resin. Pressure during polymerization also enhances the strength and stiffness of the resin due to the reducing porosity of the material (17) .

Different studies have reported that mechaical change of properties from the denture base may affect the difference in polymerization process (18). Barbosa *et al*. (19) Assessement of the Effect of microvawe polymerization in the flexural strength indicate higher flexural properties. Dogan *et al*. (20) The effect of different temperatures and curing times assessement found that longer curing times improved the tensile strength and decreased the residual monomer of heat cured resins.

Fracture is potentially a major problem in heat polymerized resins when prosthesis is used for a long time, thickness of resin is not sufficiesnt or base has been repaired multiple times. The condition has direct effect on transverse strength of the resin and it related substance. Stability of the prosthesis is been affected inflexibility. Patient faces discormfort as a result of induce extra flexibility and chewing efficiency is being reduce. These has relation with transverse modulus of the material (6). Transverse strength is defined as resistance of the material to fracture and was evaluated in our study with an effort to simulate the clinical situation in the oral cavity. Elastic modulus is also an important property that shows mechanical behavior of the resin. The machine chosen for the tests, the Lloyd's Instruments Materials Testing Machine is routinely used and widely accepted in similar studies and tests were carried out according to the International Standard Organization (ISO 1567) (21).

Two limitations could be discussed in the present study. First one is that we tested twelve randomize autoclave polymerization protocols; however, the change of resin's properties after autoclave heating for longer period of time or higher temperature is unknown. The second is that only two properties were used for the polymerized samples. Thus, it is suggested for the up coming studies on residual MMA that the effect of different curing processes (for autoclave-polymerized samples) as well as the effect of polymerization time, and temperature would also be included in the study.

Conclusion

The research come to conclusion that higher temperature with pressure increases the strength and stiffnes of methyl methacrylate heat polymerizing resin. Autoclave polymerization method at 130ºC for 20-30 minutes may be an alternative method to improve the mechanical properties of the denture base resins. Further research is required to be conducted on the effect of biological properties of this polymerization conditions on denture base resins.

Conflict of interest

Current research seem is free of conflict of interest.

Acknowledgment

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