ORIGINAL ARTICLE

FLEXURAL STRENGTH OF MODIFIED AND UNMODIFIED ACRYLIC DENTURE BASE MATERIAL AFTER DIFFERENT PROCESSING TECHNIQUES

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Background: Conventional heat cure polymerized acrylic resin(unmodified) is most acceptable denture base material in dentistry since decades. It has been modified with reinforcement of fillers and different processing techniques were introduced to enhance its mechanical and physical properties. The objective of this research is to determine and compare the effect of different processing techniques on flexural strength of modified and unmodified denture base acrylic resin. Air circulating oven is introduced for the first time in this study and its efficacy is also compared with other conventional processing techniques. **Methods:** In this study total number of 114 rectangular specimens were fabricated by conventional heat cured acrylic (Stellon QC 20, Dentsply) for Group A (n=57), and rubber reinforced acrylic resin (High impact, Meadway) for Group B (n=57). Three equipment including water bath, dry oven and air circulating oven were utilized for processing specimens individually. Each sub-group of processing techniques (n=19) were tested for flexural strength through a three-point bending test by a universal testing machine. The statistical analysis initiated with descriptive analysis followed by independent t test for mean comparison of flexural strength of all three processing techniques among both testing group. One-way ANOVA and 2-way ANOVA followed by Scheffe post hoc test were also applied. *p*-value of 0.05 or less was considered as significant. **Results:** Statically significant *p*-value <0.001 was found in response of flexural strength in all processing techniques (water bath, dry oven, air circulating oven) of both testing groups. Water bath processing demonstrated highest flexural strength values in both denture base material used in this study. The unit used for flexural strength was MPa. **Conclusion:** This study manifested highest flexural strength in conventional and rubber reinforced heat cure samples when processed through water bath. Air circulating oven also presented acceptable flexural strength in conventional heat cure acrylic resin specimens when compared with other techniques.

Keywords: Processing technique; Water bath; Dry oven; Air circulating oven; Conventional heat cured acrylic resin; Rubber reinforced acrylic resin

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INTRODUCTION

Since earlier than the 20th century till present, the most dominant heat cured acrylic denture base resin material is Poly methyl meth acrylate (PMMA).[1,2] It has remained the material of choice due to it exhibiting acceptable aesthetics, cost effectiveness and compatibility with the oral environment, as well as its simplicity in use and maintainace.[3] Contrarily, PMMA has shown low fracture resistance of the base of denture due to repeated functional occlusal loads.[4,5] Flexural strength denotes the highest stress experienced within the material at its time of fracture.[6]

It manifest that the prosthesis will perform the functions for which it was designed in a sufficient and secure manner, for a reasonable duration. Low flexural strength property of any denture base material may cause a fracture of the denture base over long-term use of the denture. According to ISO 20795-1 (international standard of denture base polymer), to avoid any compromised strength, the denture base material should have flexural strength not be less than 60 MPa.[7] Researchers have attempted to modify the composition of PMMA by the addition of fillers, fibres and rubber, in order to improve its strength property, however none have succeeded to develop the ideal one.[8–10] In comparison with unmodified polymer, rubber reinforced polymers containing rubber particles have low modulus of elasticity which lowers the rigidity of the denture base.[5] Polymerization time, cycle and methods have a strong effect on the mechanical properties of heat cured denture base resins.[11,12] various polymerization methods and cycles were introduced to achieve the maximum strength of the denture base.[13,14] Researchers have experimented with different polymerization equipment as well, to compare the effect on strength with other conventional processing techniques.[15–17]

The water bath processing technique is the most widely used technique to process heat cure acrylic resin for denture bases.[18,19] The dry oven has been rarely used in the past invitro researches to process dentures and compared with other techniques. In this research, an air circulating oven was used for processing heat cured acrylic resin. It provides a convection heating system and includes a fan, a blower for moving the convection air homogenously, and a heat source for heating the convection air.[20]

The air circulating oven is a new equipment and used for the first time to process denture base materials in order to evaluate and compare the flexural strength of modified and unmodified acrylic resins. The present study was conducted to determine the effect of different processing techniques on flexural strength of conventional heat cured and rubber reinforced acrylic resins. The null hypothesis of the study was that processing techniques does not effect on flexural strength of conventional and rubber reinforced heat cured acrylic resins.

MATERIAL AND METHODS

In this experimental Invitro study fabrication and processing of specimens for flexural strength were carried out at Pakistan Council of Scientific and Industrial Research laboratories (PCSIR), Department of Plastic and Polymer, Karachi, Pakistan. Data entry and write up of thesis was done at Dow Dental College (Department of Science of Dental Materials), Karachi, Pakistan. Samples measurements 65mm long, 10mm wide and 2.5mm thick for flexural strength. Dimensions were followed by ISO standard specification 20795-1:2008: Dentistry. Denture base polymer. Two commercially available brands of heat cure acrylic resin for denture base were tested for this study; conventional heat cure acrylic resin (Stellon QC-20, Dentsply) and rubber reinforced heat cure acrylic resin (High impact, meadway). Hard plastic sheets (Figure 1, 2 & 3) were made to create space for samples in the plaster poured in flasks. Fifty-seven samples (n=57) were fabricated from each material following the measurement.

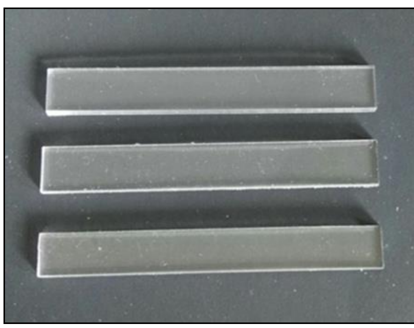

Figure-1: Hard plastic sheets

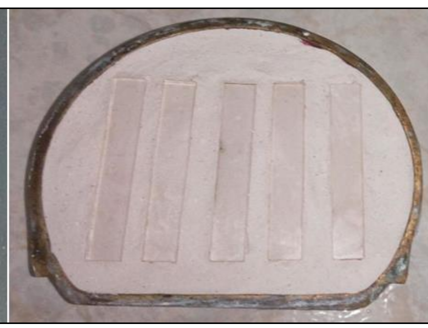

Figure-2: Plastic sheets embedded in plaster

Figure-3: Space for packing of material

The mixing of material was performed according to the manufacturer's instructions. Specimens were processed through an air circulating oven (92 ºC for 120 mins), a dry oven (92 ºC for 120 mins), and through a water bath (74 ºC for 90 mins and then 100 ºC for 30 mins). Deflasking was conducted to remove specimens from the flask, and was proceeded by finishing and polishing. The polishing was done with a slurry pumice and with a cotton buff. Samples measurement were rechecked by manual Vernier calliper (VIS, Poland) to verify dimensions. Samples were kept in a covered and labelled distilled water container for 3-point bending test. The flexural strength of specimens was tested by a universal testing machine, instron, Model #4301 and Serial #H 1853. The sample was placed on the support beam with 50 mm span. A load was applied to the testing machine and applied to the centre of the sample at a cross head speed of 5mm/minute until it fractured.

The formula followed for calculation of flexural strength was.[21]

The flexural strength (FS in MPa) $FS = 3PL/2wt^2$

Where P, is the maximum load (N). L, is the span length (m). w, is the specimen width (m) and t, is the specimen thickness (m).

Dependent variable included flexural strength and independent variables included all 3 processing techniques these and two heat cured acrylic resins used in the study. Descriptive statistics was performed for flexural strength in control and experimental groups, 1-Way ANOVA was applied for comparing mean of flexural strength among three different processing techniques (water bath, dry oven, air circulating oven) in both testing groups individually followed by Scheffe post hoc test. Independent sample t test was applied for comparing mean between two groups control and experimental on flexural strength of each processing technique. Furthermore 2-way ANOVA was utilized to test interaction on flexural strength between testing groups and all three processing modes (water bath, dry oven, air circulating oven). The measured data was entered into SPSS version 21. *p*-value of 0.05 or less was considered as significant.

RESULTS

For conventional heat cured samples, the calculated mean flexural strength values difference between all processing techniques were statistically significant at the 0.05 level. (p<0.001). In the post hoc scheffe test, significant difference in the values of flexural strength was found when comparing a combination of two processing techniques at a time, i.e., water bath with dry oven, water bath with air circulating oven, and dry oven with air circulating oven. These results revealed that each processing technique affected differently on the flexural strength of the conventional heat cure and rubber reinforced heat cure acrylic. The water bath processing technique exhibited enhanced values of flexural strength on both heat cured acrylic samples followed by air circulating oven. The lowest flexural strength was observed in samples processed by a dry oven. In experimental group, results revealed a significant effect of different processing techniques on flexural strength on the rubber reinforced acrylic samples. Post hoc Scheffe test also showed significant results when comparing a combination of all three processing techniques.

The highest flexural strength values in the experimental group were found in samples processed by a water bath followed by a dry oven. The lowest value was found in air circulating processed samples. Convincingly, the two-way Anova test also confirmed the interaction effect is also statistically significant between processing techniques and study groups (p<0.001). An alternative hypothesis was accepted in that different processing techniques have affected differently on flexural strength of conventional and rubber reinforced acrylic resins, hence the null hypothesis was rejected.

Table-1: Sample size distribution

	Water Bath	Dry Oven	Air Circulating Oven	Total samples (n)
Group A Control Conventional Heat Cure Acrylic Resin (n = 57)				
Flexural Strength	19	19	19	57
Group B Experimental Rubber Reinforced Heat Cure Acrylic Resin (n = 57)				
Flexural Strength	19	19	19	57
Total Sample Size:				114

Table-2: Mean comparison of Flexural Strength between control and experimental group with water bath, dry oven and air circulating oven

Test Variable	Curing Modes	n	Mean	S.D.	Min	Max	F statistics	Sig.
Control Group								
Flexural Strength	Water bath	19	88.081	6.450	80.04	98.75	174.395	<0.001
	Dry oven	19	57.937	4.468	50.40	66.10		
	Air circulating oven	19	74.912	3.617	69.50	80.10		
Experimental Group								
Flexural Strength	Water bath	19	76.683	4.052	66.10	80.67	236.471	<0.001
	Dry oven	19	63.616	2.476	60.00	67.20		
	Air circulating oven	19	55.815	2.061	51.60	58.80		

**p*-value 0.005 or less was considered significant

Table-3: Scheffe Multiple Comparisons Post Hoc test on flexural strength in control

	Water Bath	Dry Oven	Air Circulating Oven	Mean Difference
Control Group	88.081	57.937		30.14368*
	88.081		74.912	16.97421*
		57.937	74.912	13.16947*
Experimental Group	76.6830	63.6163		13.06668*
	76.683		55.8153	20.86774*
		63.616	55.8153	7.80105*

*Sign is indicating significant difference of mean values of flexural strength among the combination of two processing techniques in study groups

Table-4: Two-way analysis of variance for mean flexural strength among curing techniques between control and experimental group

Source	Type III Sum of Squares	Degree of freedom	Mean Square	F- test statistic	*p*-value
Intercept	550766.239	1	550766.239	32577.251	<0.001
Groups	1950.050	1	1950.050	115.343	<0.001
Curing Modes	9847.746	2	4923.873	291.242	<0.001
Groups *Curing Modes	3054.886	2	1527.443	90.347	<0.001
Error	1825.899	108	16.906		
Total	567444.819	114			
R Squared =0.891 (Adjusted R Squared =0.885)					

DISCUSSION

The study data of the control group and experimental group examined revealed that conventional heat cured acrylic and rubber reinforced samples showed significant results (*p*-value <0.001) for flexural strength among water bath, dry oven and air circulating oven processing techniques. Results demonstrated that the water bath cured samples of conventional heat cured acrylic resins had shown the highest mean value of flexural strength compared to the dry oven and air circulating oven processing techniques. These results were supported by past study conducted by Seo *et al.*[15] They determined flexural strength and Vickers hardness of a heat cure acrylic denture base. The materials in their study tested were cold cure acrylic (Kooliner-K) and conventional heat cure acrylic (Lucitone 550-L) which were processed under a long curing cycle (71 ºC for 9 hours), and a short curing cycle (73 ºC for 90 minutes followed by terminal boiling at 100 ºC for 30 minutes).

They concluded that long curing cycles without terminal boiling resulted in lower flexural strength values, while conventional heat cure acrylic using short curing cycle with terminal boiling at 100 ºC showed higher flexural strength. Urban *et al*,[20] in their study, also supported the significance of terminal boiling in the processing procedure. They compared residual monomer among chair side reline resin and conventional heat cure resin (Lucitone550-L), which was cured by a water bath short curing cycle (73 ºC for 90 minutes and then terminal boiling at 100 ºC for 30 minutes) and long curing cycles (at 73 ºC for 9 hours) of microwave and water bath curing techniques. Their study concluded that the post polymerization treatment in both processing techniques reduced the residual monomer content in processed samples.

The findings of both studies supported conclusion of present study, that flexural strength was enhanced in conventional heat cure resin when cured at 74 ºC for 90 minutes and then at 100 ºC for 30 minutes as compared to dry heat and air circulating oven, because of terminal heat treatment. The already stated fact could further be explained by certain conclusions extracted from other past studies, that residual monomer remain in the polymerized resin is reduced by diffusion in water. The polymerization process is temperature dependent, thus increased temperatures enhance diffusion of residual monomer, and its reduced remaining content in cured acrylic resin resulted in improved flexural strength.[22,23] In a past study conducted by Nejatian *et al*,[18] it showed the impact of packing and curing techniques on biaxial flexural strength (BFS). They used a water bath and a dry oven as curing devices and followed three different curing cycles including 4 hrs at 75 ºC, 2 hrs at 95 ºC 8 hrs at 75 ºC, 2 hrs at 95 ºC (3) 2 hrs at 95 ºC. The results showed that 95 ºC for 2 hrs was the optimum temperature for curing acrylic resin and a water bath is preferable over dry heat oven, as it provides the highest BFS value at 95 ºC for two hours. Similar results were observed in our study when the flexural strength of the specimen fabricated from a water bath was compared with a dry oven. The possible cause of low values of flexural strength, is the production of slow heating inside the oven.

According to the results in experimental group, a high impact rubber reinforced heat cured acrylic resin showed highest mean values when cured through water bath. The air circulating oven technique also showed acceptable, mean and standard deviations of flexural strength in the control group and was 74.912±3.617 respectively, which follows the recommended flexural strength values standardized by ISO 20795-1, denture base polymer. The possible reason is likely to be homogenous hot air in air circulating chamber. Heat which is used to activate resin effects the maturity of the reaction, therefore its maintenance during processing influenced on properties of cured acrylic resin.[24] Among all processing techniques, water bath processed samples showed the highest flexural strength in both acrylic denture base resin used in the study. No previous research was available on the processing of heat cure acrylic resin through an air circulating oven to compare with this study.

This study also demonstrated that flexural strength in a conventional heat cure acrylic was enhanced more than rubber reinforced heat cure acrylic resin. The addition of rubber in acrylic resin has been successful, but its effect on modulus of elasticity is not beneficial and hence effects the rigidity of the material.[25] The reinforcement of rubber in acrylic resin was considered successful, but it has an adverse effect on the flexural strength and therefore also on the rigidity denture base. Rubber reinforced polymers have low modulus of elasticity because they are filled with rubber particles.[26]

This finding favours the results of the study which revealed high flexural strength values in the control group (conventional heat cure acrylic resin), when compared with high impact acrylic resin cured through the water bath processing technique. Another study conducted by Jagger *etal*,[5] investigated the transverse and impact strength among six high strength denture base acrylic resins (Metrocryl High, Lucitone 199, Sledgehammer, Enigma Hi–Base and N.D.S Hi), and a conventional heat cure acrylic resin (Trevalon), which was used in control group. These heat cure acrylics were processed by water bath for 7 hrs at 70 °C and 3 hrs at 100 °C. It was observed in their study that flexural strength was improved in the samples that were fabricated with conventional heat cured acrylic. Their results explained the fact that an increase in flexural strength is related with an increase in the rigidity of the denture base material. Also, that the incorporation of rubber in high strength acrylic resins results in less rigidity and therefore their flexural strength was compromised when compared with un-reinforced conventional acrylic resin.

The limitation of this invitro experimental study includes that the followed measurements of testing samples do not simulate clinically the dimensions of the dentures. Flexural strength was assessed through machines so oral environment, occlusal and functional loads were not possible to perform. A new of processing technique of denture base materials by an air circulating oven was performed, a direct comparison of this equipment with the results of previous studies was not possible.

CONCLUSION

Under the limitations and experimental conditions of this study, it was concluded that the use of the water bath processing technique has resulted in improved flexural strength for both materials when compared with two ovens. Flexural strength was enhanced in conventional heat cure acrylic resin when compared with rubber reinforced heat cure acrylic resin.

Air circulating oven was used first time for the processing of denture base resins. It was also established that it can be avail as an alternative processing equipment for the fabrication of heat cure acrylic denture base materials but still more studies are suggested to be done to reassess the results of the present study for their clinical or laboratory implications.

AUTHORS' CONTRIBUTION

AK: Sample fabrication, testing samples data entry and write up. FA: Planned research methodology and Proof reading. SJM: Guide in testing samples and Performed calculation, AA: Data analysis and interpretation

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