EVALUATION OF THE FLEXURAL STRENGTH OF TWO DIFFERENT DENTURE BASE MATERIALS SUBJECTED TO DIFFERENT CURING PROCEDURES: AN IN VITRO STUDY

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Abstract

The aim of the study was to evaluate the flexural strength of different types of denture base acrylic resin when they were subjected to different curing procedures (Short and long curing procedures).
Materials and Methods: In this study, a total of 160 samples were made using high impact and conventional denture base acrylic resin, 80 samples of each. 40 samples of each denture base resin material where subjected to long and short curing cycle. Samples were carefully retrieved after complete cooling and trimmed and polished. Width and thickness of samples were measured using a digital vernier caliper. The flexural strength of the samples was recorded using the three-point bending test device present in universal testing machine. The results obtained were then statistically analyzed using ANOVA and paired t test.
Results: It was observed that the flexural strength of high impact denture base material cured using long and short curing cycle had mean value of 86.52 MPa and 81.23MPa respectively. Conventional denture base resin cured using long and short curing cycle had a mean value of 74.03 MPa and 68.02 MPa respectively.
Conclusion: it was concluded that the denture base resin material cured using long curing cycle had higher flexural strength then the denture base material cured using short curing cycle. Trevalon HI showed higher flexural strength compared to DPI, when cured using both long and short curing cycle.

Keywords Polymerization Procedure, Denture Base Resin, Flexural Strength, Polymethyl Methacrylate, Long Curing Cycle, Short Curing Cycle

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1. Introduction

Since 1930s Poly-methyl methacrylate has been used as a denture base material as this material fulfils the indispensable properties like dimensional stability, low water sorption and high strength. Commonly, the drawback of denture base material was breakage which could have been due to any laboratory error or due to insufficient thickness.[1]

It has been observed that the processing techniques affect the mechanical properties including flexural strength and impact strength of the denture base resin. Mechanical property like flexural strength is of foremost importance as over a long period of clinical usage of acrylic resin prosthesis they are vulnerable to fracture. Time and temperature are two variables which play a salient role in processing of heat cured acrylic denture base resins.[2]
It was perceived that the mechanical properties improved for denture base resin where the curing cycle lasted for more than six hours with or without the terminal boiling as it led to lower amount of residual monomer. There was almost complete conversion of monomer which showed remarkably improved flexural and impact strength when polymerization using longer curing cycles of 8 hours at 74°C with a terminal boiling for 1 hour was subjected.[2]

To save substantial amount of laboratory time, shorter curing cycle of about 74°C for 2 hours with a terminal boiling for 1 hour was introduced to shorten the polymerization process. The main drawbacks of this curing procedure were porosity and high residual monomer content in the denture base resin. It was established that if the polymerization process was incomplete or if the terminal boiling was avoided in polymerization process than the residual methyl methacrylate concentration was high. This residual methyl methacrylate would percolate out from the denture base resin and can cause several adverse effects on the oral mucosa.[2]

Over the years, many refinements were sought out to enhance the mechanical properties of poly-methyl methacrylate denture base resin. The modification includes chemical modification of poly-methyl methacrylate by introducing butadiene styrene in the denture base resin to produce graft copolymer (high impact denture base resin) and mechanical reinforcement by incorporating silanized (E)- glass fibers.[3]

Fracture usually sets in due to debility, when poly methyl methacrylate cannot tolerate intra-oral and extra oral impact forces because of inadequate flexural, compressive, transverse, fatigue and impact strength. Various modalities have been proposed to strengthen the resin by reinforcing the resin with various fillers and embedding a solid metal form in the resin.[4]

There are numerous approaches by which the mechanical and physical properties of the denture base resin can be ameliorated by copolymerization of poly methyl methacrylate with isobutyl-methacrylate, ethyl-methacrylate or butyl-methacrylate.[5]

It is studied that there is difference in the flexural strength, surface hardness and the flexural modulus of denture base resin when cured using different procedures. Light and heat cured urethane di methacrylate denture base resin exhibited enhanced flexural strength, surface hardness and the flexural modulus when compared to heat only cured and self-cured denture base polymers.[6]

Recently it was discovered that the reinforcement of denture base resin with titanium dioxide nanoparticles[7], graphene and silver nanoparticles[8], zirconium dioxide nanoparticles[9], silicon dioxide nanoparticles[10] and aluminium oxide[11] affects the mechanical and physical properties. It was observed polymethyl methacrylate incorporated with graphene and silver nanoparticles[8] showed increased antibacterial activity as well as improved flexural properties but no notable variance in flexural strength with the others.

Incorporation of fibers (e-glass fibers[9], woven glass fibers[12], micronized glass flakes[13]) showed increase in the flexural strength when reinforced with e-glass fibers[9], woven glass fibers[12] whereas flexural strength decreased with increase in micronized glass flakes[13] concentration. It has also been reported that the variation in the polymer to monomer ratio greatly effects the strength of unreinforced material whereas very limited amount is known about its action on the reinforced denture base resin.[14]

Therefore, there is a clear requirement of understanding why these types of breakage occurs and to discover different courses of action to fortify the dentures to fend off such failures.[15]

The study behind this investigation was to assess which curing procedure helps in increasing the flexural strength of the denture base acrylic resin.

2. Methodology

A stainless-steel die was fabricated according to ADA Specification No.12 having dimension of (65 mm x 10 mm x 3 mm) (fig.1). The die was embedded in flask with type III dental stone according to conventional flasking procedure. Two brands of heat cure acrylic resin material (DPI and Trevalon HI) were used to prepare specimens.

After the dental stone (type III) had set, the die was removed from the flask and heat cure acrylic resin (DPI and Trevalon HI) were mixed in ratio of 3:1 (polymer to monomer) and the dough were packed into the flask under hydraulic press. The flask was placed in clamp and immersed in an acrylizer unit (Unident) containing water at room temperature and cured using two different standard curing procedures (short and long curing procedures).

Short Curing Procedure: The specimens were cured in water bath for 90 minutes at 74°C and increasing the temperature of the water bath to 100°C for 30 minutes and processing for 1 hour. Then acrylizer was switched off and the flasks were bench cooled overnight at room temperature before deflasking.

Long Curing Procedure: The specimens were processed at 74°C for 8 hours. After completion of curing cycle, the acrylizer was switched off and the flasks were bench cooled overnight at room temperature before deflasking.

After complete cooling, the specimens were carefully retrieved and excess resin was trimmed using a laboratory micromotor and polished. The acrylic resin samples were hand polished using #320-, 600-grit silicon carbide paper. The samples were then polished using a lathe with a rag wheel and polishing paste (pumice and water).

The width and thickness of the specimens were then measured using a digital vernier caliper of ±0.1mm accuracy (Zhart, India). All the specimens were trimmed and finished to a final dimension of 65x10x3mm.

The accuracy of the dimensions was verified at three locations of each dimension. Since the width and thickness are the factors assessed for determining flexural strength, the resin specimens only with slight variations in size (up to 0.2mm) were included in the study. The final sample dimensions were measured as

follows: length 65±0.2mm, width10±0.2mm, height 3±0.2mm.
The samples were stored in distilled water at 37°C for one month.
A measurement of 6 cm was marked on the sample using a compass which held two fine point black permanent marker pens on all the specimens. The markings were then check again with a divider which had adjustable screw to ensure the point were marked correctly on all the specimens. Then the third point was marked at 3cm at the center of the markings made before on all the specimens.
The samples were divided in 4 groups (40 each). (Fig.2)

Group 1: 40 specimens packed using heat cure acrylic resin (DPI) were subjected to short curing cycle.
Group 2: 40 specimens packed using heat cure acrylic resin (DPI) were subjected to long curing cycle.
Group 3: 40 specimens packed using heat cure acrylic resin (Trevalon HI) were subjected to short curing cycle.
Group 4: 40 specimens packed using heat cure acrylic resin (Trevalon HI) were subjected to long curing cycle.

Method of collection of data

The flexural strength of all the specimens were recorded using the three-point bending testing device in a Universal Testing Machine according to the American Society for testing and materials standard D790 for flexural testing of reinforced plastics.
The testing device consists of a central loading plunger and two polished cylindrical supports 3.2mm in diameter and 10.5mm long. The distance between the centers of the support is 50mm. The specimens were centered on the device, the loading wedge was brought down at a crosshead speed of 5mm/min and the loading continued until fracture occurred. The compressive force was applied perpendicular to the center of the specimens until a deviation of the load deflection curve and the fracture of the specimen occurred.
Transverse strength is computed using the following equation

$$S = \frac{3 \times W \times L}{2 \times b \times d^2}$$

Where,
S= Transverse strength
W= load at fracture (N)
L= distance between supporting wedges (50.00mm)
b= width of the specimen (mm)
d= thickness of the specimen (mm)
Thereafter, the result was statistically analysed.

3. Observations And Results

Table I: Descriptive analysis of Trevalon HI: Long Cycle and Short Cycle

Trevalon HI	Mean	SD	Paired t test	p value
Long Cycle	86.52	2.14	9.32	<0.01*
Short Cycle	81.23	2.31		

***statistically significant**

Table I shows the distribution of the mean and standard deviation values of flexural strength of Trevalon HI heat cure acrylic material cured using long and short curing cycle. The results with Trevalon HI long curing cycle are significant.

Table II: Descriptive analysis of DPI: Long Cycle and Short Cycle

DPI	Mean	SD	Paired t test	p value

Long Cycle	74.03	2.32	10.97	<0.01*
Short Cycle	68.02	2.46		

***statistically significant**

Table II shows the distribution of the mean and standard deviation values of flexural strength of DPI heat cure acrylic material cured using long and short curing cycle. The results with DPI long curing cycle are significant.

Table III: Comparison of Trevalon HI Long Cycle vs DPI Long Cycle

Long Cycle	Mean	SD	t test	p value
Trevalon HI	86.52	2.14	23.92	<0.01*
DPI	74.03	2.32		

***statistically significant**

Table III shows the distribution of the mean and standard deviation values of flexural strength of Trevalon HI and DPI heat cure acrylic material cured using long curing cycle. The results with Trevalon HI long curing cycle are significant.

Table IV: Comparison of Trevalon HI Short Cycle vs DPI Short Cycle

Short Cycle	Mean	SD	t test	p value
Trevalon HI	81.23	2.31	24.54	<0.01*
DPI	68.02	2.46		

***statistically significant**

Table IV shows the distribution of the mean and standard deviation values of flexural strength of Trevalon HI and DPI heat cure acrylic material cured using short curing cycle. The results with Trevalon HI short curing cycle are significant.

4. Discussion

Polymethyl methacrylate has been and still continues to be highly preferred material for fabricating removable complete and partial dentures due to its properties like dimensional stability, low water sorption and improved esthetics.[2]

The most prevailing complication encountered with use of polymethyl methacrylate was breakage. Fracture of the denture can occur due to any errors in laboratory technique or can also occur during chewing due to poor flexural strength.[1]

Flexural and impact fatigue are the two main reasons for the fracture of dentures. Flexural strength is a measure to know the resistance of the polymer to flexural deformation.[3]

There are numerous factors which effect the mechanical properties of the polymerized resin. According to Harrison and Huggett[32], long curing cycle with a terminal boiling point showed 3 times lesser values of residual monomer content when compared to long curing cycle without a terminal boiling point. Cytotoxicity of acrylic denture base material is analogous to the existence of residual monomer after polymerization process as the residual monomer induces changes in basic cell structure and function, reduction of viability and inhibition of cell proliferation and differentiation, induction of cell apoptosis and necrosis.[2]

In this study, both high impact and conventional resins were used. This study compared the mean flexural strength of Trevalon HI (high impact resin) and DPI (conventional resin). The experimental design used for the samples strictly followed the ISO standards. The machine used in the study, the universal testing machine is routinely used and widely accepted for three-point bend test. Three-point bending test is used to compare various properties of the denture base material as it can simulate similar stresses that are applied on the denture base during mastication.[16]

The statistical analysis was carried out using one way ANOVA and paired "t" test. The results obtained were found to be statistically significant. The results of the study were found to be in compliance with other studies (John Francis et al)[2,] (R. Arun Jaikumar et al)[3,] (Harrison A et al)[32], (Dixon DL et al)[33].

Table I and II shows the flexural strength in MPa measured using universal testing machine of similar material when subjected to different curing procedures. It was seen that the flexural strength of Trevalon HI and DPI cured using long curing cycle were significant. The specimens cured using short curing procedure showed lesser values of flexural strength when compared to the specimens cured using long curing procedure respectively.

Although the long curing procedure is time consuming when compared to short curing procedure the residual monomer content is reduced in long curing procedure thus, the flexural strength of the specimens cured using long curing procedure is higher.[2]

Limitations of this Study:

The temperature at which the specimens were immersed. Since the denture is subjected to a longer episode of immersion in water ideally, the testing period should be longer to simulate a long-term use. The residual monomer content might have also altered the study results. For the future studies, it is recommended that the size of the specimen is same as that of the denture configuration while investigating the mechanical properties of the denture base material.

5. Conclusion

In this study two different denture base material i.e., Trevalon HI and DPI were subjected to long and short polymerization procedure.

From this study it is safe to say that Trevalon HI denture base material cured using long curing procedure can be used for long term purpose as it showed the higher values of flexural strength.

Under the limitation of this study, it can be concluded that

The flexural strength of the denture base resin is effect by the type of polymerization procedure.

The flexural strength of denture base material cured using long curing cycle is higher.

Flexural strength of chemically modified resin is higher than the conventional denture base resin.

The flexural strength of Trevalon HI (high impact resin) is higher than DPI (conventional resin) for both short and long curing procedures.

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