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Research Article

An in vitro study to evaluate and compare the flexural strength and impact strength of different heat cure and chemical cure acrylic resins under various conditions

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Abstract: Flexural and impact strength of denture base resins play a important role in success of prosthesis and many approaches have been made to improve the fracture resistance of acrylic resin dentures by strengthening them. Purpose of the study was to assess and compare the effect of high strength denture bse material with conventional heat and chemical-polymerized poly(methylmethacrylate) [PMMA] denture resin under dry and wet storage conditions. Ninety specimens of standard dimensions were prepared and 30 samples per three experimental groups;that is on the basis of storage conditions (dry and wet).All 90 specimens were then subjected to a 3-point bending test and flexural strength and Notched Izodimpact tester for impact strengthwas calculated. Statistical analysis was carried out using One Way Analysis of Variance and multiple comparison test. The mean flexural strength and impact strength of Trevelon HI heat cure resin when tested under dry conditions was high as compared to DPI Heat and chemical cure resins. All the specimens stored under wet conditions showed decrease in flexural strength in comparison to those stored in dry conditions.
Keywords: Denture base material, Flexural strength, Notched IZOD impact tester.

INTRODUCTION

The material most commonly used in the construction of many types of dental prostheses, including complete or removable partial denture, interim prostheses, and implant-supported prostheses is poly (methyl methacrylate). Polymers play a important role in the spectrum of dental materials. Although the properties of acrylic denture base resins have their own limitations, particularly in terms of flexural and impact strength. There are many research studies undergone in an attempt to improve the mechanical properties of poly (methyl methacrylate) [1]. Reinforcement of denture base materials was done commonly with different materials [2]. Many additives to Alternative materials [3] to poly (methyl methacrylate) have been introduced like fibres or beads, carbon [4,5], polyethylene[6,7], glass [8-11] have been added to acrylic resin in an attempt to improve its mechanical properties. To avoid fractures metal inserts in the form of wires, meshes and plates have been incorporated into dentures [12-13].The additives help to improve toughness, impact resistance, and to prevent crack propagation. These products are referred as “high impact” and manufacturers claim them to be new with improved strengthening properties [1, 14, 15].These materials are often expensive when compared to conventional heat-cured acrylic resin.

The purpose of this study is to determine the impact fracture strength, flexural strength of high impact and conventional heat cure and chemical cure denture base resins.

MATERIALS AND METHODS

The materials used in the study were two types of heat cure acrylic resins Trevelon HI [DENTSPLY company] and DPI heat cure acrylic resin and DPI chemical cure acrylic resin. All the above selected acrylic resins were evaluated and compared for their flexural strength and impact strengths. Conventional heat cure denture base resin was used as a control[Figure 1].

Sample preparation:

Metallic bar shaped samples [Figure 2] were made as per following measurements according to ADA specifications for testing denture base resins [16].

Strip for Transverse strength: 65x10x3mm

Strip for Transverse strength:80x12.7x3.17mm

After the metallic samples were fabricated the mould space was made in denture flasks using the compression molding technique. Small amount of wax (Modeling Wax, Hindustan Dental Products, Hyderabad India Ltd.) was filled into both ends of the metal strip to facilitate its removal. A thin layer of petroleum jelly (Bioline®) was applied on the strips and was invested in the denture flask, embedding half of the thickness of the strip into plaster investment. After the plaster set, a coat of separating media was applied. The second pour was made with dental plaster and the flask was held in compression till the final set of dental plaster. After the material set completely the flask was opened and the preformed strips were retrieved from the plaster[Figure 3&4]. Later the steps that followed were similar to one used for processing conventional complete denture.

Following measurements were used for DPI Heat Cure Polymer (P:M ratio of 15 g: 5 ml), DPI Chemical Cure polymer (P:M ratio of 15 g: 5 ml), Trevelon HI Heat Cure Polymer (P:M ratio of 15 g: 5 ml) was taken in, manipulated and packed into the mold in dough stage. Care was taken to avoid porosities due to entrapment of air bubbles. Trial closure was performed. Curing was done using a short curing cycle where the temperature was slowly raised to 73ºC and held for 90 min followed by boiling at 100ºC for 30 min. Test samples were labelled on each end before testing as A_{HC}, B_{HC}…..E_{HC} for DPI heat cure conventional resin, A_{CC}, B_{CC}…..E_{CC} for DPI chemical cure conventional resin, $A_{T\text{-}HI}$, $B_{T\text{-}HI}$…..$E_{T\text{-}HI}$ for Trevelon HI heat cure resin so that the fractured pieces could be reunited[Figure 5]. 90 resin samples were prepared.

Finishing and polishing of samples

After investing the samples were retrieved, finished with sandpaper and polished with felt cone in slow speed. Minimal finishing and polishing was required and care was taken to maintain low heat during the procedure.
Now The samples were divided into three groups i.e. **Group 1** and **Group 2 Group 3** -:

Group 1 consisted of specimens to be tested in dry conditions.

Group2 consisted of specimens to be tested after immersing it in distilled water at 37^{o} C for a week.

Group 3 consisted of specimens to be tested after immersing it in artificial salivary substitute at 37^{o}C .

The testing for flexural strength was done using Three-point bend test on Universal Instron testing machine while impact strength was tested using IZOD Impact tester.

a) Evaluation of Flexural Strength

The specimens were tested for flexural strength with a 3-point-bending test using INSTRON universal testing machine[Figure 6] at a crosshead speed of 2 mm/min and span length of 50 mm. The load was applied centrally on the bar specimen until fracture occurred. The amount of deflection and the load at fracture were noted.

The flexural strength was calculated using the formula:

$$\text{Flexural strength} = 3/2 \times pl/bd^{2}$$

Where

p - is the peak load
l - is the span length
b - is the sample width and
d - is the sample thickness

b) Evaluation of impact strength

For impact testing the samples were tested using a Notched IZOD impact tester [Figure 7] . The specimens were clamped at one end and a swinging pendulum of 0.5 J was used to break the unnotched specimens. The absorbed energy by the specimen was noted.

The impact strength was calculated using the formula:

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

where

E - is the absorbed energy
b - is the sample width and
d - is the sample thickness

The values for comparison of flexural and impact strength of various heat cure resins and chemical cure resins was evaluated using One Way Analysis of Variance and multiple comparison test was done.

RESULTS

Table-1 shows the mean impact strength of the three materials tested and the strength values are highest for Trevelon HI heat cure resin when tested under dry conditions[Figure 8].

Table-2show the mean flexural strength of the three materials tested and the strength values are highest for Trevelon HI heat cure resin when tested under dry conditions[Figure 9].

Fig-1: Different types of Acrylic resins

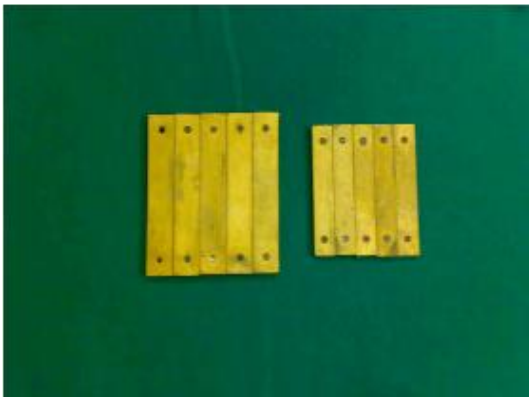

Fig-2: Metallic Bar samples

Fig-3: Preparation of mould space

Fig-4: Mould space

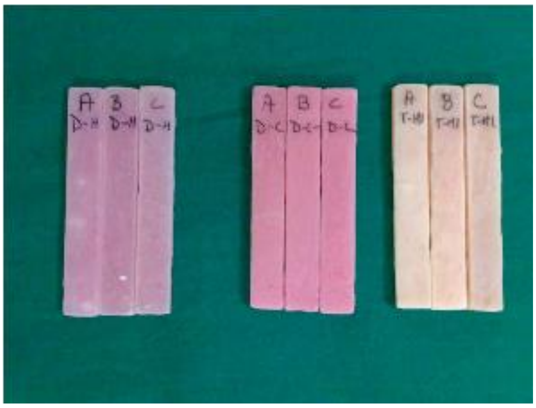

Fig-5: Acrylic resin samples

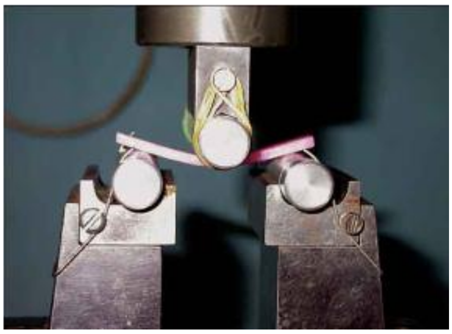

Fig-6: Three point bend test

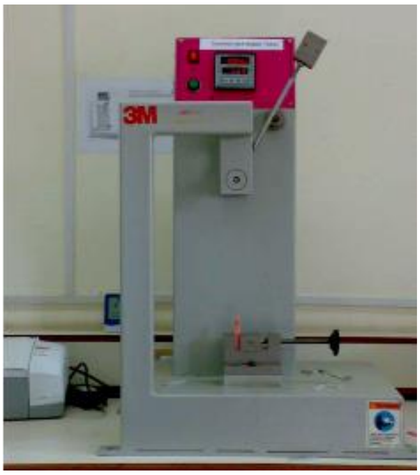

Fig-7 : Notched IZOD Impact Tester

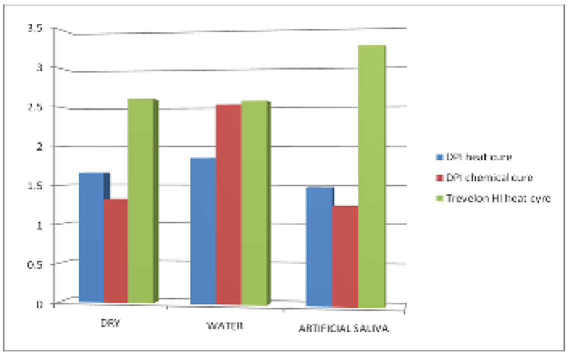

Fig-8: Graph depicting mean Impact strength in different mediums

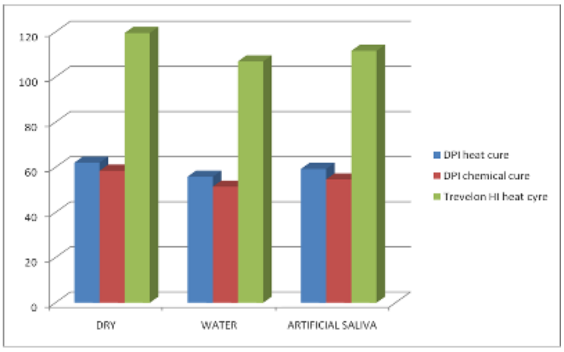

Fig-9: Graph depicting mean Flexural strength in different mediums

Table-1: Mean impact strengths (KJ/m^2) of samples

Materials	DRY	WATER	ARTIFICIAL SALIVA
DPI heat cure	1.66 ± 0.60	1.85 ± 1.4	1.48 ± 0.03
DPI chemical cure	1.32 ± 0.36	2.52 ± 1.14	1.25 ± 0.28
Trevelon HI heat cyre	2.60 ± 0.35	2.56 ± 0.31	3.23 ± 0.23

Table-2: Mean flexural strengths (MPa) of samples

Materials	DRY	WATER	ARTIFICIAL SALIVA
DPI heat cure	62.05 ± 2.16	55.87 ± 3.07	59.29 ± 1.08
DPI chemical cure	58.45 ± 2.59	51.43 ± 1.67	54.67 ± 1.7
Trevelon HI heat cyre	119.53 ± 2.45	106.96 ± 3.16	111.63 ± 1.87

DISCUSSION

In removable prosthodontics fracture of acrylic resins is anunre solved problem despite of numerous attempts made to rectify its causes. Upper denture fracture is more common with a ratio of 2:1 as compared to the lower dentures. Two types of failures are commonly analyzed with respect to fracture they are: (1) outside the mouth, caused by impact forces, i.e., a high stress rate and (2) inside the mouth, usually in function, which is probably a fatigue phenomenon, i.e., low and repetitive stress rate. Inside the mouth, generally repetitive stress like flexural stress occurs most commonly over a period of time. This type of fracture is typically seen in midline of maxillary than in mandibular dentures. Acrylic resins have shown to flex in function to a much greater degree than would be expected [15, 17]. Therefore to overcome such disastrous eventualities many modifications in the conventional denture base resin to improve its strength were introduced [7-10].

Many such attempt led to modification of the acrylic resins includes plasticization, copolymerization, cross linking and reinforcement to improve the specific properties of the polymer[8]. One such attempt led to the chemical modification of acrylic resin through the incorporation of rubber in the form of butadiene styrene has been successful in terms of improving the impact strength [18, 19]. However, the incorporation of rubber has not been entirely successful in that it can have detrimental effects on the modulus of elasticity and hence the rigidity of the denture base. Various mechanical tests are done to test the fracture resistance, the common among them are the flexural strength and impact strength. This study compared the impact and transverse strengths of `high strength' denture base acrylic resin with a conventional heat-cured and chemical cured acrylic resin. The sample obtained in this study are similar to one adopted by Jhon J *et aI* [20], but here metal strips are used instead of wax pattern, and the strips are directly invested with dental stone to prevent any processing errors[15].

Transverse bend test

The transverse (flexural strength) of a material is a measure of stiffness and resistance to fracture[14]. Flexural strength tests were undertaken as these were considered relevant to the loading characteristics of a denture base in a clinical situation. Sample dimensions were taken as per ADA specification No 12[16] where in a three point bend test was carried out using Instron universal testing machine with predictability. Reinforced resins require higher forces to fracture them and hence have better transverse strength.

Impact Strength

There are basically two types of tests for impact strength that is Charpy and Izod tests. Here a Izod impact tester is utilized .Impact tests are influenced by loading conditions and specimen geometry, such as the dimensions of the sample and the presence and configuration of notches and hence can give different values[14, 15].

Flexural strength was tested to get an understanding of how denture base resins hold up under function. There were significant differences in the acrylic resin denture base materials tested. Trevelon HI heat cure resin material has higher impact strength and flexural strength, compared to DPI heat cure acrylic resin and DPI chemical cure acrylic resin. But on the other hand, statistically, there was no significant difference in impact strength as well as flexural strength of DPI heat cure acrylic resin and DPI chemical cure acrylic resin. These higher properties are indicative of the needed strength and durability of resins used for denture prostheses.

It was noted that when these specimens were stored in water for a week the strength decreases as they release residual monomer during immersion for a week. This would cause them to become more brittle and accentuate the difference between the conventional resins and the high impact denture base resins.Clinically a resin material exhibiting a lower flexural strength may be more prone to fracture during function as a denture base, than would a resin with higher flexural strength. This potential for fracture may increase due to water sorption, further decreasing their strength. The polymers therefore behave differently in air and after immersion in water as well as in artificial saliva; the present data justifies this observation.

From the above discussion of results as well as the statistical analysis it is evident that after immersion in water the denture base resins compared, were more prone to fracture than when they are tested dry.

CONCLUSION

The overall success of denture base resins does not only depend on the mechanical behaviour but also on the design and fabrication, the action of residual stresses and on the conditions of loading..Hence the interpretation of laboratory results obtained to produce comparative data on different materials may differ. Mechanical properties are also depended on factors like different powder/liquid ratios, homogenous copolymer beads, differences in water uptake.

Within the limitations of thisstudy, results showed high flexuralstrength and impact strength reinforced denture base resins in dry conditions as compared to the conventional heat and chemical cure denture base resins.

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