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Original Research

Comparison of Impact Strength and Fracture Morphology of Different Heat Cure Denture Acrylic Resins: An *In vitro* Study

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***Abstract*:**

Background: The fracture of acrylic resin denture is rather common occurrence and causes inconvenience to the patients. This study was carried out to evaluate and compare the impact strength and fracture morphology of four different heat cure acrylic materials.

Materials and Methods: Acrylic resin specimens were prepared using preformed metal die of dimension 65 × 10 × 3 mm. The specimens were finished, polished and subjected to impact strength evaluation using impact testing machine. The loads at which the specimens fracture are recorded and subjected to statistical analysis. Fracture surface analysis was done. Macroscopic analysis was performed by visual inspection of the fractured surfaces using a stereoscopic microscope. About 5 mm sections of all the fragments were subjected to scanning electron microscopy for microscopic analysis to verify fracture morphology.

Results: Mean values of the impact strength were compared by statistical methods. The impact strength data were subjected to variance homogeneity tests. Fracture surface analysis data was analyzed by statistical methods. The mean impact strength of Lucitone 199 was higher than Acrylyn-H, DPI Heat cure & Trevalon.

Conclusion: Within the limitations of this study, it was concluded that the impact strength of the acrylic resins is affected by the reinforcement of fibers. Increased intermediate fractures increased impact strength. Brittle fractures morphology showed fewer undercuts and clearer surface. Intermediate fractures morphology showed more undercuts than clear surfaces.

Key Words: Denture base resin, fractographic analysis, fracture morphology, impact strength, polymethyl methacrylate

Introduction

The material most commonly used for fabricating removable partial and complete denture is polymethyl methacrylate. Despite its popularity, the material although adequate in satisfying aesthetic demands is not ideal in fulfilling the mechanical requirements of such appliance. This material presents limitations particularly in flexural strength and impact strength.[1] The fracture of acrylic resin denture is rather common occurrence and causes inconvenience. In addition to this, fracture has been attributed to porosity, presence of residual monomer, cracks, and poor adaptation of the removable prosthesis to the residual ridge. Removable prosthesis is susceptible to high impact extra oral forces, such as being accidentally dropped. As a result, stress concentration is generated, and the denture base acrylic resin can initiate or propagate the existent cracks, thus by influencing failure rate.[2] Therefore, studies on morphology and micro structural behaviour, surface defects and fracture initiation sites may help to identify the cause of the fracture. To simulate experimentally, impact tests such as IZOD or CHARPY are used to study the energy absorbed by the acrylic resin until it fractures. Although, impact testing is influenced by the loading configuration, there is a good correlation between the CHARPY and IZOD impact measurements.

This study is an effort to evaluate and compare the impact strength and fracture morphology of four commercially used heat cure denture acrylic resins.

Materials and Methods

Fabrication of samples

Metal dies were prepared for mentioned dimension (65 mm × 10 mm × 3 mm) (Figure 1a). The dies were coated with a thin layer of petroleum jelly and were invested in the lower half of the denture flask. While taking care, the one-half of the thickness was embedded in the dental plaster but in the base of the flask. This was allowed to set for half an hour, and a single layer of separating medium was applied. Second pour was made in the dental plaster, and the flask was held in compression till the final set of dental plaster. The denture flask was then opened, and the preformed dies were retrieved from the dental plaster (Figure 1b). The steps that followed were similar to one used for processing conventional complete denture.

Lucitone 199 (P:M) 21 g:8 ml and DPI Heat cure 21 g:10 ml; Trevalon (P:M) 21 g:9 ml and Acrylyn-H 21 g:10 ml were

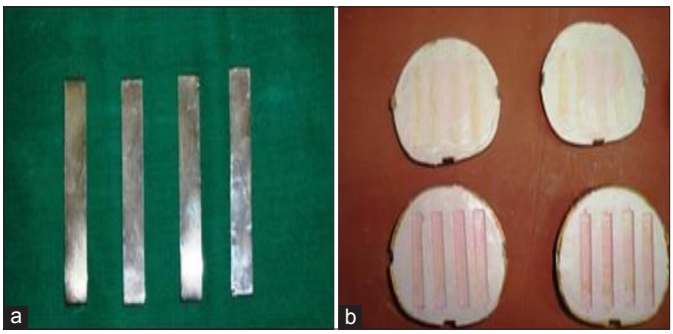

Figure 1: (a) Preformed metal dies. (b) Moulds after retrieval of dies.

manipulated according to manufacturer's instructions and material was packed into the mould in the dough stage. Care was taken to avoid porosities due to entrapment of air bubbles. Trial closure was performed. Bench curing was done for 3 h and short curing cycle was followed for acrylization i.e. 74°C for 2 h and 100°C for 1 h.

Finishing and polishing

Totally 120 test samples were trimmed by using acrylic trimmer. Finishing was done by sand paper (Emery 120 grit). Polishing was done using pumice and polishing cake (Figure 2).

Grouping of samples

One hundred and twenty test samples were labelled on each end before testing as follows:

- Total number of specimen: 120 specimens
- Total number of group: 4 groups
- Total number of specimens in each group: 30 specimens
- Group D (DPI) was labelled as $D_1, D_2, D_3 \ldots\ldots D_{30}$
- Group A (Acrylyn-H) was labelled as $A_1, A_2, A_3 \ldots\ldots\ldots A_{30}$
- Group L (Lucitone 199) was labelled as $L_1, L_2, L_3 \ldots\ldots\ldots L_{30}$
- Group T (Trevalon) was labelled as $T_1, T_2, T_3 \ldots\ldots\ldots T_{30}$

Evaluation of impact strength

For impact strength, the samples were tested with Pendulum impact tester (S.C. Dey & Co., Calcutta, India) (Figure 3a) using IZOD method. The specimens were clamped at one end vertically, and the swinging pendulum was used to break the unnotched specimens (Figure 3b). The load at which the specimen fractures were noted and values obtained were tabulated for statistical analysis. The fracture surface of the specimen was evaluated by stereoscopic microscope (Lawrence and Mayo [London] LM-52-1802 Trinocular Research Microscope [N-400M]) to determine the type of fracture.

The samples were examined with a scanning electron microscope (SEM) (Leo, Japan) (Figure 4) and photo micrographs of respective areas were obtained to verify fracture morphology. Statistical methods used were one-way ANOVA, Scheffe's *Post hoc* test, *t*-test, Contingency co-efficient test.

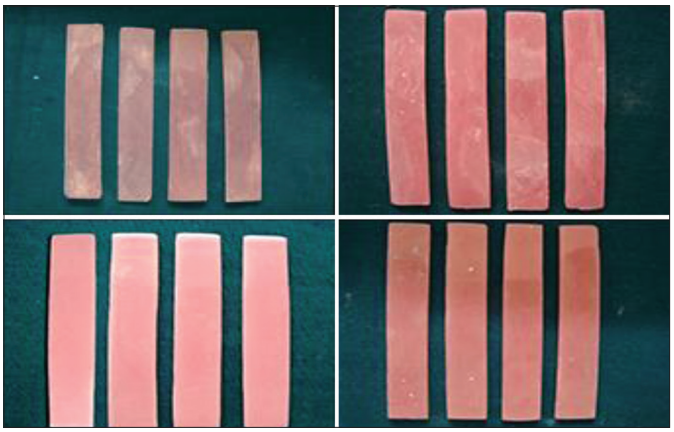

Figure 2: Specimens of four acrylic resins used.

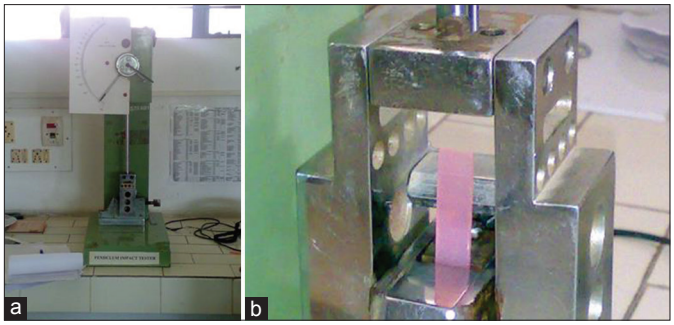

Figure 3: (a) Pendulum impact tester. (b) Position of sample in impact tester.

Figure 4: Scanning electron microscope.

Results

The 120 specimens of heat cure denture base resins were tested for impact strength by using impact testing machine and fracture morphology was observed by using SEM. The SEM microscopy showed that brittle fractures exhibited well-defined, flat, compact and organized surface fractures whereas intermediate fractures presented disorganized and jagged surfaces (Figures 5a and b, 6a and b). The values of impact strength were statistically analyzed.

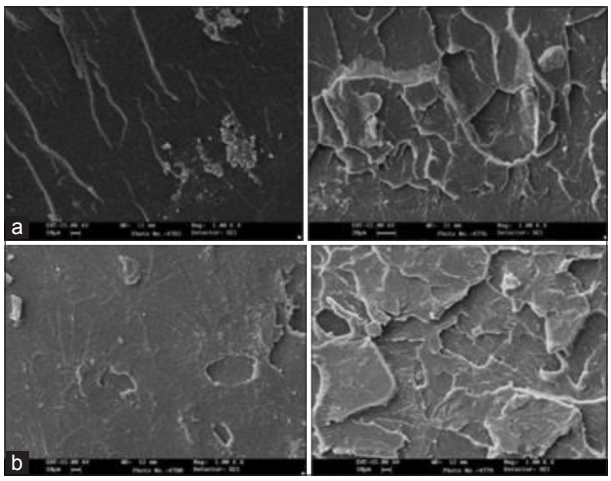

Figure 5: (a) Photomicrograph of Acrylyn-H brittle and intermediate fractures. (b) Photomicrograph of DPI brittle and intermediate fractures.

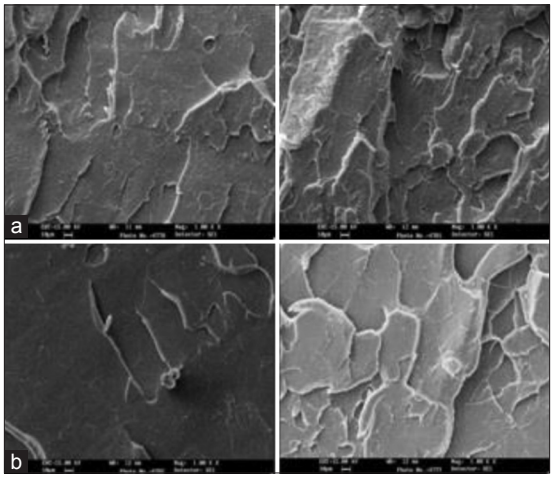

Figure 6: (a) Photomicrograph of Lucitone 199 brittle and intermediate fractures. (b) Photomicrograph of Trevalon brittle and intermediate fractures.

Impact strength of DPI is 0.1447 and standard deviation (SD) of 2.623 and mean impact strength of Acrylyn-H is 0.1463 and SD of 3.429 and mean impact strength of Lucitone 199 is 0.1973 and SD of 4.638 and mean impact strength of Trevalon is 0.1727 and SD of 4.510.When the *"F"* values (12.339) using one-way ANOVA are significant then individual mean is different from other so we must analyze using Scheffe's *post hoc* tests, which showed significance (Table 1).

Values between the DPI Heat cure and Acrylyn-H were not statistically significant. The mean impact scores of DPI Heat cure and Acrylyn-H materials and results of independent samples by *t*-test were obtained. The SD for DPI was 0.026 and Acrylyn was 0.034, the "*t*" value was 0.211. The values were not statistically significant because *P* = 0.833 (Table 2).

Table 1: Results of Scheffe's *Post hoc* tests for mean values on impact scores of different materials.

Material	*N*	Subset for alpha=0.05	
		1	2
DPI	30	0.1447	
Acrylyn-H	30	0.1463	
Trevalon	30		0.1727
Lucitone	30		0.1973

Table 2: Mean impact scores of DPI and Acrylyn-H materials and results of independent samples *t*-test.

Material	Mean	Standard deviation	"*t*" value	*P* value
DPI	0.1447	0.026	0.211	0.833 (NS)
Acrylyn-H	0.1463	0.034		

NS: Non-significant

The mean impact scores of Trevalon and Lucitone 199 materials and results of independent samples were analyzed by *t*-test. The SD of Lucitone 199 was 0.046 and for Trevalon was 0.045; the "*t*" value obtained was 2.088. The values were significant (Table 3).

The occurrence of the type of fracture in each material used was as follows (21-brittle and 9-intermediate in DPI, 20-brittle, and 10-intermediate in Acrylyn-H, 10-brittle and 20-intermediate in Trevalon, 9-brittle and 21-intermediate in Lucitone 199) percentage of occurrence was calculated in each material and cross tabulation of all materials and type of fractures was done using contingency coefficient test (CC). The value by CC test was 0.346 and was statistically significant (Table 4).

Discussion

The fracture of acrylic resins is an unresolved problem in removable prosthodontics despite numerous attempts to determine the causes. Modification of acrylic resins designed to improve the specific properties include plasticization co-polymerization cross-linking and reinforcement. An attempt has been done to study the influence of the cross linking agent on the mechanical properties of acrylic resin, and it has been found that an improvement in impact strength with the use of 10% cross-linking agent added to the monomer is possible, but the impact strength decreases progressively with higher concentrations. One such attempt led to the production of high impact resins that contain low molecular weight butadiene- styrene-b co-polymer the exact nature of this inclusion is regarded as manufacturers' trade secret and requires extensive research in chemical engineering.[2-5]

This study investigated the impact strength properties and fractographic analysis of 4 heat-cure acrylic resins. To compare the performance of different products, various mechanical tests were carried out for the study; impact strength is taken into consideration because of their influence on the selection of a denture base resin materials. The sample preparation followed here was similar to the one adopted by John *et al.*[6]

Table 3: Mean impact scores of Lucitone 199 and Trevalon (Fiber reinforced) materials and results of independent samples *t*-test.

Material	Mean	Standard deviation	"*t*" value	*P* value
Lucitone 199	0.1973	0.046	2.088	0.041 (S)
Trevalon	0.1727	0.045		

S: Significant

Table 4: Cross tabulation of materials and type of fractures and results of contingency coefficient test.

Groups	Fracture		Total
	Brittle	Intermediate	
DPI			
Frequency	21	9	30
Percent	35.0	15.0	25.0
Acrylyn-H			
Frequency	20	10	30
Percent	33.3	16.7	25.0
Trevlon			
Frequency	10	20	30
Percent	16.7	33.3	25.0
Lucitone			
Frequency	9	21	30
Percent	15.0	35.0	25.0
Total			
Frequency	60	60	120
Percent	100.0	100.0	100.0

CC=0.346; *P*=0.001 (S)

In this study, metal strips were preferred over wax patterns to avoid distortion in mould space and for ease of preparation and finishing. The preformed metal strips were directly invested in the dental plaster to form plaster moulds for fabrication of test samples.[6] It was observed that the mean impact strength showed higher values when tested under dry conditions, and long curing cycle when compared to wet conditions and short curing cycle.[7,8]

The sample dimension of 65 × 10 × 3 mm was prepared as per the ADA specifications no. 12 to test the impact strength.[6] Impact strength was tested by impact pendulum tester. There are basically two types of test, CHARPY and IZOD for evaluation of impact strength.[9-13] Depending upon the loading configuration, specimen dimensions and presence of notches and their geometry, these tests can result in different values.[10]

The IZOD impact test was used in this study. Although there is a good co-relation between the two tests, the absolute values differ from each other. Unnotched samples were cantilevered, and a swinging pendulum was used to break the specimens. The reduction in the swing of the pendulum or the energy absorbed by the material was measured. Comparison of impact strength values among four acrylic resins showed DPI Heat cure and Acrylyn-H presented the lower values which are not re-in forced. Lucitone 199 and Trevalon presented higher values that are re-in forced; this may be attributed to reinforcement of fibers in the resin. The mean impact strength values between DPI heat cure and Acrylyn-H was not statistically significant and the values between Lucitone 199 and Trevalon were statistically significant. The values between DPI heat cure, Lucitone 199 and Trevalon were statistically significant. The values between Acrylyn-H, Lucitone 199 and Trevalon were statistically significant.

By the help of stereoscopic microscope, the fractures were classified into brittle fractures and intermediate fractures. Lucitone 199 and Trevalon exhibited more intermediate fractures than brittle fractures. Acrylyn-H and DPI Heat cure also exhibited more brittle fractures than intermediate fractures. Analysis of fractured surfaces by SEM revealed the micro structural behaviour of brittle and intermediate fractures.

Acrylyn-H and DPI heat cure showed well-defined crystallographic surface compared to Lucitone 199 and Trevalon. Although irregularities could be seen in each acrylic resins fracture, a common finding was that a granular micro structure was clearly distinguishable demonstrating that acrylic resin fails by transgranular or transcrystalline fracture.[14]

The results from impact strength indicate that differences observed can be attributed to the composition of the acrylic resins.

Conclusion

In this study, impact strength and fracture morphology was compared between four heat cure denture base resins. The mechanical behavior of a denture in services depends not only on the strength but also on the design and construction, but also on the effect of residual stresses and the conditions of loading. Within the limitations of this study, it was concluded that,

1. The impact strength of the acrylic resins is affected by the reinforcement of fibers.
2. Increased intermediate fractures increased impact strength.
3. Brittle fractures morphology showed fewer undercuts and clearer surface.
4. Intermediate fractures morphology showed more undercuts than clear surfaces.

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