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A comparative evaluation of impact strength and residual monomer content in denture base resins processed by compression and injection molding technique

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ABSTRACT

Objectives: This In-vitro study was designed to compare the Impact strength and Residual monomer content of conventional and high impact types of denture base resins polymerized by Compression and Injection molding technique with short curing cycle.

Materials and Methods: Forty samples were made (twenty from each technique)in the dimension of 60 × 10 × 3 with 2 mm notch on the thickness side. The Impact strength was measured in Izod type of impact tester and Nuclear magnetic resonance method estimated residual monomer content. T-test and Anova were used to statistically analyze the result.

Results: High Impact acrylic resin hadsignificantly high impact strength and less residual monomer content than the Conventional acrylic resin in both the techniques. Resins processed by Injection molding technique produced greater Impact strength and reduced Residual monomer content as compared to resins processed by Compression molding technique.

Significance: High impact acrylic resin and injection molding technique were found to be material and technique of choice respectively for high impact strength and reduced residual monomer content.

Keywords: Impact strength, Residual monomer, Compression molding technique, Injection molding technique, Conventional acrylic resin, High impact acrylic resin.

INTRODUCTION

Dentists use many forms of synthetic plastics in one way or the other. The particular synthetic resin used currently in dentistry is based on acrylic resin, poly (Methyl meth acrylate).[1] Poly(Methyl meth acrylate) polymers were introduced as a denture base materials in 1937[2], and to date no other material has been found that matches the appearance of oral soft tissues with as great fidelity as acrylic resin. Its overall performance being satisfactory and it is widely used for construction of complete denture.[3] Since its inception acrylic resin denture base material is studied extensively for its physical, mechanical and chemical properties. Several factors have been accounted for influencing the impact strength and residual monomer content. Processing techniques used to polymerize the denture base resin has been found to be one of them. The

compression molding technique has been the most conventionally used technique. In spite of many advantages of this technique, some authors, [1-3] believe that denture bases fabricated by injection molding provide slightly improved clinical accuracy and adaptability due to lower residual monomer content than compression molding technique. Other authors [4] believe that injection molding technique require more amount of monomer to increase flow of resin during packing so it has a higher residual monomer content than the compression molding technique. Residual monomer content has a direct effect on the impact strength. Various author [1, 2,5] believe that increase in residual monomer content decreases the impact strength while other[6] believe increase in residual monomer content increases the impact strength. Hence this study was performed to know the influence of residual monomer content on impact strength and to compare these two properties of denture base resins with compression and injection molding technique.

MATERIALS AND METHODS

Two types of denture base resins were selected to compare the impact strength and residual monomer content viz Conventional acrylic resin (Trevalon, Dentsply India Ltd, Batch No. Powder-UL100201& Liquid- T110101) and High impact acrylic resin (Trevalon Hi, Dentsply India Ltd, Batch No. Powder-THL040503 & Liquid-TH040702) Compression and Injection molding technique with short curing cycle (74^0C for 90 minutes in a water bath and then increasing the temperature of the water bath to 100^0C and processing for 30 minutes) were chosen for processing the samples. Forty samples were made (twenty from each technique i.e. ten from each material) in the dimension of 60 × 10 × 3 as standardized by the American standards for testing and material (ASTM) [7]. The Impact strength was measured in Izod type of impact tester (FIE group India.com - Model IT-30 D) and same samples were used to estimate residual monomer content by Nuclear magnetic resonance method (Bruker- Germany**)** after impact testing. The molds for the specimens were fabricated by metal strips (62×12×5 mm).The method of preparation of mold was common for all the specimens fabricated by compression molding technique and injection molding technique. Samples were then retrieved, finished with Carbide bur to make it to the dimension prescribed by ASTM Standard. Sand Paper and polishing cake were used to polish the samples.

Sample Testing

A. Impact Test:

The samples were subjected to Izod type of impact tester .Caliper was used to locate the midpoint of the sample and the midpoint was marked using marking pen. On each specimen, a V-notch was cut to a depth of 2 mm on the thickness side as standardized by the Organization of International Standard (ISO) leaving an effective depth under the notch of 8 mm. The samples were placed in a metal fixture so that the middle of the sample or notch portion coincided with the striking pendulum (fig-1). The energy required to fracture the sample was measured in joules. Impact strength was calculated using following formula-

Impact strength= Energy/width × (thickness-notch depth)

B. Detection and Estimation of Residual Monomer:-

Quantitative analysis of residual monomer was carried out using Nuclear Magnetic Resonance (NMR) Spectroscopy on the same samples after impact testing. NMR spectra was recorded on 20 mg sample dissolved in 0.5 ml of CdCl3 (Deuterated Chloroform).This was scanned under Bruker 500 ultrashield NMR (fig-2).

The results were determined using the formula:

% Residual monomer = Integration of OCH3 of monomer×100/ Integration of OCH3 of monomer + Integration of OCH3 of polymer.

% Residual monomer = $I_{3.7}\times100/I_{3.7}+I_{3.58}$

I= Integration of area under the curve.

Fig-1: Sample is placed vertically with notch facing towards the pendulum for Izod impact test

RESULTS

The energy required to break the samples (fig-3&4) were recorded in Joules. (Table-1) and the residual monomers were estimated in % (Table-2). These values were then statistically analyzed and results obtained are shown in following tables. Table 3 shows a significantly higher mean impact strength of high impact acrylic resin 4.483KJ/m^2 (SD=0.252) compared to conventional acrylic resin 3.609KJ/m^2 (SD=0.342) in injection molding technique at significance level of $p<0.001$.Table 4 shows significant reduction in mean Residual monomer content of High impact acrylic resin 0.66% (SD=0.3026) and 0.65% (SD=0.2366) as compared to Conventional acrylic resin 1.362% (SD=0.2051) and 1.32% (SD= 0.3795) when both were processed by Compression molding and Injection molding technique respectively at significance level of $p<0.001$.Technique wise NO significant difference in mean residual monomer content of conventional acrylic resin and high Impact acrylic resin processed by compression molding technique 1.362% (SD=0.2051) and0.66% (SD=0.3026) as compared to injection molding technique 1.32% (SD=0.3795) and 0.65% and (SD=0.2366) respectively at significance level of $p>0.05$

Fig-2: Nuclear Magnetic Resonance Spectroscopy

DISCUSSION

Through the result of investigation of Izod Impact test, it was found that High impact denture base resin has significantly higher impact strength ($p<0.001$) than the conventional denture base resin in both the techniques. Jagger et al (2002, 2003)[8,9] who were of the view that incorporation of rubber in the form of butadiene styrene has increased the impact strength by absorbing energy in impact as it stretches across cracks in the brittle matrix. Further impact strength of High impact acrylic resin processed by Injection molding (4.483 KJ/m^2) was significantly high as compared to Compression

molding technique (4.273 KJ/m^2). These finding were somewhat in agreement with the studies done by Anusavice[1], Craig[2] and Ganzarolli et al [10] who were of view that in Injection molding denture base resins fills all voids completely and compactly under continuous pressure. The sensitivity of denture base resins to the presence of notches was reported by **Robinson and McCabe (1993)[11],** who performed a series of Charpy impact tests on several commercial materials and found that these defects significantly reduced the impact resistance of materials. The significance of the notch is that it concentrates the impact on the notch and result is not affected by any other surface defect. Quantitative analysis of residual monomer was done by Nuclear Magnetic Resonance (NMR) method. Of all other methods[4,10,12-17,22] it is the only one from which a complete analysis and interpretation of the entire spectrum is normally expected. Through the result of investigation of residual monomer content it was found that High impact denture base resin possess lower residual monomer content as compare to conventional acrylic resin processed by both the techniques but the difference was not significant ($p>0.05$). Further High impact resin processed by Injection molding procedure (0.65%) has the lowest residual monomer content than that processed by compression molding technique (0.66%) .These results are in agreement with the studies done by Craig[2] and Polat et al (2003)[21] who stated that reactivity of oxygen with free radicals is higher than that of radical contained monomers to each other,the polymerization is inhibited by oxygen. This may result in higher residual monomer content in polymer with air voids than with dense polymers structure i.e. specimens processed by compression molding technique has a higher monomer content than that processed by injection molding technique. Lee et al[4] and Phoenix et al [22] also reported that injection molded acrylic resin generally requires a greater monomer content to improve flow characteristics which may often result in additional unreacted monomer in specimen cure by injection molding technique but the difference was not significant. Conventional acrylic processed by compression molding has highest residual monomer content (1.36%) than injection molding technique (1.32%) for the same reason.

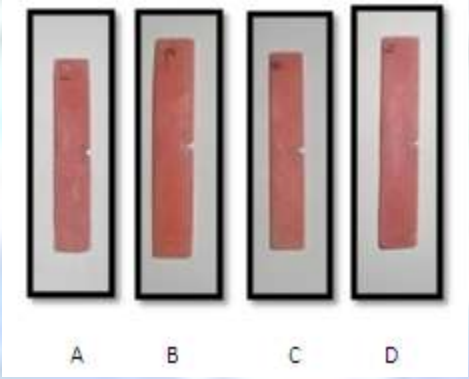

Fig- 3: Showing A- Conventional acrylic resin specimens cured by compression molding;
B- High Impact acrylic resin specimens cured by compression molding;
C- Conventional acrylic resin specimens cured by Injection molding ;
D- High Impact acrylic resin specimens cured by injection molding technique.

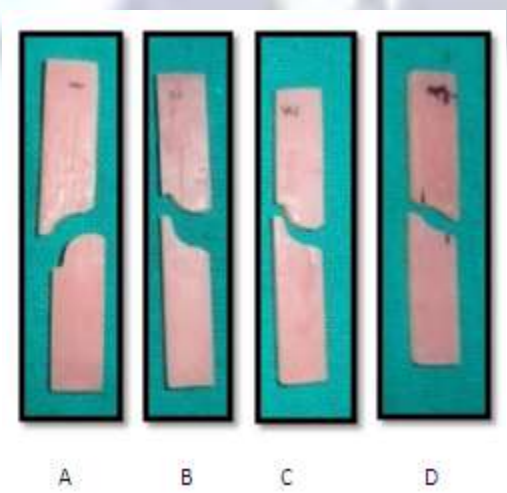

Fig- 4: Showing A-Fractured Conventional Acrylic Resin Specimens Cured by Compression molding technique;
B- Fractured High Impact acrylic resin specimens cured by compression molding;
C- Fractured Conventional acrylic resin specimens cured by Injection molding ;
D- Fractured High Impact acrylic resin specimens cured by injection molding technique.

CONCLUSION

Within limitations of the study, following conclusions can be drawn:

A) Impact strength of High Impact acrylic resin is greater than the Conventional acrylic resin in both the techniques.
B) Residual monomer content of High Impact acrylic resin is less than the Conventional acrylic resin in both the techniques.
C) Injection molding technique produces greater Impact strength and reduced Residual monomer content as compare to Compression molding technique.

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TABLES

Table 1: Results showing impact strength (KJ/m^2) of different denture base resin

SAMPLE NO.	CONVENTIONAL ACRYLIC		HIGH IMPACT ACRYLIC	
	COMPRESSION	INJECTION	COMPRESSION	INJECTION
1.	3.29	3.67	4.29	5.00
2.	3.50	4.00	4.42	4.83
3.	3.33	3.92	4.63	4.50
4.	2.88	3.25	4.21	4.54
5.	3.04	3.50	4.13	4.42
6.	3.08	3.29	4.25	4.29
7.	3.17	3.04	4.21	4.33
8.	3.08	3.54	4.21	4.21
9.	3.04	3.88	4.13	4.29
10.	3.33	4.00	4.25	4.42
MEAN	3.17	3.60	4.27	4.48

Table 2: Results showing residual monomer content (%) of different denture base resin.

SAMPLE NO.	CONVENTIONAL ACRYLIC		HIGH IMPACT ACRYLIC	
	COMPRESSION MOLDING	INJECTION MOLDING	COMPRESSION MOLDING	INJECTION MOLDING
1.	1.31	0.9	0.5	0.89
2.	1.31	0.9	0.5	0.89
3.	1.31	0.9	0.5	0.89
4.	1.31	0 .9	0.5	0.89
5.	1.57	1.5	1.0	0.59
6.	1.57	1.5	1.0	0.59
7.	1.57	1.5	1.0	0.59
8.	1.57	1.5	1.0	0.59
9.	1.05	1.8	0.3	0.29
10.	1.05	1.8	0.3	0.29
MEAN	1.36	1.32	0.66	0.65

TABLE 3: t-test to Compare Mean Difference of Impact Strength of Conventional Acrylic Resin and High Impact Acrylic Resin Processed by Compression and Injection Molding Technique.

Technique	Material	N	Mean	Std. Deviation	t-value	p-value
Compression molding technique	**Conventional acrylic resin**	10	3.174	0.185	14.576	<0.001
	High impact acrylic resin	10	4.273	0.150		
Injection molding technique	**Conventional acrylic resin**	10	3.174	0.185	14.576	<0.001
	High impact acrylic resin	10	4.273	0.150		

Table 4:- t-test to Compare Mean Difference of Residual Monomer Content between Conventional Acrylic Resin and High Impact Acrylic Resin Processed by Compression Molding and Injection molding Technique.

TECHNIQUE	MATERIAL	N	Mean	Std. Deviation	t-value	p-value
Compression molding technique	Conventional acrylic resin	10	1.36	0.2051	6.073	<0.001
	High impact acrylic resin	10	0.66	0.3026		
Injection molding technique	Conventional acrylic resin	10	1.32	0.3795	4.738	<0.001
	High impact acrylic resin	10	0.65	0.2366