Research Article

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A Comparative Evaluation of Flexure and Impact Strength of Three Different Denture Base Materials: An In Vitro Study

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ABSTRACT

Aim: Aim of the study is to evaluate and compare the impact strength and flexure strength of heat cured-Lucitone199, microwave cured-Vipi Wave and glass-fibre modified Lucitone199 denture base materials.

Material & Methods: The materials were used are Heat cure poly (methacrylate) denture base resin Lucitone 199 (Dentsply York Division USA), Microwave cured denture base material- Vipi Wave (VIPI Industria, odontologics Ltd. Brasil) & 2% Glass-fibres modified Lucitone199 (Mechan Co. Ind, Mumbia). A total of 120 specimens were made and divided equally into three groups (Group A, B and C). Each group contained 40 specimens and in each group 20 specimens of dimensions 65mm x 10mm x 2.5mm were used to evaluate flexure strength and another 20 specimens of each group with dimension 60mm x 7.5mm x 4mm were used to evaluate impact strength.

Results: The data obtained were subjected to statistical analysis. Mean, standard deviation and standard error were calculated, with the one-way analysis of variance (ANOVA) test followed by Post hoc tukey's test used to determine the level of significance and for multiple group wise comparison. Student t-test was also performed for pair wise comparison. Results revealed that glass fibre modified Lucitone 199 shows statistically higher significant values in relation to impact strength and flexure strength as compared to Microwave cured denture base material- Vipi Wave and Heat cure poly (methacrylate) denture base resin Lucitone 199. There were intergroup differences in the values the groups showed statistically significant difference in their transverse strengths and impact strength.

Conclusion: Among the different denture base materials used in the study Glass fibre reinforced proved to have better transverse and impact strength, followed by this is denture base resin.

Keywords: flexure strength, impact strength.

INTRODUCTION

The introduction of a more satisfactory plastic denture base material occurred in 1937 when Dr. Walter Wright described the results of his clinical evaluation of methyl methacrylate resin.[1] During the past 65 years since acrylic resins were introduced, the quality of dental resins has been more refined and improved than during the entire history of dentistry before that time. The methyl methacrylate polymers and copolymers continue to be the most popular dental resins for denture base purposes and are fundamentally unchanged from

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those first introduced, except for slight modifications and refinements.

There is still a need for a better denture base material which possesses features such as radiopacity, higher impact strength and better tissue compatibility. The denture base is subjected to various mechanical stresses in the oral cavity. Numerous studies have been conducted to compare mechanical properties of various materials. They all revealed that adequate mechanical properties are required to prevent fracture during functional loading and due to accidental breakdown. However, conclusive evidence in respect to a single method and material to attain this objective is inconspicuous. This creates a dilemma in the minds of the clinicians regarding superiority of impact and flexural strength of various denture base materials.[2,3]

Therefore, a need was felt to design a study, to evaluate and compare the impact strength and flexure strength. The aim of the study is to compare the flexural strength, impact strength of denture base polymers of different materials.

AIMS & OBJECTIVES

Aim of the study is to evaluate and compare the impact strength and flexure strength of heat cured-Lucitone199 (Densply York Division USA), microwave cured-Vipi Wave (VIPI Industrai, Odontologiecs Ltd. Brasil) and glass-fibre modified Lucitone199 (Mechan Co. Ind, Mumbia) denture base materials.

OBJECTIVE

- To assess the impact strength of heat cured (Lucitone199), Microwave cured (vipi wave) and glass-fibre modified Lucitone199 (Mechan Co. Ind, Mumbia).
- To compare impact strength of heat cured (Lucitone199), Microwave cured (vipi wave) and glass-fibre modified Lucitone199 (Mechan Co. Ind, Mumbia).
- To assess the flexure strength of Heat cured (Lucitone199), Microwave cured (vipi wave) and glass-fibre modified Lucitone199 (Mechan Co. Ind, Mumbia).
- To compare the flexure strength of Heat cured (Lucitone199), Microwave cured (vipi wave) and glass-fibre modified Lucitone199 (Mechan Co. Ind, Mumbia).
- To help the clinicians to select and advocate an appropriate denture base materials in terms of adequate impact strength and flexural strength in different clinical situations and cases.

MATERIALS AND METHODS

The materials were used in the study are as follows:

1) Heat cure poly (methacrylate) denture base resin Lucitone 199 (Dentsply York Division USA)
2) Microwave cured denture base material- Vipi Wave (VIPI Industria, odontologics Ltd. Brasil)
3) 2% Glass-fibres modified Lucitone199 (Mechan Co. Ind, Mumbia)

METHODOLOGY

A total of 120 specimens were made and divided equally into three groups (Group A, B and C). Each group contained 40 specimens and in each group 20 specimens of dimensions 65mm x 10mm x 2.5mm were used to evaluate flexure strength and another 20 specimens of each group with dimension 60mm x 7.5mm x 4mm were used to evaluate impact strength. The groups were as follows:

i) Group A: 40 specimens of heat cure denture base resins (Lucitone 199), and was further divided into two sub-groups a_1 and a_2.

   a_1 – 20 specimens for impact strength

   a_2 – 20 specimens for flexural strength

ii) Group B: 40 specimens of microwave cured denture base resins (Vipi Wave) and was further divided into two sub-groups b_1 and b_2.

   b_1 – 20 specimens for impact strength

   b_2 – 20 specimens for flexural strength

iii) Group C: 40 specimens of Glass fibre reinforced Lucitone 199 denture base resins and was further divided into two sub-groups c_1 and c_2.

c_1 – 20 specimens for impact strength

c_2 – 20 specimens for flexural strength

PREPARATION OF GYPSUM MOULD TO OBTAIN THE SPECIMENS:

One Stainless steel master die measuring 65 mm in length, 10 mm in width and 2.5 mm in thickness(Fig. 1), and other stainless steel master dies of dimension 60mm in length, 7.5mm in width and 4mm in thickness (Fig. 1) were used to prepare gypsum mould. The stainless steel metal dies were coated with a thin layer of petroleum jelly and were invested horizontally in the dental stone in the base of the flask (Kavo). After the dental stone had set, the screws were tightened into the holes of the dies and were removed, without damaging the moulds. Two coatings of alginate separating media (Stellon cold mold seal) were then applied onto the set stone mould. The metal dies were replaced in the mould. Screws were removed and the holes filled with carding wax. The counter part of the flask was positioned over the base and filled with dental stone. The flask was clamped immediately to ensure metal to metal contact between the base and the counter part of the flask. After the dental stone had set, the flask was carefully opened and the carding wax from the holes was removed. The screws were threaded into the holes and the metal dies weres carefully teased out from the investing material. The moulds formed were then immersed in hot water and flushed with a suitable detergent solution to remove any trace of petroleum jelly and wax; then the mould was flushed with hot water. Thus it warms the mould to facilitate the application of cold mold seal. The mold cavities so obtained were used for the preparation of acrylic resin specimens.

PREPARATION OF DENTURE BASE RESIN:

i) Group A (LUCITONE 199)

The appropriate amount of heat cure acrylic resin required was prepared from a mixture of polymer and monomer in the ratio of 21 gm : 10 ml.

The monomer was poured in a mixing jar and the polymer was slowly added to allow for wetting of the powder particles. Excess powder was removed. Then it was thoroughly mixed for 20 secs. After attaining the dough stage in 9 mins, the dough was thoroughly kneaded between the fingers and the mould cavities were filled. The flask was closed under 2000 psi. The flask was then clamped and pressure was maintained for 30 minutes to allow proper penetration of monomer into polymer. The flask was immersed in an acrylizer at room temperature. The temperature was raised to 73°C, held for 1 ½ hours, then raised to 100°C and was maintained for half an hour. After the completion of the curing cycle the flask was removed from the water bath and bench cooled for 30 minutes, immersed in cool tap water for 15 minutes prior to deflasking. [4] The acrylic specimens were then retrieved, finished by using carbide bur, round tapered stone bur and sand papering by sand paper and then polished with buff and pumice cake on lathe cut machine. The dimension and quality of the specimens was verified. The specimens with porosity were discarded. Twenty specimens of 65 mm x 10 mm x 2.5 mm and twenty specimens of 65 mm x 7.5 mm x 4 mm dimension were obtained by this procedure.

PREPARATION OF MICROWAVE CURED SPECIMENS:

ii) Group B (Vipi wave)

Vipi wave is microwave cure denture base material. Test specimens were processed by mixing 100gm of powder in 43ml of monomer (mixing time 30 secs.). The mixture reached the dough stage at room temperature in 20 mins. The dough was packed in a special fabricated fibre reinforced plastic flask (Supreme Fibre Glass INC. Bombay). And was cured in microwave oven Panasonic model NE-541 for 3 min at 500 watt. The acrylic specimens were then retrieved, finished and polished. The dimension and quality of the specimens was verified. Twenty specimens of 65 mm x 10 mm x 2.5 mm and twenty specimens of 65 mm x 7.5 mm x 4 mm dimension were obtained by this procedure.

PREPARATION OF GLASS FIBRE REINFORCED RESINS

iii) Group C (Glass fibres)

The material used was heat cured denture base material (Lucitone 199) reinforced with 2% by wt of 6 mm glass fibres (Mechan Co. Ind., Mumbai). Glass fibres were wrapped in aluminium foil and were cut ~ 6 mm length with the help of sharp BP blade.[5] 10 ml of monomer and 21 gm of polymer were measured using the electronic measuring balance. These weighed 12.195 and 21 gm respectively. This weight was added (12.195 + 21 = 33.195) and 2% glass fibre of this weight (0.66 gm) was measured using the electronic balance. This measured quantity of glass fibres were immersed in a beaker for 5 min with the minimum amount of monomer liquid that was compatible with thorough wetting. Then PMMA powder was sprinkled on top and mixed.

After the material reached the dough stage, it was kneaded and packed into the mould. The specimens were trial packed, polymerized, recovered, finished and polished as stated for the group A. Twenty specimens of 65 mm x 10 mm x 2.5 mm and twenty specimens of 65 mm x 7.5 mm x 4 mm dimension were obtained by this procedure.

The test specimens were stored in water bath at 37°C for two weeks before doing the mechanical testing. Before testing, the thickness, length and width of each specimen were verified with digital caliper.

Impact Strength:

Impact strength test was carried out at polymer department, CIPET, Jaipur. The impact strength of specimens was tested on Pendulum Impact Tester (Tinius Olsen code no.: CIPET/JPR/PTC/EQUIP/51) (Fig. 2). Prior to the impact test the specimens were notched (fig.3) with impact specimen notcher (Tinius Olsen code no.: CIPET/JPR/PTC/EQUIP/51) (Fig.4). In this test the test piece is clamped vertically with the notch facing the striker (Fig. 5). The striker swings downwards impacting the test specimen. A pendulum of 2J testing capacity was used. The impact speed of the pendulum was 3.46 m/s.

Transverse Strength:

The transverse strength of the specimen was tested on universal testing machine (AGIS SHIMADZO, Japan). The range and accuracy is 0 - 100 KN/1N. The machine has a digital monitor which indicates the amount of force applied. The specimens were kept under load and the reading on the digital scale indicated the force applied, once the specimen broke under the load, the reading automatically stopped. To measure the transverse strength, a jig was fabricated. This jig consisted of 2 parallel pins. These pins were adjusted 50mm apart, which represented the distance between the molars in complete maxillary denture.[6] All the specimens were marked in the centre. The jig was positioned on the universal testing machine and the specimen were loaded one at a time. Load was applied at the centre of the specimen at a cross head speed of 5mm/min, until it fractured. The load at which fracture occurred was noted and the transverse strength was calculated using the following formula:

$$S = \frac{3pi}{2bd2}$$

Where,

S = transverse strength

p = fracture load

i = distance between supports, 50 mm

b = specimen width, 10 mm

d = specimen thickness, 4 mm

RESULTS

There were three groups and each group was divided into two sub-groups with their respective standard dimensions (65mm x 7.5mm x 4mm) was used to evaluate impact strength and dimensions (65mm x 10mm x 2.5mm) was used to evaluate flexure strength.

IMPACT STRENGTH

The mean, standard deviation and coefficient of variation were calculated for further analysis. The results revealed that Sub-group c_1 shows statistically higher significant values in relation to impact strength as compared to Sub-group b_1 and Sub-group a_1. Sub-group a_1 shows significantly higher values of impact strength as compared to b_1. Therefore, sub-group c_1 was considered superior to the rest of the sub-groups

Table 1: Energy absorbed (joules) to fracture the specimens in three study groups.

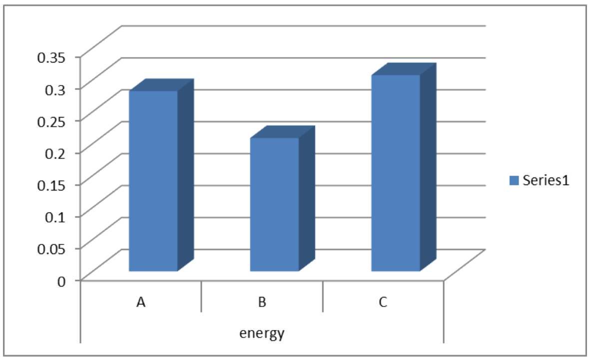
SUB-GROUPS	Energy absorbed (joules)				Difference between groups		
	Range	Mean	SD	CV (%)	Sub-Groups compared	Mean difference	Significance*
a_1	0.24-0.31	0.28	0.02	7.1	a_1-b_1	0.07	0.001
					a_1-c_1	-0.02	0.05
b_1	0.18-0.28	0.20	0.02	10	b_1-a_1	-0.073	0.001
					b_1-c_1	-0.09	0.001
c_1	0.25-0.35	0.30	0.03	10	c_1-a_1	0.025	0.05
					c_1-b_1	0.098	0.001

One way ANOVA F = 35.33 p = 0.001

Table 2: Impact strength (joules/mm²) of three study groups.

SUB-GROUPS	Impact strength (joules/mm²)				Difference between groups		
	Range	Mean	SD	CV (%)	Sub-Groups compared	Mean difference	Significance*
a_1	7.42-8.2 x 10^{-3}	7.73 x 10^{-3}	0.26	3.3	a_1-b_1	1.11	0.001
					a_1-c_1	-0.30	0.042
b_1	6.2-6.92 x 10^{-3}	6.62 x 10^{-3}	0.27	4.0	b_1-a_1	-1.11	0.001
					b_1-c_1	-1.41	0.001
c_1	7.4-8.5 x 10^{-3}	8.03 x 10^{-3}	0.39	4.8	c_1-a_1	0.301	0.042
					c_1-b_1	0.1.41	0.001

One way ANOVA F = 55.89 p = 0.001

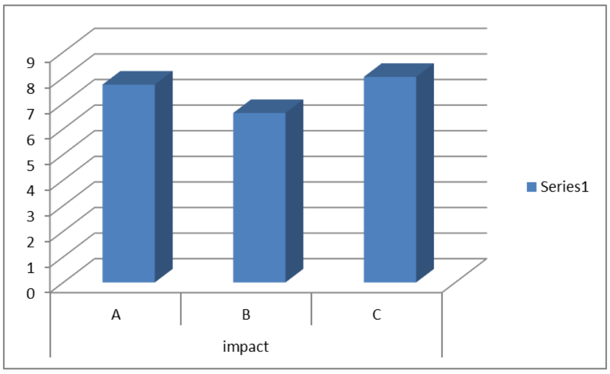


Graph 1: Energy absorbed (Joules) to fracture the specimens in three study groups.

Flexural Strength:

To identify any significant differences between the data obtained for the groups of materials tested, a One-Way analysis of variance (ANOVA) was undertaken.

Sub-group c_2 shows statistically highly significant flexure strength as compared to sub-group a_2, sub-group b_2. Sub-group a_2 also shows statistically highly significant value of flexure strength as compared to sub-group b_2



Graph 2: Impact strength (Joule/mm²) of three study group.

Table 3: Load (kg) at fracture of three study groups (for flexure strength).

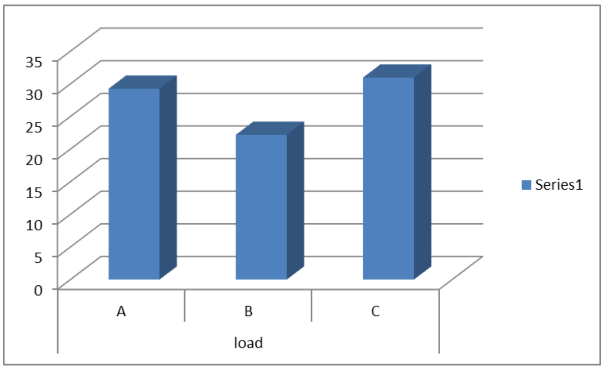
SUB-GROUPS	Load (Kg)				Difference between groups		
	Range	Mean	SD	CV (%)	Sub-Groups compared	Mean difference	Significance*
a_2	26.62-32.28	29.25	1.57	5.3	a_2-b_2	7.06	0.00
					a_2-c_2	-1.71	0.101
b_2	18.05-28.02	22.18	3.31	14.9	b_2-a_2	-7.06	0.00
					b_2-c_2	-8.78	0.00
c_2	29.87-33.21	30.964	1.35	4.3	c_2-a_2	1.71	0.101
					c_2-b_2	8.78	0.00

One way ANOVA F = 42.56 p = 0.001

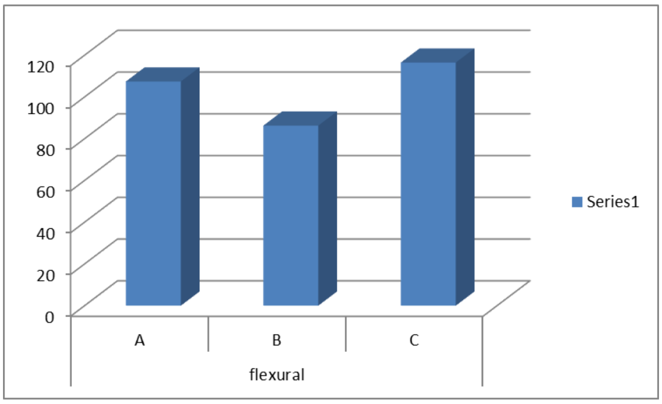
Table 4: Flexure strength (mpa) of three study groups.

SUB-GROUPS	TRANSVERSE STRENGHT (MPa)				Difference between groups		
	Range	Mean	SD	CV (%)	Sub-Groups compared	Mean difference	Significance*
a_2	90.05-118.4	107.37	9.07	8.4	a_2-b_2	21.1	0.001
					a_2-c_2	-9.06	0.008
b_2	78.02-102.84	87.23	7.69	8.8	b_2-a_2	-21.13	0.001
					b_2-c_2	-30.20	0.001
c_2	112.55-120.32	116.43	2.50	2.1	c_2-a_2	9.06	0.008
					c_2-b_2	30.2	0.001

One way ANOVA F = 48.72 p = 0.001



Graph 3: Load (kg) fracture of three study groups (for flexure strength).



Graph 4: Flexure strength of three study groups.

DISCUSSION

The methyl methacrylate polymers and copolymers continue to be the most popular dental resins for denture base purposes and have been the most widely used ever since they were first introduced.[1] Poly (methyl methacrylate), though widely used as a denture base material, exhibits low resistance to impact and fatigue fracture (Smith 1962).[7, 8] The fracture of acrylic resin dentures remains an unresolved problem till date. Fractures in dentures result mainly from two different types of forces – impact and flexure.[9] While impact may fracture dentures when they are dropped, repeated flexing from chewing ultimately fatigues many dentures in mouth.

An important criterion for selection of denture base materials is dimensional stability and adaptability on the surface. Poly methyl methacrylate are most popular or commonly used acrylic resin for denture fabrication. Although volumetric shrinkage which is about 8% during processing. The acrylic resin that is cured with microwave energy have better adaption than heat cured resin because the microwave generates heat with in the resin. This results in a more rapid and even polymerization if the denture base is rotated on a carousal during microwave processing. Consequently, the microwave technique should eliminate some of the stresses produced by polymerization shrinkage.[10] but have mechanical properties same as the heat cured denture base.

One successful way to increase the strength of poly methylmethacrylate is to incorporated with fibres – glass, carbon, graphite, poly ethylene.[6] Carbon and graphite fibres have poor esthetics and are difficult to polish. Glass fibres are the most commonly form used.[11] They not only improve mechanical properties of denture base polymers, but are also aesthetic. Moreover, they are easy to manipulate. The effect of adding glass fibers to improve the strength of poly methyl methacrylate has been demonstrated in many studies, [12,13] it has been shown that the length & the orientation of the glass fibers in the resin matrix play a major role in determining the mechanical properties of the reinforced poly methyl methacrylate.

The impact strength of denture base material depends on many factors including material selection, geometry of the specimen, fabrication variables, stress concentrations, position of specimen, and temperature.[14] The result of this investigation indicated that the reinforcement of glass fibres significantly increase the impact strength of high impact acrylic denture because the fibres reinforced in the denture impedes the crack propagation. However, the fact that glass fibre reinforcement enhances the impact strength of acrylic resin is in agreement with other research.[15, 16, 17, 18] Vallittu[15], Aydin C[19] and Kim S H[14] concluded that glass fibres are considered to be suitable for strengthening denture. In addition, the translucency of glass fibres provides aesthetically pleasing denture.

The flexural strength of a material is a combination of compressive, tensile, and shear strengths. As the tensile and the compressive strength increases, the force required to fracture the material also increases. An increase in the flexural strength with the incorporation of glass fibres is in agreement with the previous studies done by Uzun, Tenser, Hersek [20] Vallittu [21]; Vallittu, Lassilla, Lappalainen and Marie.[22] Glass fibres have high tensile strength thus, increasing the flexural strength. Vallittu, Lassilla and Lappalainen [23] showed that an increase in the amount of fibres increase(36%) enhanced the fracture resistance.

Limitation of the study is that more number of denture base resin systems and more number of reinforcement systems can be tested. But in our study as one denture base material was a high-impact resin, similar reinforcement effects might be expected with other high-impact resins using the same fibre system and for low-impact resins as well. It should be noted that impact strength of acrylic denture base reinforced with glass fibres varies according to the test condition, composition of resin, geometry of denture, fibre type, fibre form, fibre position, fibre orientation, and fibre fraction. These factors have an important influence on clinical performance of the dentures. Thus these factors should be considered for further studies.

CONCLUSION

From the present study following conclusions were drawn:

1) The glass fibre reinforced denture base resins showed higher transverse strength as compared to the heat cure resins (Lucitone199), microwave cured resin (Vipi Wave). The Lucitone199 also shows higher flexure strength as compared to Vipi Wave. There were intergroup differences in the values the groups showed statistically significant difference in their transverse strengths.

2) The glass fibre reinforced denture base resins showed slightly higher impact strength than the Lucitone199 and showed highly significant increase in impact strength as compared to the microwave

cure resin (Vipi Wave). The Lucitone199 shows higher impact strength as compared to Vipi Wave.

Among the different denture base materials used in the study Glass fibre reinforced proved to have better transverse and impact strength, followed by this is denture base resin.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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