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Comparative Evaluation of the Flexure Strength of Heat Cured (Lucitone199), Microwave Cured (Vipi Wave) and Glass-Fibre Modified Denture Base Material

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Abstract: Flexural strength is a measure of stiffness and resistance to fracture and it's a combination of compressive, tensile and shear strengths. Repeated flexing from chewing ultimately fatigues many dentures in mouth, which necessitate the need for improving flexural strength of high impact denture base resins.

Keywords: Poly (methylmethacrylate); denture base resins; flexural strength.

Introduction

Earlier, the materials available for dental treatment were simple in nature, few in number, and the art of application was elementary, with much disappointment often with the final results. It seems probable that the need for superior materials and improved restorations was recognized by those who were responsible for the early dental art, but it remained for future generations of scientists to provide the needed refinements and improvements, through slow evolutionary processes. The fracture of acrylic resin dentures is an unresolved problem in removable prosthodontics despite numerous attempts to determine its causes.[1] Fracture of an acrylic resin complete denture base poses a problem for all dentists and laboratory technicians. A common site is on an anteroposterior line that coincides with the notch for the relief of the labial fraenum of either the maxillary or mandibular complete denture. This type of fracture is caused by flexure of the complete denture base caused by tissue changes such as alveolar resorption, which results in superiorly deflected left and right halves of the denture with a fulcrum along the midline of the palate. In the mandibular complete denture, flexure occurs primarily in a lateral direction with the posterior elements forced apart as much as 1.5mm. In both of these fracture locations, repeated stress caused by chewing will produce material fatigue at the fulcrum of the flexure. Another common cause of fracture of denture base is traumatic breakage when the denture is dropped onto a hard surface.[2] Attempts have been made to improve the strength of the denture base has been addressed in 3 ways: Introduction of various substitutes for PMMA such as nylon, polycarbonates and polyamides, the chemical modification of PMMA through the addition of rubber in the form of butadiene styrene, incorporation of fibres inserts or beads. Various polymer substitutes such as vinyl acrylic, polystyrene and acrylic styrenes have not shown to produce dentures of greater accuracy or better performance. Polycarbonate has been used to produce dentures with increased strength and good clinical performance but it is injection moulded and therefore requires more complex equipment for processing. Another way to increase the strength of polymethyl methacrylate is to incorated with fibres-glass, carbon, graphite, polyethylene. Carbon and graphite fibres marginally increase the strength but have poor esthetics and are difficult to polish.[3]

Materials and Methods

This study was performed to evaluate the flexure strength of heat cure- Lucitone199, microwave cured denture base materials - Vipi Wave, 2% glass fiber reinforced lucitone 199 and then compare their respective values in relation to flexure strength. And also investigate the effect of a new fiber system i.e. randomly oriented, 6 mm, and glass-fibres on impact strength and flexural strength of conventional heat cured lucitone199 denture base resins. 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: Stainless steel metal strips of dimensions 65mm x 10mm x 2.5mm were selected (According to ADA no; 12, 1975, American National Standard Specification for denture base polymers, Chicago, 1994) for evaluation of flexural strength. The specimens were invested to create a mould space for preparation of different denture base materials specimens.

A total of 60 specimens were made and divided equally into three groups (Group A, B and C) and in each group 20 specimens of dimensions 65mm x 10mm x 2.5mm were used to evaluate flexure strength.
The groups were as follows:

i) Group A: 20 specimens of heat cure denture base resins (Lucitone 199),

ii) Group B: 20 specimens of microwave cured denture base resins (Vipi Wave),

iii) Group C: 20 specimens of Glass fibre reinforced Lucitone 199 denture base.

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, were used to prepare gypsum mould. Master dies were accurate and convenient to use in preparing the moulds. The dies had threaded holes at each corner to permit easy removal from the moulds. 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. 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 were then applied onto the set stone mould.[4] 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 were 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.[5] 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 and trial closure was carried out using Hydropress (Dentalfarm Torino-Italy) (Fig. 7) 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 (C-73A Confident Dental Equipments Ltd. Bangalore) (Fig. 8) at room temperature. The temperature was raised to 73 ^{o}C, held for 1 ½ hours, then raised to 100 ^{o}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.[6,7] 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 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 (Mistubishi electric trading colld, Osaka Japan) (Fig. 9) 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 dimension were obtained by this procedure.[8]

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.[10,11] 10 ml of monomer and 21 gm of polymer were measured using the electronic measuring balance (Chyo balance corp., Kyoto, Japan).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

The test specimens were stored in water bath at 37 ^{o}C for two weeks before doing the mechanical testing. Before testing, the thickness, length and width of each specimen were verified with digital caliper. The flexural strength of specimens was tested by a three-point loading device affixed to a dynamic testing machine (Agis Shimadzo, Japan) [12,13]

Results

The flexural 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.[12,14] 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:

$$S = \frac{3pi}{2bd^2}$$

Where,

S = transverse strength
p = fracture load
i = distance between supports, 50 mm
b = specimen width, 10 mm
d = specimen thickness, 4 mm

The flexural strength values for each material are summarized and graphically displayed in (Bar diagram). The data comprise the mean values obtained together with the standard deviation of coefficient of variation. To identify any significant differences between the data obtained for the groups of materials tested, a One-Way analysis of variance (ANOVA) was undertaken.

Table I: Load (Kg) At Fracture Of Three Study Groups (For Flexure Strength)

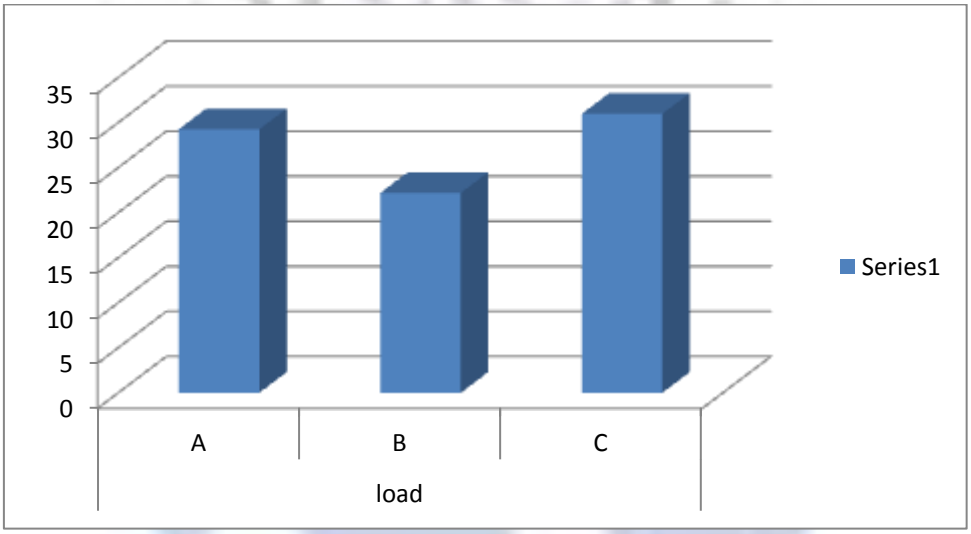
SUB-GROUPS	Load (Kg)				Difference between groups		
	Range	Mean	SD	CV (%)	Sub-Groups compared	Mean difference	Significance*
A	26.62-32.28	29.25	1.57	5.3	a_2-b_2	7.06	0.00
					a_2-c_2	-1.71	0.101
B	18.05-28.02	22.18	3.31	14.9	b_2-a_2	-7.06	0.00
					b_2-c_2	-8.78	0.00
C	29.87-33.21	30.964	1.35	4.3	c_2-a_2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

One way ANOVA F = 42.56 p = 0.001

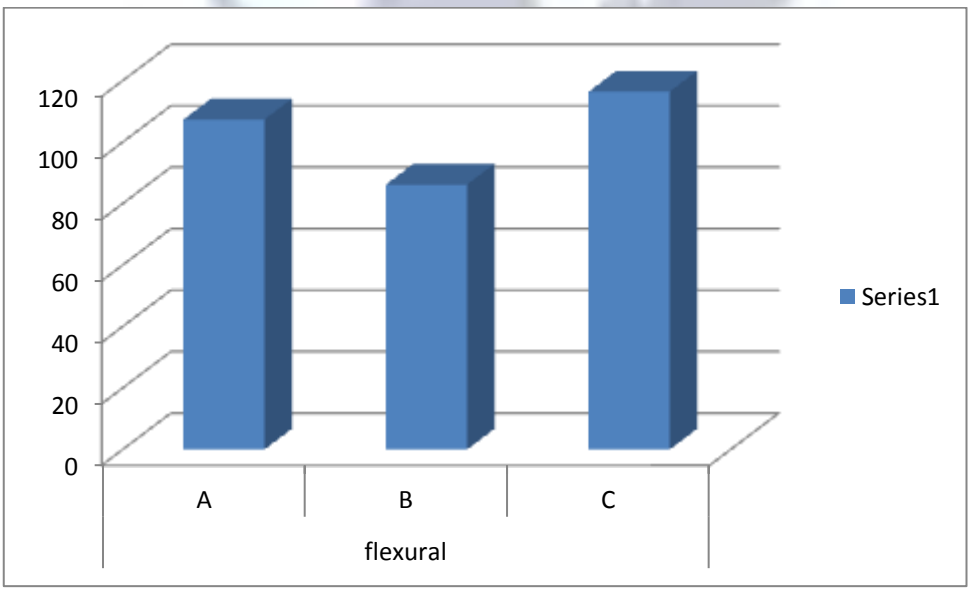
Table II: Flexure Strength (MPA) Of Three Study Groups

SUB-GROUPS	TRANSVERSE STRENGHT (MPa)				Difference between groups		
	Range	Mean	SD	CV (%)	Sub-Groups compared	Mean difference	Significance*
A	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	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	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



BAR DIAGRAM 1: Load (kg) fracture of three study groups (for flexure strength)



BAR DIAGRAM 2: Flexure strength of three study groups

Discussion

The flexural strength of a material is a measure of stiffness and is resistance to fracture. Flexural strength, is essentially a strength test of a bar supported at each end, or a thin disk supported along a lower support circle, under a static load. For a bar subjected to three - point flexure (upper central loading), the mathematical formula for computing the flexure strength is as follows.

$$\sigma = \frac{3pl}{2bd^2}$$

σ: Flexural strength

l: The distance between the supports

b: Width of the specimen

d: Depth or thickness of the specimen

p: The maximum load at the point of fracture

Flexural strength tests were undertaken as these were considered relevant to the loading characteristics of a denture base in a clinical situation. The strength of a material in bending, expressed as the stress on the outermost fibres of a bent test specimen, at the instance of failure. For the measurement of the flexural strength, a three point bending test was used. The values of the load to fracture the specimens and the flexural strength are summarized in Tables I & II. 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. Increase in mean load to fracture the specimens and corresponding mean flexural strength was highest in Group C (116.43 MPA) followed by Group A(107.37 Mpa) and Group B(87.23 Mpa). The flexural strength was least in Group B. Group A also shows higher flexure strength than B. Analysis of variance showed that the difference in load at fracture and corresponding flexural strength was statistically significant (p=0.001).The Group C 2% fibre reinforced lucitone199 shows statistically significant higher flexure strength as compared to sub group A Lucitone 199 and sub group B Vipi-wave.

An increase in the flexural strength with the incorporation of glass fibres is in agreement with the previous studies done by Uzun, Tenser, Hersek[15] Vallittu[16]; Vallittu, Lassilla, Lappalainen and Marie.[18,19] An increase in flexural strength with incorporation of glass fibres is due to the load shared between the matrix and glass fibres. Glass fibres have high tensile strength thus, increasing the flexural strength. Vallittu, Lassilla and Lappalainen[20] showed that an increase in the amount of fibres increase (36%) enhanced the fracture resistance.[20,21]

Hayden[23] found that the flexural strength of acrylic resin cured by microwave energy did not absorb as much energy before fracture as the heat cured denture base resin. Smith investigated hardness, flexural strength, modulus of elasticity of seven resins cured using heat and microwave energy and concluded that microwave curing improve the modulus of elasticity of two resins, decrease the impact strength.[24,25,26] 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, it can be concluded that 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.

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