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Comparative Evaluation of the Impact Strength of Heat Cured (Lucitone199), Microwave Cured (VIPI WAVE) and Glass-Fibre Modified Denture Base Material

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Abstract: Impact strength is described as the energy needed to fracture a material under an impact force and the reaction of the stationary object to a collision with the moving object is defined as impact. There is a need for denture base resins to have features like high impact strength to withstand forces in the oral cavity.

Keywords: high impact denture base resin; polymethylmethacrylate; 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 An American Dental Association specification No.12 has been developed for acrylic denture base material and other modified plastics that have been developed in more recent years. The acrylic plastics generally have been found to have relatively satisfactory qualities, including appearance, dimensional stability, and a simple procedure for processing the denture. The patient generally is pleased with the colour, characteristics, and function of the dentures produced from acrylic plastics. 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 2, 3. The methyl methacrylate polymers and copolymers continue to be the most popular dental resins for denture base purposes and are fundamentally unchanged from 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. It has many advantages, particularly its appearance and ease of manipulation, but it has certain poor mechanical properties. Fractures may occur in use because of its unsatisfactory transverse strength, impact strength or fatigue resistance 4,5,6. The fracture of acrylic resin dentures is an unsolved problem in removable prosthodontics despite numerous attempts to determine its causes. The objective of higher impact resin is self evident, in that it absorbs greater amount of energy at a higher strain rate before fracture, than the standard resin.

Materials and Methods

This study was performed to evaluate the impact 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 impact strength. And also investigate the effect of a new fiber system i.e. randomly oriented, 6 mm, glass-fibres on impact 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)

Stainless steel metal strips of dimensions 60mm x 7.5mm x 4mm, were selected (According to ADA no; 12, 1975, American National Standard Specification for denture base polymers, Chicago, 1994) for evaluation of impact 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). Each group contained 20 specimens with dimension 60mm x 7.5mm x 4mm were used to evaluate impact 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 resins

Preparation of gypsum mould to obtain the specimens:

The stainless steel master dies of dimension 60mm in length, 7.5mm in width and 4mm 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.[7,8,9]

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 placed on top of the vibrator (Whip mix 361 made in Korea) taking care not to cause air entrapment. 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 resins:

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) 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) 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. [10] 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 (Mistubishi electric trading colld, Osaka Japan) 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.[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 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 ^{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. 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). Prior to the impact test the specimens were notched with impact specimen notcher (Tinius Olsen code no.: CIPET/JPR/PTC/EQUIP/51). In this test the test piece is clamped vertically with the notch facing the striker. 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.

Results

Impact strength:

The impact strength of specimens were tested by pendulum impact strength tester (Tinius Olsen, Jaipur). The mean, standard deviation and coefficient of variation were calculated for further analysis.

1. Group A: The energy absorbed to break the specimens which were in the range of 0.24-0.31 joules with a mean of 0.28 joules. The impact strength was then calculated using the formula.

Impact strength = E/N

The range of impact strength was between 7.4 x 10^{-3} – 8.26 x 10^{-3} joules/mm^2 with a mean of 7.73 x 10^{-3} joules /mm^2

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2. Group B: The energy absorbed to break the specimen ranged from 0.18 – 0.28 Joules with the mean of 0.20 joules. The range of impact strength was between 6.2 x 10^{-3} - 6.92 x 10^{-3} Joules / mm^2 with the mean of 6.62 x 10^{-3} joules/mm^2 .

3. Group C: The energy absorbed to break the specimens which are in the range of 0.25 – 0.35 joules with a mean of 0.30 joules. The range of impact strength was between 7.4 x 10^{-3} – 8.51 x 10^{-3} joules/mm^2 with the mean of 8.03 x 10^{-3} joules/mm^2 .

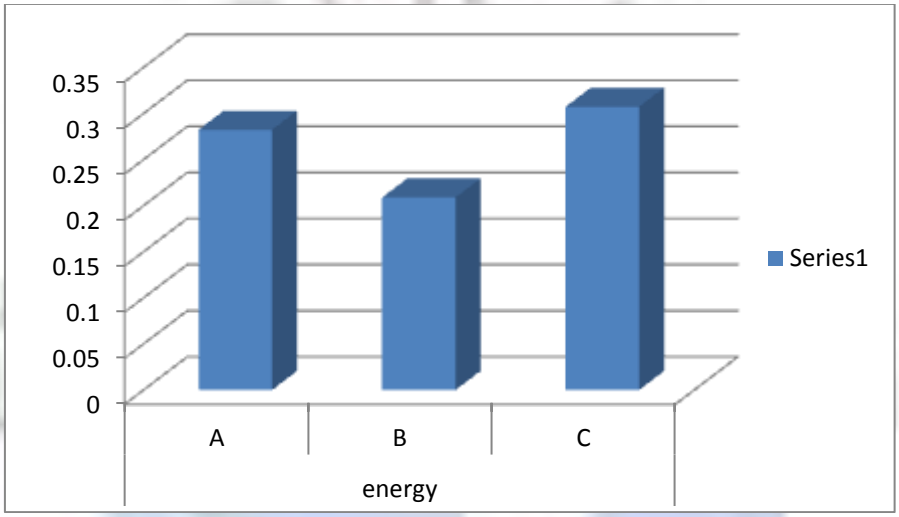
The mean energy absorbed to break the specimens of group A was 0.28 joules, group B was 0.20 joules and group C was 0.30 joules. The above analysis showed that higher the energy absorbed to fracture the specimens, greater the impact strength. The impact strength of group A was 7.73 x 10^{-3} joules/mm^2 , group B was 6.62 x 10^{-3} Joules/mm^2 , and group C was 8.03 x 10^{-3} Joules/mm^2 .

The analysis of the difference in impact strength was then carried out by One Way analysis of variance (ANOVA), which reveals significance in the different groups. The results revealed that group C shows statistically higher significant impact strength as compared to group B. Group C shows statistically just significant higher impact strength as compared to group A. Group A shows significantly higher values of impact strength as compared to B. Group C was considered superior to the rest of the groups .

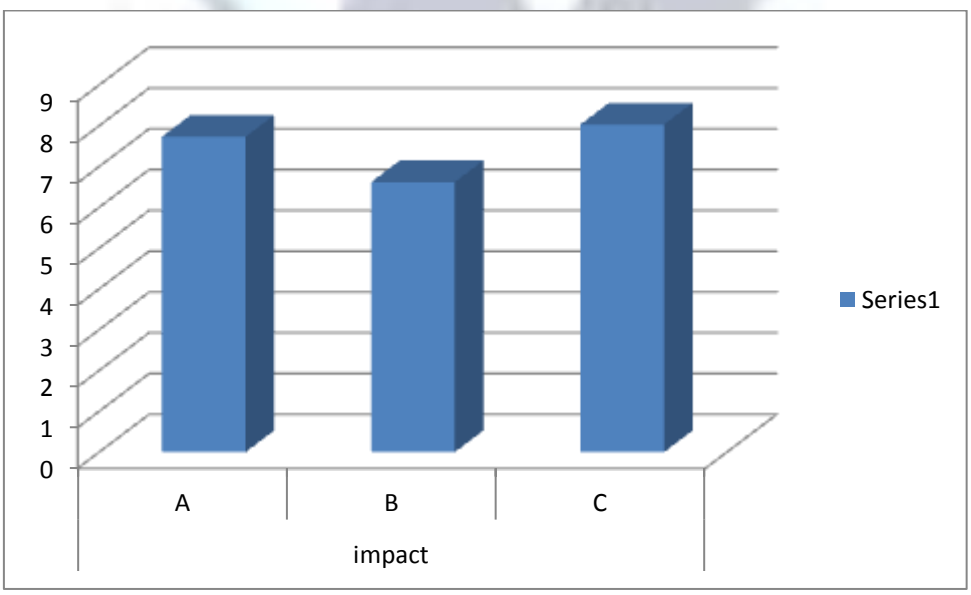
IMPACT STRENGTH (joules/mm^2) OF THREE STUDY GROUPS

GROUPS	Impact strength (joules/mm^2)				Difference between groups		
	Range	Mean	SD	CV (%)	Groups compared	Mean difference	Significance*
A	7.42-8.2 x 10^{-3}	7.73 x 10^{-3}	0.26	3.3	A-B	1.11	0.001
					A-C	-0.30	0.042
B	6.2-6.92 x 10^{-3}	6.62 x 10^{-3}	0.27	4.0	B-A	-1.11	0.001
					B-C	-1.41	0.001
C	7.4-8.5 x 10^{-3}	8.03 x 10^{-3}	0.39	4.8	C-A	0.301	0.042
					C-B	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



GRAPH -2: Impact strength (Joule/mm^2) of three study group

Discussion

Impact strength may be defined as the energy required to fracture a material under an impact force.[11] The term impact is used to describe the reaction of the stationary object to a collision with the moving object. Impact strength of a material depends on the characteristic energy absorbed to fracture the material during sudden blow or due to accidental fall of the denture outside the mouth.

Among several different types of test to measure impact strength, the pendulum impact test and falling weight test are two major impact tests.[12,13] The primary disadvantage with falling weight tester is that they require a large no. of specimens and the results may not be as repeatable as desired. The Izod and Charpy are two methods of pendulum impact test which are most commonly used. In comparing the impact resistance of plastic materials, Izod test has become the recognized standard for comparing the impact resistance of plastic materials, it is fast and economic test and the tests are often performed at different temperatures to more closely simulate the actual service conditions.
In this study the Izod pendulum impact tester was used to evaluate and compare impact strength of different denture base materials. The impact strength data and fracture characteristics depend on many factors including material selection, geometry of the specimen, fabrication variables, stress concentrations, position of specimen, and temperature.[13] Stress concentration is the main contributor to the impact failure in denture and include notches, scratches, depressions, sharp corners, rough surface, grooves, holes, textured surface, sudden change in thickness, foreign particles, or gas inclusions. The surrounding temperature also has an effect on the impact strength of material. As the temperature increases to the glass transition temperature or higher, the impact strength of amorphous polymer increases because molecular motion is the back bone of polymer chain is increased enough to relieve stress concentrations. Thus the temperature can make a material fail either in brittle or ductile manner. Plasticizer can increase the impact strength of a polymer because they lower the glass transition temperature of the polymer and increase the energy dissipation per unit volume. Plasticizers also decrease notch sensitivity and impede crack propagation. Brittle polymers can be converted into high-impact polymer by addition of rubber.[13]

The energy absorbed to fracture the specimens and corresponding impact strength of three study groups are presented. The mean energy absorbed to fracture the specimens and corresponding mean impact strength was highest in Sub group C (energy absorbed 0.30 joules/mm^2 and impact strength 8.03 x 10^{-3} Joules/mm^2) followed by Sub group A (Energy absorbed 0.28 Joules, Impact strength 7.73 x10^{-3} Joules/mm^2). Sub group B exhibited least impact strength (Energy absorbed 0.20 joules, impact strength 6.62 x10^{-3} joules/mm^2). Thus, higher the energy absorbed to fracture the specimens, greater the impact strength.

Analysis of difference in impact strength was then carried out by one way classification (ANOVA). The sub group C shows statistically significant higher impact strength compared to Sub group A and Sub group B. 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 stopped the crack propagation. However, the fact that glass fibre reinforcement enhances the impact strength of acrylic resin is in agreement with other research.[14, 15, 16, 17] Vallittu[15], Aydin C[18] and Kim S H[13] concluded that glass fibres are considered to be suitable for strengthening denture. In addition, the translucency of glass fibres provides aesthetically pleasing denture. The group A also shows statistically significant higher impact strength as compared to group B because the group Ais rubber reinforced acrylic resin. If a crack develops in rubber reinforced acrylic resins, it will propagate through the poly methyl methacrylate but will decelerate at the rubber inter phase. The interface and bond between the fibre and matrix in relation to the success of the reinforcement is a controversial area. Isaac[19] reported that the importance of the interface of the fibre and the matrix cannot be over emphasized and suggest that poorly bonded fibres to which little load is transferred can act as voids. Therefore, decrease the impact strength.

Conclusion

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.

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