doi:10.5368/aedj.2011.3.4.1.2

EFFECT OF GLASS FIBER AND SILANE TREATED GLASS FIBER REINFORCEMENT ON IMPACT STRENGTH OF MAXILLARY COMPLETE DENTURE

¹ Hari Prasad A	Assistant Professor
² Kalavathy	Professor and Head
³ Mohammed H S	Assistant Professor

^{1,3} Department of Prosthodontics including Crown and Bridge and Implantology, M. R. Ambedkar Dental College & Hospital, #1/36, Cline Road, Cooke Town, Bangalore-560005, Karnataka, India,
 ² Department of Prosthodontics, D A P M R V Dental College & Hospital, #37, 24 main, J.P.Nagar first phase, Bangalore-560078, Karnataka, India.

ABSTRACT

Background and objectives : The fracture of acrylic maxillary complete dentures is a commonly seen clinical problem which usually occurs due to heavy occlusal forces or accidental damage. The objectives of the study were to measure the impact strength of maxillary complete dentures fabricated with high impact acrylic resin and to evaluate the effect of woven E-glass fiber and silane treated glass fiber reinforcement on the impact strength of the Maxillary complete dentures. **Methods :** One commercially available heat cured acrylic resin (Trevalon HI) was selected. Preimpregnated woven E-glass fibers (Stick Net) and Silane treated glass fibers were used to reinforce ten maxillary complete dentures each. Ten unreinforced complete dentures served as the control group. The impact strength in Joules of the dentures were measured with a falling-weight impact test. **Results :** The mean impact strength of dentures reinforced with preimpregnated woven E-glass fibers was 165.91+/- 12.929 J at crack initiation, and 84.62+/- 11.495 J at complete fracture. The mean impact strength of dentures reinforced with preimpregnated woven E-glass fibers was 165.91+/- 12.929 J at crack initiation, and 187.06+/- 17.972 J at complete fracture. The mean impact strength of dentures reinforced with silane treated glass fibers was 112.30+/- 8.709 J at crack initiation, and at complete fracture was 126.43 +/- 8.709 J. **Interpretation and Conclusion :**The impact strength of maxillary complete dentures fabricated with high impact acrylic resin increased significantly after reinforcement with preimpregnated woven E-glass fibers and silane treated glass fibers. The best improvement, however , was obtained by preimpregnated woven E-glass fibers.

KEYWORDS: Heat cured acrylic resin, Woven E-glass fibers, Silane treated glass fibers, Complete Denture and Impact Strength.

INTRODUCTION

Good complete dentures are essential to improve the quality of life of completely edentulous patients. It is a challenge for the dentist to provide a good prosthesis that meets the functional demands of the oral cavity. The most commonly used material for the construction of complete dentures is Poly Methyl Methacrylate. Good esthetics and ease of manipulation are the main advantages of Poly Methyl Methacrylate. Excellent duplication of the appearance of the tissues is possible with PMMA. However the strength characteristics, such as impact strength and fatigue strength are poor with PMMA¹.

Studies have shown that 68% of acrylic resin dentures break within a few years of fabrication. Intra orally, repeated masticatory forces lead to fatigue failure and fracture, while extra orally high impact forces may occur as a result of dropping of the prosthesis, with consequent fracture of the denture bases². Most maxillary denture fractures are caused by a combination of fatigue and impact failure, where as for mandibular dentures, 80 % of fractures are caused by impact. In most situations fractures occur along the midline of the denture base. This type of fracture is more commonly seen in maxillary dentures than in mandibular dentures³.

Due to these fractures the patient is put to severe inconvenience as they have to be with out dentures until the denture is repaired. A lot of money is spent worldwide annually to repair fractured dentures. This puts a lot of strain on financial and technical resources³. Furthermore the repaired dentures do not have the same strength, thus limiting the functional use of the prosthesis.

Earlier, attempts had been made to improve the mechanical properties of the acrylic resin with emphasis on impact and flexural strength. These included addition of more bulk of material in areas receiving more stresses, copolymerization of resin with rubber⁴, reinforcement with various fibers like polycarbonate fibers, carbon fibers⁵, glass fibers⁶, aluminum and sapphire whiskers and the

addition of metal strengtheners⁷. Although the addition of reinforcing fibers and metal strengtheners increased impact strength properties, it resulted in poor esthetics and poor bonding between the reinforcing material and acrylic resin⁷.

To over come the problem of poor esthetic appearance of reinforced dentures, E-glass fibers were developed. Since these fibers were transparent or colorless they provided very good esthetics⁸. However the problem with these fibers was poor bonding between the glass fibers and acrylic resin. To over come this problem various types of surface treatment of the glass fibers have been advised. Significant among them are preimpregnation of glass fibers with polymer⁶, and silane treatment of glass fibers⁹.

Although there are many studies regarding impact strength of acrylic resin reinforced with various kinds of fibers, all the studies used rectangular specimens of acrylic resin which did not simulate the clinical situation^{10,11}. All the tests were carried out with the flexedbeam impact test methods. The main draw back with using flexed beam impact test methods is that the values obtained for impact strength cannot be correlated clinically¹¹. The falling weight impact test method is an acceptable alternative to measure impact strength¹². This test simulates the clinical situation better and therefore the impact strength values obtained may be more relevant clinically. The effect of fiber reinforcement on conventional heat cure resin was determined in most of the studies. There are very few studies regarding the effect of fiber reinforcement on the rubber phase-incorporated high-impact resin¹². Studies, which were conducted earlier, were mostly on the effect of E-glass fiber reinforcement on the impact strength of maxillary complete dentures. There are very few studies comparing the effect of silane treated glass fiber reinforcement and E-glass fiber reinforcement on the impact strength of maxillary complete dentures.

The aim of this study was to examine the effect of Eglass fiber-reinforcement and silane treated glass fiber reinforcement on the impact strength of maxillary complete dentures fabricated with high impact acrylic resin.

Methodology

Thirty identical maxillary complete dentures were fabricated for impact strength evaluation. The various steps involved in preparation of the samples were :

- A) Preparation of edentulous casts
- B) Arrangement of artificial teeth in ideal class I relationship
- C) Fabrication of a silicone mold
- D) Duplication of dentures.
- E) Finishing and polishing

Annals and Essences of Dentistry

Dental stone was poured in an edentulous maxillary mold (Nissin corporation, Japan) to make thirty master casts that were used to fabricate the dentures. On one of the maxillary edentulous casts a denture base of 2 mm thickness was fabricated using auto polymerizing acrylic resin. Over this denture base an ideal occlusal rim of specified standard dimensions was fabricated. This occlusal rim along with an ideal occlusal rim fabricated on an edentulous mandibular cast was mounted on a mean value articulator. Over this mounted occlusal rim artificial acrylic teeth [Premadent acrylic teeth,M1 shape, shade 24] were arranged in class I relationship. Wax up and carving was done. After this the maxillary denture base was sealed to the cast with wax. Maxillary cast with teeth arrangement was dearticulated from the articulator. Then this cast was flasked using varsity flasks and clamp. Subsequently dewaxing was done following standard procedures. After dewaxing, the acrylic resin teeth were carefully separated from the mould to leave an empty space in the mould. Addition silicone in putty consistency was packed into this mould and closed under pressure until it set. The flasks were carefully separated to obtain the silicone index. The excess was trimmed from this index. This index was used to duplicate thirty maxillary complete dentures. For duplication this index was placed on a maxillary edentulous cast and sealed with wax. Then the sealed cast was flasked in the usual manner .After the investing stone had set, the flask assembly was placed in hot water for five minutes so that the sealing wax softened. After the wax had softened the flask was opened and the silicone index was retrieved. Acrylic teeth (Premadent acrylic teeth, M1 shape, shade 24) were placed in the mould. In this manner thirty moulds were made. They were divided into 3 groups of ten each.

- **Group I** Moulds processed with high impact acrylic resin according to the manufacturers instructions.
- Group II Moulds processed with high impact acrylic resin modified with woven pre impregnated E - glass fiber reinforcement.
- **Group III** Moulds processed with high impact acrylic resin modified with silane treated E- glass fibers.

Group I – Dentures processed with high impact acrylic resin. Following dewaxing acrylic resin teeth were placed in the mold in the space meant for it. Separating medium was applied to the mold. High impact acrylic resin (Trevalon HI, Dentsply) was packed into the mould as per standard procedures. Closing pressure was applied using a pneumatic press. The flask assembly was kept for bench curing for 30 minutes. Long curing cycle without terminal boil out was done in an electrically controlled polymerization unit to cure the resin. After curing the flasks were deflasked and the maxillary complete denture was retrieved. Ten dentures were similarly duplicated.

Group II - Dentures processed with high impact acrylic resin modified with E - glass fiber reinforcement. The glass fiber mesh was placed on the maxillary cast and cut to the required shape (Fig.1). The glass fiber mesh was then wetted in an aqueous mixture of acrylic resin (i.e. 1:1 mixture of polymer to monomer), and placed in the mould prior to packing with acrylic resin. Heat cured acrylic resin stops were placed on both halves of the mould to ensure that the glass fiber mesh was 1mm away from both the tissue and polished surface of the finished denture base. Closing pressure was applied using a pneumatic press. Standard protocol was followed to pack and cure the dentures.



Fig.1. glass fibers cut according to shape

Group III - dentures processed with high impact acrylic resin modified with silane treated glass fibers. Since the glass fibers were pretreated with silane, wetting with polymer was not required and a similar protocol was followed as for Group II. Ten dentures were similarly duplicated . The cured dentures were subjected to standard finishing and polishing procedures. While finishing, denture base was trimmed to a uniform thickness of 2m.m. The samples thus obtained were stored in water for 14 days at 37⁰ c.

Measurement of impact strength :

To measure impact strength falling weight method of impact test was used. A hard wooden impactor weighing 800 grams was used. A specially designed instrument was used to guide the impactor on to the denture(Fig.1). It consisted of a plastic tube measuring 1.2 meter in height and held in place by a metal stand. A window was cut into this plastic tube to facilitate the placement of the impactor and also to reduce the friction between the impactor and the tube. A hook was attached on to the top surface of the impactor so as to facilitate the dropping of the impactor. A wooden plate was kept on the bottom of the apparatus on which dentures were kept during testing. A scale was attached to the plastic tube so as to facilitate measurement. A denture was kept in the middle of the wooden table at the bottom of the apparatus. Then the

Fig.2. Apparatus used for dropping method of impact strength test.

Results

All the samples were tested for impact strength using falling weight impact test method. Two measurements were obtained for each denture. One was at crack initiation and the other was at complete fracture. Measurements obtained in joules were statistically analyzed.

- Graph 1 shows the analysis of impact strength of maxillary complete dentures at crack initiation
- Graph 2 shows the analysis of impact strength of maxillary complete dentures at complete fracture.

Discussion

PMMA is simple to use, cost effective and has good esthetics. But the main disadvantage of PMMA is inadequate mechanical properties. Fracture of the base may occur during function because of the poor transverse, impact, and flexural strengths of PMMA¹. One of the most

Annals and Essences of Dentistry

wooden impactor was lowered in the plastic tube up to a point where it was 60-centimeter away from the base. From this point the impactor was allowed to fall freely on to the denture. The number of times the impactor had to fall on to the denture before it started to crack was noted.(Fig.3) Also the additional number of impacts required for complete fracture was noted.(Fig. 4) The impact energy was calculated using the following formula :

$E = mg \Sigma h_i$ Where

- = impact strength in joules F
- М = mass of wooden impactor in kilograms = acceleration due to gravity in m/sec g
- = height, from which the impactor is dropped.(mts) h I = number of impacts.



Fig.3 Reinforced denture at crack initiation Fig.4.Reinforced denture

at complete fracture

common causes for breakage of dentures is flexural fatigue due to continued flexing of the base during function, which leads to crack development. Midline fracture of the denture base is the usual sequelae of flexural fatigue failure^{3,13-17}.

Various materials have been used to reinforce maxillary complete dentures to improve their mechanical properties. These include materials like carbon fiber^{5,15,16}, steel fibers^{7,17,-,23}, Kevlar fibers¹⁹ and Ultra High Modulus Polyethylene (UHMPE) glass fibers^{1,18}. Poor esthetics precludes the use of carbon fibers, steel fibers and Kevlar fibers^{5,7,19}. Though Ultra High Molecular Weight Polyethylene glass fibers and Polyethylene fibers are more esthetic they did not bond well to the acrylic resin and hence did not significantly improve the strength^{1,18}.



A key advantage of woven E- glass fiber is high tensile strength. Thus, the highest tensile strength effect can be achieved when the fiber is positioned as far as possible on the tension side of prosthesis rather than at the compression side. In this study, the fiber was positioned on the intaglio surface side, at a depth of 1 mm from the

Vol III. Issue 4 Oct- Dec 2011

Annals and Essences of Dentistry

resin, to increase the effect of reinforcement¹².In order to improve the bonding between the glass fibers and acrylic resin different types of surface treatment of the glass fibers have been done. Significant among them are silane treatment of glass fibers⁹ and preimpregnation of glass fibers with a porous prepolymer network⁶.Untreated glass fibers act as inclusion bodies in the acrylic resin mixture and instead of strengthening they weaken the resin. To overcome this glass fibers are silane treated by soaking glass fibers in 3 - methacryloxypropyl - trimethoxysilane (MPS) in acetone³². Silane treatment of glass fibers chemically bond glass fibers to the resin matrix resulting in a stronger PMMA matrix. Silane treatment is done by using a bifunctional silane-coupling agent, which has an intermediary carbon-connecting segment to provide the interfacial phase that holds together the organic polymer matrix with the reinforcing inorganic phase^{9, 24}. A recent fiber reinforcement system (Stick-Net) is based on preimpregnation of reinforcing fibers with highly porous polymer, which allows good impregnation of fibers with the polymer matrix in the end product. The highly porous polymer of Stick Net (SN) reinforcement systems will be wetted with a mixture of polymer and monomer and subsequently, the porous preimpregnation polymer was plasticized by dissolution. This leads to better bonding between the fibers and the denture base resin and allows high impregnation of the reinforcing fibers with the multiphase resin matrix⁶.



The weight percentage of fiber impregnation in the denture base is critical for the increase in impact strength. Glass fibers that are improperly impregnated in the resin decreases the tensile strength and elastic modulus of the resin because of the voids between fibers, increased water sorption, and decreased degree of conversion³².Impact strength data and fracture characteristics depend upon many factors including material selection, geometry of the specimen, fabrication variables, stress concentrations, position of the specimen, and temperature. Areas of stress concentration are the main contributors of impact failure in dentures. These

include notches, scratches, cuts, depressions, sharp corners, holes, grooves, rough surfaces, textured surfaces, sudden changes in thickness, foreign particles, or gas inclusions. In this study since maxillary complete dentures were fabricated as test specimens, all these factors that affect the clinical service of the denture was closely duplicated.

The surrounding temperature of the prosthesis also has an effect on the impact strength of a material. As the temperature increases to the glass transition temperature of the resin, the impact strength of amorphous polymers and most crystalline polymers increases, because molecular motion in the backbone of the polymer chains is increased enough to relieve stress concentrations. Thus, temperature can make a material fail in either a brittle manner or ductile manner. Plasticizers 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 polymers by the addition of a rubber phase^{4,12}.

This study was designed to simulate the clinical situation by using maxillary dentures and by testing using the falling weight impact test. The dimensions of the specimens approximated the dimensions of actual prostheses fabricated by the conventional method. Therefore, the results from this test may be more clinically relevant.

The results of this study showed that when the denture was reinforced with Stick Net fibers, the impact strength increased 220% at crack initiation, and 223% at complete fracture. It also showed that when silane treated glass fibers were used the impact strength increased 149% at crack initiation and 150% at complete fracture. The results of this investigation indicated that the reinforcement of dentures with pre impregnated E-glass fibers and silane treated E-glass fibers significantly increased the impact strength of high-impact acrylic denture. The strength values obtained by the pre impregnated E-glass fiber reinforcement was considerably higher than that with the silane treated E-glass fiber. This was due to better bonding of resin matrix with pre impregnated E-glass fiber reinforcement.

A limitation of this study is that only one denture base resin was used. As this was a high-impact resin, similar reinforcement effects might be expected with other high-impact resins using the same fiber system and for low-impact resins as well. It should be noted that impact strength of the acrylic denture base reinforced with glass fibers varies according to the test condition, composition of resin, geometry of denture, fiber type, fiber form, fiber position, fiber orientation, and fiber fraction. These factors have an important influence on clinical performance of the dentures. Thus these factors should be considered for further studies. Another limitation of this study was that it was an in vitro study. The nature in which the reinforced denture base behaves in oral cavity has to be investigated further.

CONCLUSION :

Within the limitations of the study, the following conclusions were drawn :

- 1. The impact strength of high impact, acrylic maxillary complete denture reinforced with woven pre impregnated E-glass fibers was significantly higher, by a factor of more than 2, than that of the unreinforced denture both at crack initiation and at complete fracture.
- 2. The impact strength of high impact, acrylic maxillary complete denture reinforced with silane treated glass fibers was significantly higher, by a factor of more than 1, than that of the unreinforced denture both at crack initiation and at complete fracture.
- 3. The impact strength of high impact acrylic maxillary complete dentures reinforced with woven pre impregnated E-glass fibers was significantly higher, by a factor of 0.5, than that of silane treated E- glass fiber reinforced denture.
- 4. The crack propagation energy of the high impact, acrylic maxillary complete denture reinforced with woven pre impregnated E-glass fibers and silane treated E-glass fibers was significantly higher than that of the unreinforced denture.

Summary :

This study evaluated the effect of glass fibers and silane treated glass fiber reinforcement on the impact strength of high impact acrylic resins. Thirty maxillary dentures were fabricated as samples using high impact acrylic resins. Out of thirty maxillary dentures ten served as control group, ten were reinforced using pre impregnated E-glass fibers and ten were reinforced with silane treated glass fibers. Falling weight impact test was used to measure the impact strength. Among the sample group dentures reinforced with pre impregnated E-glass fibers showed significant improvement over control group followed by silane treated glass fibers.

References

 D.L.Gutteridge. The effect of including ultra-high modulus polyethylene fiber on the impact strength of acrylic resin. Brit Dent J 1988; 164:177-181 PMid:3163487 <u>http://dx.doi.org/10.1038/sj.bdi.4806395</u>

- E Johnston, JL Nicholls, D Smith. Flexural fatigue of ten commonly used denture base resins. J Prosthet Dent 1981; 46: 478-483<u>http://dx.doi.org/10.1016/0022-3913(81)90232-8</u>
- U.R.Darbar, R.Huggett, A.Harrison. Denture fracture â□^w a survey. Brit Dent J 1994; 176:342-345. PMid:8024869 <u>http://dx.doi.org/10.1038/sj.bdj.4808449</u>
- 4. William. J.O Brien. Polymers and polymerization. A text book on dental materials and their selection (Quintessence books) 3rd edition; 2001: 74-90.
- C.K.Schreiber. Poly methyl methacrylate reinforced with carbon fibers. Brit Dent J 1971; 130:29-30 PMid:5276471 http://dx.doi.org/10.1038/sj.bdj.4802623
- P.K.Vallittu. Flexural properties of acrylic resin polymers reinforced with unidirectional and woven glass fibers. J Prosthet Dent 1999; 81(3): 318-326. http://dx.doi.org/10.1016/S0022-3913(99)70276-3
- <u>http://dx.doi.org/10.1016/S0022-3913(99)70276-3</u>
 7. A.J. Bowman, T.R.Manley. The elimination of breakages in upper dentures by reinforcement with carbon fiber. Brit Dent J 1984; 156:87-89. PMid:6365128
- http://dx.doi.org/10.1038/sj.bdi.4805275
 D.C.Jagger, A.Harrison, K.D.Jandt. The reinforcement of dentures. J Oral Rehab 1999; 26: 185-194 PMid:10194725 http://dx.doi.org/10.1046/j.1365-2842.1999.00375.x
- Solnit. Reinforcement of Polymethyl methacrylate reinforcement with silane treated glass fibers. J Prosthet Dent 1991; 66(3) : 310-314
- http://dx.doi.org/10.1016/0022-3913(91)90255-U
 10. P.K.Vallittu, Katja Narva. Impact strength of a modified continuous glass fiber â□^w poly methyl methacrylate. Int J Prosthodont 1997; 10: 142-148. PMid:9206454
 11. Gulay uzun, Nur Hersek, Teoman tincer. Effect of five woven
- Gulay uzun, Nur Hersek, Teoman tincer. Effect of five woven fiber reinforcements on the impact and transverse strength of a denture base resin. J Prosthet Dent 1999; 81:616-620 http://dx.doi.org/10.1016/S0022-3913(99)70218-0
- S.H.Kim, David.C.Watts. The effect of reinforcement with woven E-glass fibers on the impact strength of complete denture fabricated with high impact acrylic resin. J Prosthet Dent 2004; 91: 274-280. PMid:15060499 http://dx.doi.org/10.1016/j.prosdent.2003.12.023
- M.S.Beyli, J.A.von Fraunhofer. Analysis of causes of fracture of acrylic resin dentures. J Prosthet Dent 1981; 46(3):238-241. http://dx.doi.org/10.1016/0022-3913(81)90206-7
- C.E.Carroll, J.A.von Fraunhofer. Wire reinforcement of acrylic resin prostheses. J Prosthet Dent 1984; 52(5): 639-641. http://dx.doi.org/10.1016/0022-3913(84)90132-X
- J.De Boer, S.G. Vermilyea, R.E. Brady. The effect of carbon fiber orientation on the fatigue resistance and bending properties of two denture resins. J Prosthet Dent 1984; 51(3):119-121. <u>http://dx.doi.org/10.1016/S0022-3913(84)80117-1</u>
- N.Yazdanie, M.Mahood. Carbon fiber acrylic resin composite: An investigation of transverse strength. J Prosthet Dent 1985; 54(4): 543-547 <u>http://dx.doi.org/10.1016/0022-3913(85)90431-7</u>
- Anthony R Ruffino. Effect of steel strengtheners on fracture resistance of the acrylic resin complete denture base. J Prosthet Dent 1985; 54(1): 75-81.

Annals and Essences of Dentistry

http://dx.doi.org/10.1016/S0022-3913(85)80074-3

- M.Braden, K.W.M.Davy, S.Parker, N.H.Ladizesky, I.M.Ward. Denture base poly (methyl methacrylate) reinforced with ultra-high modulus polyethylene fibers. Brit Dent J 1988; 164:109-113 PMid:3279982 http://dx.doi.org/10.1038/sj.bdi.4806373
- Joseph.M.Berrong, Roger.m.weed, John.m.Young. fracture resistance of Kevlar-reinforced Polymethyl methacrylate resin: a preliminary study. Int J Prosthodont 1990; 3: 391-395. PMid:2088377
- Donna.L.Dixon, Larry.C.Breeding. The transverse strength of three denture base resins reinforced with polyethylene fibers. J Prosthet Dent 1992; 67(4): 417-419. PMid:1507114
 N.H.Ladizesky, C.F.Ho, T.W.Chow. Reinforcement of
- N.H.Ladizesky, C.F.Ho, T.W.Chow. Reinforcement of complete denture bases with continuous high performance polyethylene fibers. J Prosthet Dent 1992; 68(6): 934-939 <u>http://dx.doi.org/10.1016/0022-3913(92)90554-N</u>
- P.K.Vallittu, V.P.Lassila. Effect of metal strengthenerâ □[™]s surface roughness on fracture resistance of acrylic denture base material. J Oral Rehab 1992;19: 385-391. PMid:1432353

http://dx.doi.ora/10.1111/i.1365-2842.1992.tb01580.x

- P.K.Vallittu. Effect of some properties of metal strengtheners on the fracture resistance of acrylic denture base material construction. J Oral Rehab 1993; 20: 241-248 <u>http://dx.doi.org/10.1111/j.1365-2842.1993.tb01606.x</u> PMid:8496730
- Ozgul Karacer, Tulin Polat, Arzu Tezvergil, Lippo Lassila, P.K.Vallittu. The effect of length and concentration of glass fibers on the mechanical properties of an injection and compression molded denture base polymer. J Prosthet Dent 2003; 90: 385- 393. <u>http://dx.doi.org/10.1016/S0022-3913(03)00518-3</u>

Corresponding Author

Dr. Hari Prasad. A. BDS., MDS., Assistant Professor,
Department of Prosthodontics including Crown and Bridge and Implantology,
M R Ambedkar Dental College & Hospital, #1/36, Cline Road, Cooke Town,
Bangalore-560005, Karnataka, India.
E-mail: ramp218@yahoo.com
Mobile: +91-9341071088