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To evaluate the fracture resistance of maxillary complete dentures reinforced with full and partial glass fibre mesh: An in vitro study

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Abstract
The present study was conducted to evaluate and compare the fracture resistance of maxillary complete dentures reinforced with full and partial glass fibre mesh with that of the conventional dentures
Material and Methods: The present study included a sample of 30 dentures, Group 1: Conventional dentures (unreinforced). Group 2: Complete dentures reinforced with partial glass fibre mesh. Group 3: Complete dentures reinforced with full glass fibre mesh. The fracture resistance of the dentures was measured using the Universal testing machine, by applying a load at a cross head speed of 10mm/min.
Results showed that there was statistically significant difference in the mean fracture resistance values in three groups, 1, 2 and 3. Group 3 has higher fracture resistance than the group 2. ($p=0.003$). Followed by group 1and the results were highly statistically significant. Group 2 has higher fracture resistance than the group 1($p<0.001$) and statistically highly significant.
Conclusion: Reinforced dentures either partial or full have significantly high fracture resistance compared to conventional dentures.
Clinical Implication: It is advisable to reinforce the dentures either partially or completely to improve the fracture resistance, particularly in patients with frequent mid line fracture of the dentures.

Keywords: denture reinforcement, fibre mesh, fracture resistance

1. Introduction
Inspite of emerging implant dentistry, maxillary complete denture has been a common and cost effective prosthetic treatment for people with edentulous maxillae. The fracture and deformation of dentures are recurrent and common problem for denture-wearers [1].
One of the most widely used materials in prosthetic dentistry for complete denture fabrication is polymethyl methacrylate. The denture base resin is subjected to various stresses during function, including compressive, tensile, and shear stresses. Though widely used, acrylic resins have the disadvantages like poor strength characteristics which include low impact strength and low fatigue resistance. The fatigue failure occurs when the denture base deforms repeatedly through occlusal forces and impact failure occurs when the dentures are accidentally dropped on a hard surface. Hence, the dentures tend to break during usage in the due course of time [2].
The fracture of complete dentures constitutes a challenge and remains an unresolved problem. Single maxillary complete dentures especially in patients with natural mandibular teeth midline fracture of is an inevitable problem. Midline fracture may be due flexural fatigue resulting from cyclic deformation and those factors which exacerbate the deformation of the base or alter its stress distribution, maxillary complete denture is 2 to 3 times more prone to midline fractures than mandibular dentures [3].
The midline fracture of maxillary complete dentures most commonly occurs as a result of fatigue failure by masticatory forces, and also because of microcrack propagation where stress is focused [4].
A traditional method of preventing the fracture of denture is to reinforce them with wire and plates made of Co-Cr alloy or stainless steel. However, the poor adhesion between the denture base resin and metal reinforcement often causes them to separate at the interface, exposing the metal color and resulting in an unesthetic outcome [5].
To improve the mechanical properties of dental polymers, attempts have been made to incorporate some type of reinforcement. Fibres like aramid, carbon/graphite, polyethylene, and glass fibers to improve their physical and mechanical properties [6].
Unlike carbon and Kevlar fibers, glass fibers are almost invisible in denture base acrylic resins. The reinforcement of denture base resin with glass fibres may be a useful means of strengthening denture bases [7]. The reinforcement using these fibres may either be total fibre reinforcement or partial fibre reinforcement. Many studies have compared the mechanical properties of dentures reinforced with different materials. Previous studies have compared the compressive properties of SES and GC CLOTH mesh and found that SES have better compressive properties. However, none of the studies have estimated the fracture resistance of complete dentures

reinforced with SES glass fibre mesh of different designs i.e, covering the entire palate and glass fibres covering mid palatal region with the conventional denture. The null hypothesis was that reinforcing the complete denture with different designs of glass fibre mesh does not show any effect on fracture resistance.

The purpose of the study is to evaluate the reinforcing effect of SES glass fibre mesh on fracture resistance of complete dentures fabricated with full and partial glass fibre mesh.

2. Materials and methods

2.1 Materials

Heat cure denture base material (DPI Heat Cure, DPI, India), Teeth sets - 30 ACRYROCK, size S – 13, A1 (Acrylic teeth crosslinked, Combination Ruthinium group, Italy.), Glass fibre mesh (SES MESH, INOD. South Korea) (fig. 1)

Fig 1: SES Glass fibre mesh

2.2 Methodology

2.2.1 Fabrication of maxillary wax dentures

30 maxillary edentulous casts were prepared by pouring type III dental stone in the maxillary edentulous mould. All the maxillary casts were trimmed and polished. A 2-mm modelling wax sheet was adapted over the maxillary edentulous cast and occlusal rims with ideal measurements, and 30 teeth sets of similar size (s -13) were selected.

Teeth arrangement was done following the principles of teeth setting followed by carving and finishing of the waxed denture.

2.2.2 Making of the plaster index

Plaster index of the wax denture was made, to guide in the preparation of 30 identical dentures. All 30 identical wax dentures were prepared using plaster index by following the standard technique.

2.2.3 Grouping of the samples

Flasking and dewaxing of the dentures was done and 30 samples were then divided into three groups, (n=10) Group 1: Conventional dentures, Group 2: Complete dentures reinforced with partial glass fibre mesh, Group 3: Complete dentures reinforced with full glass fibre mesh.

2.2.4 Preparation of the dentures

Group 1 dentures (10) were fabricated by following conventional method without glass fibre mesh. For Group 2 (partial mesh) samples, SES partial mesh was placed on the wax spacer on the master covering the mid palate region extending labially, and then was put into vacuum film. Using vacuum absorber, mesh was adapted onto the master cast and placed in the light polymerizing unit along with the film and cast and then cured for 3min.

The mesh can now be used in processing of the denture. For Group 3 (full mesh) samples, Wax was adapted covering all the denture bearing areas on the master cast. Wax was removed for tissue stops in canine, mid palatal raphe and molar regions in 4 x 2mm dimensions and self-cure denture base resin was then added in the regions where wax was removed. SES glass fibre mesh was adapted on the wax covering the entire denture base area, and then it was put into vacuum film. Using vacuum absorber, glass fibre mesh was adapted on the wax over the master cast (fig 2) and is placed in the light polymerizing unit along with the film and the cast, and is then cured for 3 mins. The mesh can now be used in processing of the denture. After dewaxing, the flasks were allowed to cool. Separating media was applied and for group 2 (partial mesh) and group 3 (full mesh) samples, light cured mesh was now placed over the master cast (fig 3). Dentures of all the three groups were acrylised following the short curing cycle. The processed dentures were finished and polished. Before testing all the samples were stored in distilled water at 370 C for 50 hours.

Fig 2: Adapting SES glass fibre mesh over the cast under vacuum

Fig 3: Glass fiber mesh adapted over the cast

2.2.5 Evaluation of Fracture resistance of the dentures

Fracture resistance of all the three groups were evaluated using the Universal testing machine. To measure the compressive properties, complete dentures were placed on a Universal testing machine and load was applied to the tissue surface of the denture with a rod having a square shaped end with dimension of 10mm, at a crosshead speed of 10 mm/min, until the dentures were fractured (Fig.4,5).

Fig 4: testing the fully reinforced denture using the Universal testing machine

Fig 5: testing the partially reinforced denture using the Universal testing machine

The maximum force that resisted fracture was recorded as fracture resistance in Newtons. The end of the test was determined either by fracture or when load dropped 30% from the maximum load. The fracture resistance of all the three groups were measured. The results were tabulated and statistically analysed using the software, SPSS version.

The fracture line of all specimens was observed with the naked eye. After analysing the failure aspects of all the specimens, the failure mode was classified into 1 of 3 patterns according to the fracture line. In pattern A, the complete denture was completely fractured into 2 parts. In pattern B, the denture was not fractured completely, with fracture only at the loaded area and the posterior midline area. In pattern C the fracture occurred only at the loaded area.

3. Results

Tests performed were descriptive for scale data, Independent t test for intergroup comparision.

3.1 Formulation of Hypothesis

Null Hypothesis: H_0 = No difference in fracture resistance values when three groups are compared

Alternate Hypothesis Ha = There is difference in fracture resistance values when the three groups are compared.

- p value < 0.05 is considered as statistically significant.
- If p value < 0.05 we can reject the null hypothesis and consider the alternate hypothesis

Table 1: Arithmetic Mean and SD of fracture resistance values in three groups

Group	N	Minimum	Maximum	Mean	SD
Group 1 (conventional)	10	560.0	690.0	602.0	130.0
Group 2 (Partial Mesh)	10	870.0	1209.0	1035.30	131.33
Group 3 (Full Mesh)	10	950.0	1552.0	1285.00	188.47
N= Sample size; Mean= Arithmetic mean; SD= Standard deviation.					

Mean fracture resistance in Group 1: 602 ± 130N.Group 2: 1035.30 ± 131.33 N. Group 3: 1285 ± 188.47 N. Among all the three groups tested, the mean fracture resistance of Group 3 (1285 ± 188.47) was greater than Group 2 (1035.30 ± 131.33) followed by Group1 (602 ± 130).

Table 2: Comparison of fracture resistance values in test groups (independent t- test)

Group	N	Mean	SD	Std. Error Mean	mean	t value	p value
Group3 (full mesh)	10	1285.000	188.4705	59.5996	249.7	3.48	0.003*
Group2 (Partial Mesh)	10	1035.300	131.3334	41.5313			

*-statistically significant (p<0.05)

Table 2 shows the comparison of fracture resistance in group 3 and group 2. The mean difference in their fracture resistance was 249.7 N and the p value is 0.003, that there is statistically significant difference present in the mean fracture resistance values in both groups. Group 3 has higher fracture resistance than the group 2 (p=0.003)

Table 3: Intergroup comparison of fracture resistance

Comparison	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2522618.610	2	1261309.305	74.362	<0.001**
Within Groups	474926.100	28	16961.646		
Total	2997544.710	30			

**Highly significant (p<0.001)

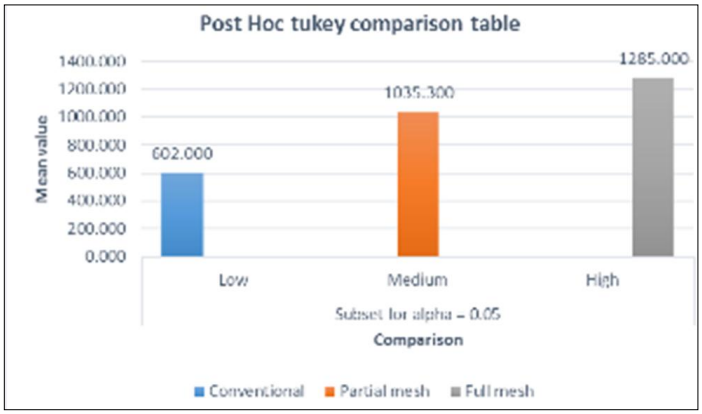
Table 3 shows the comparison of fracture resistance between and within the groups. Inter group comparison between three groups, showed that there was statistically significant difference (p < 0.001) in the mean fracture resistance between various groups. There was no significant difference present in the mean fracture resistance within the groups.

Table 4: Post hoc Tukey table for individual pairwise comparisons

Comparison between		Mean difference	P value
Group 2	Group 1	433.3000*	<0.001**
Group 3	Group 2	249.7000*	0.001*
Group 3	Group 1	683.0000*	<0.001**

*Statistically significant (p<0.05), highly significant (p<0.001)

Table 4 shows the comparison between Group1 and Group 2, Group 3 and Group 2 and Group 3 and Group 1. p<0.001, there was statistically highly significant difference in fracture resistance between all the three groups. The order of fracture resistance was
Full mesh > Partial mesh > Conventional



The order of fracture resistance of the three groups. Group 3 > Group 2 > Group 1, that is
Full mesh > Partial mesh > Conventional

Fig 6: Post hoc Tukey comparison chart

4. Discussion

Lambrecht and Kyddll ascertained that the midline in the anteroposterior direction remains undeformed during function [8]. In order to improve the strength of the material, various methods have been proposed like, 1. Using Polycarbonates and polyamides as substitutes for PMMA. 2.Chemical modification of PMMA by the addition of rubber in the form of butadiene styrene. The incorporation of fibers or metal inserts into the denture bases.

Metal inserts have been used in the form of wires, meshes, and plates and the different fibers include carbon, aramid, glass, and polyethylene fibers [2, 9]. The primary problem of using metal wire reinforcement is poor adhesion between wire and acrylic resin. Although several methods have been used to improve the adhesion between these components, enhancement in mechanical properties, such as transverse strength and fatigue resistance, was not significant. Moreover, metal-reinforced dentures may be unesthetic. Cast metal plates have been used to replace some parts of the denture. Although metal plates increase the flexural strength and impact strength, they may be expensive, unesthetic, and prone to corrosion [10].

Polycarbonates and polyamides although improve the strength are expensive and technique sensitive. Modification of the chemical structure by the addition of cross-linking agents like polyethylene glycol or by copolymerization with rubber in the form of Butadiene styrene have been tried, but this did not show significant enhancement on the strength properties [10, 3].

Different types of fibers like carbon, Kevlar, aramid, polyethylene, and glass fibers have been used for reinforcement [2]. The potential toxicity of carbon fibres was considered to be a possible problem although Manley, Bowman & Cook (1979) [11] reported no long term toxicity or carcogenicity in a study involving the implantation of carbon in rats. However, Yazdanie & Mahood (1985) experienced some problems with skin irritation on handling specimens [12]. A failure to further investigate this method of reinforcement could be due to problems associated with the fibres, such as the difficult handling characteristics of the fibres and their precise placement in the resin; problems with polishing a denture base incorporating fibres; poor aesthetics due to the black colour the fibres impart on dentures which can be unacceptable to some denture wearers; the potential toxicity of carbon; and the development of alternative methods of reinforcement [13].

Glass fibres have been found to be more effective in increasing the flexural strength of denture base resin than aramid or nylon fibres. Because glass fibres produce a significant reinforcing effect, are less cytotoxic, and are more esthetically pleasing than other fibres, they can be used in various dental fields for posts, splints, and the reinforcement of fixed dental prostheses. Compared with conventional polymer materials, fibre-reinforced polymers can be used successfully primarily because of their high specific modulus and specific strength. The modulus of elasticity of glass fibres is very high, and thus they absorb most stresses without deformation. Glass fibres have been used in different forms to strengthen dental polymers, including woven, loose and continuous such as roving or fibre bundles. Smith (1957) [52] reported on glass reinforcement of PMMA by simply mixing discrete fibres with the dough or by lamination with glass cloth. The incorporation of glass was limited to 20% due to the deleterious effects on the doughing properties above this percentage [14]. Vallittu studied the effect of two different silane compounds on the adhesion between different types of fibres including glass fibres. The silanized glass fibres used as reinforcement markedly increased the fracture resistance. Certain mechanical testing has proved that glass fibres are useful in reinforcing heat-cured denture base acrylic resin [13].

Yu SH *et al*., conducted a study comparing SES mesh with glass cloth arranged in different layers thickness that is 2, 3 and 4 layers and stainless- steel mesh [5]. The fracture resistance of the SES group was significantly higher than that of the control, GC4, and metal groups, but not significantly different from the GC2 and GC3 groups. The toughness of the SES and GC3 groups was significantly higher than that of the others, but not significantly different from that of the GC4 group.

Because of the high stiffness and fracture resistance of SES glass fibre mesh compared to glass cloth and stainless-steel mesh, SES fibre mesh has been used as reinforcement material in the present study.

Goguta *et al*., conducted a clinical study where he compared the maxillary dentures where TFR - the entire denture base being reinforced with the fibre weave (Stick net) and the mandibular dentures where PFR - the unidirectional glass fibres (Stick) being placed at the weak region of the denture. After 5 years all the mandibular reinforced dentures were in decent shape. The maxillary complete reinforced dentures suffered four partial Fractures. Fracture lines were restricted by the glass fibre net and the patients could still use their dentures [15].

Matthews and Wain'O found that the highest stresses during function occurred on the polished surface of the palatal aspect, in the region immediately behind the anterior teeth. They suggested that the palatal side of the base between the central incisors was one of the prime contributors to midline fracture [16].

The present study was conducted based on the above studies to evaluate and compare the fracture resistance of SES glass fibre mesh reinforced with two different designs, partial fibre reinforcement (PFR) [16]. Where the fibre reinforcement was placed at the weak region of the denture, i.e, at middle of the denture in the palate region and full fibre reinforcement (FFR) where the entire denture base area can be reinforced with glass fibre mesh.

Most studies regarding the effect of fibre reinforcement have been conducted by using rectangular-shaped specimens made of denture base resin [5]. However, because complete dentures are complicated 3- dimensional structures composed of artificial teeth and a denture base, the results with these specimens cannot represent those of dentures. So in this study complete dentures were fabricated instead of rectangular specimens.

On comparing the groups 1 and group 2 (TABLE 4), the mean difference in fracture resistance was 433.3000 and $p<1.001$. Reinforcing the dentures with partial mesh in the mid palate region significantly improved the fracture resistance when compared to unreinforced dentures.

On comparing the groups 2 and group 3 (TABLE 4), the mean difference in fracture resistance was 249.70000 and $p<1.001$.

Total fibre reinforcing the dentures i, e., covering the entire denture bearing area significantly improved the fracture resistance when compared with partial mesh only in the mid palate region.

On comparing the groups 3 and group 1 TABLE 4), the mean difference in fracture resistance was 683.00 and p <1.001, the results were highly statistically significant. Proving that Total fibre reinforcing the dentures i, e., covering the entire denture bearing area significantly improved the fracture resistance when compared unreinforced dentures.

The results of this study were in accordance with the studies conducted by Goguta *et al* [15]., Yu SH *et al*, [5].

Null Hypothesis that there will be no difference in fracture resistance among the three groups was proved to be wrong.

In the present study reinforcement of the mid palatal region was considered under partial fibre reinforcement while Goguta *et al*., has reinforced dentures with glass fibres in different patterns like mid palatal, ridge lap, anterior and posterior regions and he considered all these reinforcements as partial fibre reinforcement [16].

4.1 Pattern of fracture observed in all the three groups

Group 1 (conventional denture) Complete fracture at the loaded area with a fracture line at the mid line region.

Group 2 (partial mesh) Fracture occurred adjacent to the mesh in most of the samples (fig.6)

Group 3 (full mesh) there is no complete fracture of denture is seen or partial fracture seen at posterior midline or at the loaded region. (fig.6)

The failure modes of the control group showed complete fracture at the loaded area with a fracture line at the mid line region.

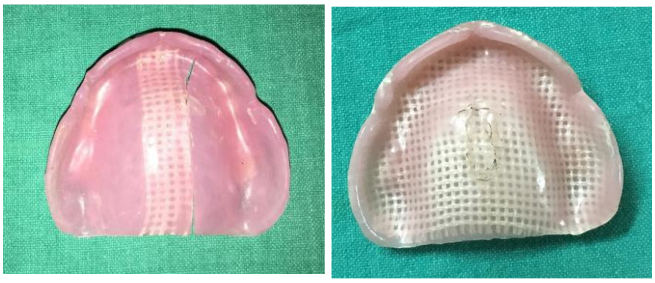


Fig 7: Pattern of fracture observed in Group 2 and Group 3

In reinforcement group the complete dentures were fully reinforced with the reinforcement (TFR) to cover the entire palate and over 4 mm from residual ridge crest. Therefore, TFR is effective in preventing the fracture of dentures. Because maxillary complete dentures are subject to flexural forces occurring on the axis of both posterior teeth in mouth, the reinforcement should be placed to resist the flexural forces.

Fully reinforced dentures showed a significant variation when compared with that of the partially reinforced and conventional dentures. Partially reinforced dentures showed significantly higher fracture resistance when compared to the conventional dentures. In single maxillary complete dentures either the partial or the total reinforcement each of these significantly extends the life of the denture compared to the conventional dentures.

4.2 Limitations of the study

As it is an in vitro study, direction of occlusal load has a variance and it cannot simulate intra oral conditions

Other properties like compressive and flexural, impact strength were not measured.

In this study we have not compared different reinforcing materials Limited sample size

5. Conclusion

Within the limitations of the present study, it can be concluded that:

There is statistically significant difference present in the mean fracture resistance values in both groups. group 3 has higher fracture resistance than group 2. There is statistically significant difference between the fracture resistance of reinforced and unreinforced dentures. Either partial or full have significantly high fracture resistance compared to conventional dentures.

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