ORIGINAL RESEARCH

Evaluation of Load-bearing Capacity of Interim Fixed Partial Dentures Reinforced with Glass Fibers: An *In Vitro* Study

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ABSTRACT

Aim: To compare the load-bearing capacity of three and four-unit fixed partial denture (FPD) with two different designs of pontics reinforced with industrial glass fibers at two different positions of the FPD.

Materials and methods: A total of 64 samples were made with Bis-acryl composite temporary material and reinforced with industrial glass fibers (E-glass). The specimens were divided into eight groups (groups I–VIII) depending on the number of units, type of pontic design and area of placement of fibers. A universal testing machine was used to evaluate and compare the load-bearing capacity of the specimens. The evaluated data were statistically analyzed using one-way ANOVA and Bonferroni *post hoc* tests ($p \leq 0.05$).

Results: Three-unit interim FPD and modified ridge lap pontic design showed greater load-bearing capacity after reinforcement with glass fibers than a four-unit interim FPD and hygienic pontic design, respectively. Fiber placement at the occlusal plus connector area as well as the cervical plus connector area had comparable results.

Conclusion: Industrial glass fibers (E-glass) could be used as a cheaper alternative but clinical performance and their safety are yet to be evaluated.

Clinical significance: Reinforcement with industrial-grade glass fibers can be a cheaper option for increasing the load-bearing capacity of interim partial dentures, but it needs to be studied *in vivo* through further studies.

Keywords: Fixed partial denture, Fiber-reinforced, Glass fibers. Interim restorations, Pontic.

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INTRODUCTION

Fixed prosthodontic treatment includes replacing missing teeth or restoring compromised natural teeth with fixed crowns and bridges. During the procedure, the tooth used as an abutment is prepared and it becomes comparatively smaller in size which affects the esthetics, function, and masticatory efficiency of the patient.[1] If there is a considerable time needed for a definitive prosthesis to be fabricated like in full-mouth rehabilitations, implant-supported prosthesis, and orthodontic cases, the role of interim restoration is to be considered.[2] The importance of it is often overlooked considering it as a temporary prosthesis till a definitive is fabricated. A well-fabricated interim fixed prosthesis mimics the definitive prosthesis.[3]

The interim prosthesis provides an evaluation of prognosis of questionable teeth, helps maintain inter- and intra-arch relationship and preserves the surrounding gingival tissues.[4,5] The purpose of an interim fixed prosthesis is to protect pulp and prepared abutments, prevent migration of teeth, aid in periodontal or orthodontic treatment, and help reinforce the patient's oral health.[6]

Various materials have been used over the period of time for the fabrication of interim fixed partial prosthesis. These are autopolymerizing polymethyl methacrylate (PMMA) resin, bis-acryl composites, polyethyl methacrylate resins (PEMA), butyl methacrylate, metals, urethane di methacrylate resins (UDMA), epimine, polycarbonate materials, and preformed matrices of cellulose shells.[7,8] The most commonly used among these are PMMA and bis-acryl composites.

The most common problem after placement of interim restoration is the fracture of it which can lead to an unscheduled and extra appointment for repair.[9] Patients undergoing long-term treatment plans or with parafunctional habits would require interims with improved properties.[10,11] Many attempts have been made to reinforce the provisional fixed restorations in order to prevent loss of time, embarrassment and inconvenience for both patient and clinician.[12] These have included reinforcing with metal wires, graphite, Kevlar, and other different types of fibers, such as carbon,[13–15] glass,[16] polyethylene, nylon,[17] polyaramide,[18] polyester, and some natural fibers such as bamboo.[19–22] The most commonly used fiber nowadays is glass fiber. Commercially, glass fibers are available as chopped strands, woven rovings, or woven cloth/mat. There are many types of glass fibers, out of which E-glass (electrical grade) and S-glass are the most commonly used for dental applications. E-glass fiber is made from the oxides of silicon, aluminum, calcium, magnesium, and boron. It is more commonly used in the fiber-reinforced industry. It offers a good balance between performance and cost, demonstrating excellent strength

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Table 1: Groups included in the study

Group I	Three-unit FPD with modified ridge lap pontic and reinforcement in the occlusal plus connector area
Group II	Three-unit FPD with modified ridge lap pontic and reinforcement in the cervical plus connector area
Group III	Three-unit FPD with hygienic pontic and reinforcement in the occlusal plus connector area
Group IV	Three-unit FPD with hygienic pontic and reinforcement in the cervical plus connector area
Group V	Four-unit FPD with modified ridge lap pontic and reinforcement in the occlusal plus connector area
Group VI	Four-unit FPD with modified ridge lap pontic and reinforcement in the cervical plus connector area
Group VII	Four-unit FPD with hygienic pontic and reinforcement in the occlusal plus connector area
Group VIII	Four-unit FPD with hygienic pontic and reinforcement in the cervical plus connector area

and stiffness as well as good resistance to chemicals, moisture, and heat.[23]

Earlier studies have shown that fiber reinforcement increases the load-bearing capacity of the provisional restoration. Previously, industrial fibers (E-glass) have been used for the reinforcement of denture polymers.[24] The following study was done where a novel technique using a scaffold for industrial-grade (E-glass) fibers for reinforcement of interim fixed partial dentures (FPDs) was carried out. It was done to evaluate if there is any difference in the load-bearing capacity of two different span lengths, modified ridge lap and hygienic pontic designs, and reinforcement of fiber at occlusal plus connector and cervical plus connector area in a composite interim fixed partial restoration.

MATERIALS AND METHODS

This *in vitro* study was approved by The Institutional Review Board with IEC Code no. IGIDSIEC2021NRP04PGJAPRI which was conducted in April 2021 at Indira Gandhi Institute of Dental Sciences, Puducherry, India.

Sample Size Calculation

Estimate a mean:

$n = (Z\sigma/E)^2$

Alpha (α) = 0.05

Relative precision = 10%

Minimum sample size needed: 8

Total sample size for eight groups: $8 \times 8 = 64$

The sample size was estimated based on the previous studies and a total of 64 samples were used as interim fixed restoration and divided into eight groups (groups I–VIII) (Table 1).[25]

Preparation of a Scaffold For Glass Fibers

Orthodontic wires were used to make a wax pattern for fiber designs for both three- and four-unit bridges at the occlusal plus connector and cervical plus connector region. Each wire was embedded in a 2 mm thick sheet of modeling wax to create space for the fibers. The wax pattern was cast. The cast scaffold was trimmed, finished, and polished.

Preparation of Teeth for Three- and Four-unit Bridge

Tooth preparations for porcelain fused metal (PFM)-FPDs on typodont teeth were done. For three-unit bridge, 35 and 37 and for four-unit bridge, 35 and 38 were prepared using diamond points. Once prepared, impressions were made with the addition of silicone putty and light body (Photosil, Dental Products of India, The Bombay Burmah Trading Corporation Ltd, Mumbai, Maharashtra, India) with wax-shaped according to the two types of pontics (modified ridge lap and hygienic) placed in the pontic area of the typodont. Two impressions, each was made for three- and four-unit bridges with the type of pontic design needed (Fig. 1).

Fig. 1: Tooth preparation for PFM restoration on Typodont for tooth 35

Preparation of Dies For Each Group

A die for unprepared three-unit and four-unit bridges was made out of die stone (type IV) with the help of a putty index of the typodont teeth before preparation. Modeling wax was added to the dies for increasing its height and width by 10 cm each for making a base. Putty index of these two were made to pour in all the 64 dies in the exact dimension of plaster base (type II) (Fig. 2).

Preparation of Glass Fiber Designs for Each Group

Industrial glass (E-glass) fibers (Owens Corning Vetrotex, Owens Corning India Pvt. Ltd, Navi Mumbai, Maharashtra, India) were taken and put into the scaffold to make the pattern required for each group. Each fiber was mixed with flowable composite and light-cured. Once cured, it was put on the die to check for the fit (Figs 3 and 4).

Preparation of Reinforced Interim Restorations

Die was coated with a layer of petroleum jelly as a separating medium. The glass fibers were placed at each die in its position and composite temporary material (Protemp 4, 3M ESPE, Germany) was dispensed into the putty index. The index was placed over the die till the material was set. Once set, the temporary bridge was removed from the die. The fibers were embedded into the composite interim bridge (Fig. 5).

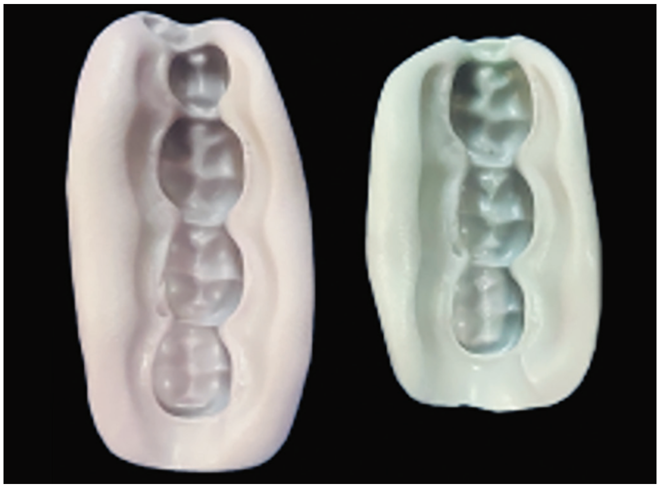

Fig. 2: Putty index of unprepared teeth (Left: For 4 Unit FPD from 35 to 38); Right: For 3 Unit FPD from 35 to 37)

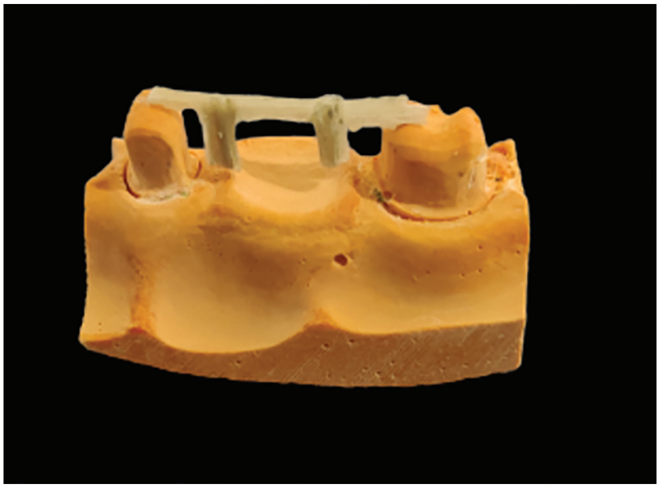

Fig. 3: Glass fiber pattern for three unit with occlusal reinforcement for three-unit FPD 35–37

Fig. 4: Glass fiber pattern for three unit with cervical reinforcement for three-unit FPD 35–37

Fig. 5: Preparation of reinforced temporary bridge for three-unit FPD 35–37

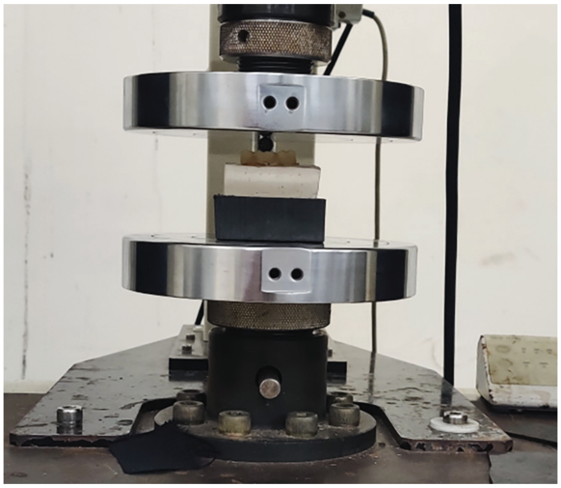

Fig. 6: Universal testing machine

Testing of Samples

The load-bearing capacity was tested at the Central Institute of Petrochemicals Engineering and Technology (CIPET), Chennai using a universal testing machine (Autograph, AG-IS 50 kN Shimadzu) with crosshead speed of 2.5 mm per minute (Fig. 6). The force was applied with a ball end (6 mm) at the middle of the pontic (36) for three-unit and at the mesial fissure of 37 for four-unit, which was standard for all the samples. The force was applied and the unit load was calculated in Newton. The point of fracture of the interim restoration was evaluated using the inbuilt software at which load it had occurred. Data were collated, tabulated, evaluated, and sent for statistical analysis.

Statistical Analysis

The observations were subjected to statistical analysis using SPSS software (Version 17.0). Mean, standard deviation, and ANOVA were conducted to evaluate any statistically significant data (Table 2). The mean load-bearing capacity of each group is presented in Table 2. ANOVA was used to study the load-bearing capacity on mean values (Table 3). The significance level was set at $p \leq 0.05$ and 95%

confidence interval. Multiple comparisons were done using the Bonferroni *post hoc* test for each variable.

RESULTS

In all comparisons for load capacity of fiber-reinforced FPDs at occlusal plus connector area vs cervical and connector area, it was seen that the mean load capacity was higher for groups II, III, VI, and 7 in comparison to groups I, IV, V, and VIII, respectively but none was statistically significant (Table 4).

Table 2: Mean load-bearing capacity values of reinforced interim partial FPDs

				95% Confidence interval for mean	
	N	*Mean*	*Std. deviation*	*Lower bound*	*Upper bound*
1.00	8	431.47	277.87	199.16	663.78
2.00	8	563.50	378.37	247.17	879.82
3.00	8	253.69	128.38	146.35	361.02
4.00	8	242.37	133.03	131.15	353.59
5.00	8	220.86	48.677	180.17	261.56
6.00	8	261.72	114.84	165.71	357.73
7.00	8	237.54	107.26	147.87	327.22
8.00	8	208.24	77.576	143.38	273.09
Total	64	302.42	214.95	248.73	356.12

Table 3: ANOVA

	Sum of squares	*df*	*Mean square*	*F*	*Sig.*
Between groups	897460.918	7	128208.703	3.566	0.003
Within groups	2013520.054	56	35955.715		
Total	2910980.973	63			

For three-unit vs four-unit reinforced interim FPD, it was seen that the mean values for load-bearing capacity were higher for groups I, II, III, and IV in comparison to groups V, VI, VII, and VIII, respectively, but none was found to be statistically significant (Table 5).

For two types of pontic designs in the reinforced interim FPD, it was seen that the mean values for load-bearing capacity were higher for groups I, II, VII, and VI in comparison to groups III, IV, V, and VIII, respectively, out of which for group II vs IV, it was found to be statistically significant (Table 6).

In the comparison for all the groups, it was seen that group B (three-unit FPD with modified ridge lap pontic and reinforcement in the cervical plus connector area) had the highest mean load-bearing capacity of 563.50 ± 378.37 N in all the eight groups signifying that a shorter span interim FPD with modified ridge lap pontic and reinforcement in the cervical area had a better load-bearing capacity in comparison with the other factors (Fig. 7).

DISCUSSION

Reinforcement of interim FPDs has gained much importance for prolonging the life of a provisional restoration. The success of an interim restoration and reinforcing capacity of fibers depends on the orientation, placement, and adhesion of fibers to resin material and the type of fibers used.

Several researchers experimented with different techniques of reinforcing provisional FPDs. An earlier study was conducted by Vallittu using glass fibers: unidirectional (Stick R) and weave (Stick W), concluded that the position of placement of fibers and

Table 4: Comparison of load capacity of fiber-reinforced fixed partial denture in occlusal and connector area with cervical and connector area

					95% Confidence interval of mean difference	
(I) Group	*(J) Group*	*Mean difference (I–J)*	*Std. error*	*Sig.*	*Lower bound*	*Upper bound*
1.00	2.00	−132.02	94.80	1.000	−443.05	179.00
3.00	4.00	11.318	94.80	1.000	−299.71	322.34
5.00	6.00	−40.851	94.80	1.000	−351.88	270.17
7.00	8.00	29.306	94.80	1.000	−281.72	340.33

Table 5: Comparison of load capacity of fiber-reinforced three and four-unit fixed partial denture

					95% Confidence interval of mean difference	
(I) Group	*(J) Group*	*Mean difference (I–J)*	*Std. error*	*Sig.*	*Lower bound*	*Upper bound*
1.00	5.00	210.60	94.80	0.851	−100.42	521.63
2.00	6.00	301.78	94.80	0.067	−9.2498	612.81
3.00	7.00	16.144	94.80	1.000	−294.88	327.17
4.00	8.00	34.132	94.80	1.000	−276.89	345.16

Table 6: Comparison of load capacity of modified ridge lap pontic with hygienic pontic in a fiber-reinforced fixed partial denture

					95% Confidence interval of mean difference	
(I) Group	*(J) Group*	*Mean difference (I–J)*	*Std. error*	*Sig.*	*Lower bound*	*Upper bound*
1.00	3.00	177.77	94.80	1.000	−133.25	488.80
2.00	4.00	321.12	94.80	0.036	10.096	632.15
5.00	7.00	−16.679	94.80	1.000	−327.71	294.35
6.00	8.00	53.478	94.80	1.000	−257.55	364.50

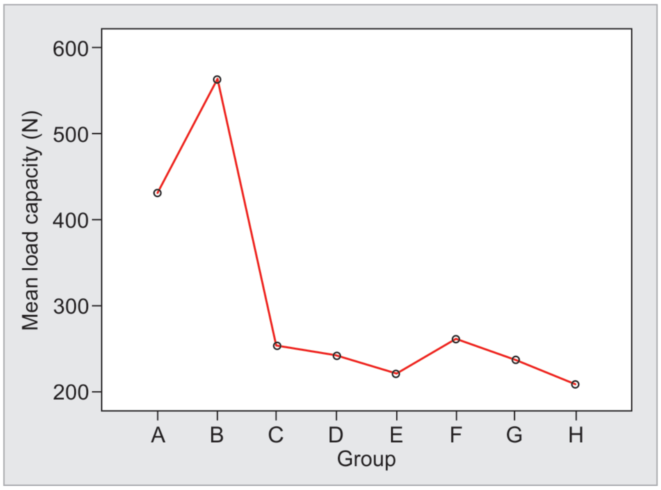

Fig. 7: Comparative evaluation of Mean of each group

amount of fibers affects the fracture resistance which influenced to add position with connector region as one of the variables in the present study.[26]

In another study, Ellakwa AE et al. concluded that placing the fibers in the cervical third of the pontic or slightly away from it, which is the tensile side of the restoration was found to increase the flexural strength values.[27]

Glass fibers, polyethylene fibers, and stainless steel wire were used for reinforcing PMMA interim FPDs in a study by Hamza et al. in which it was found that placing the fibers at different places had different results. The results revealed that fibers at the cervical third of the pontic had the highest values for fracture resistance. This could be explained as most interim materials have greater compressive than tensile strength, and so the fracture initiates at the tension side of the pontic which is the cervical third of it. At this area, the fiber would stop the propagation of the initiating fracture and increase the load-bearing capacity.[12]

By using glass fibers, polyethylene fibers, the combination of both and stainless steel wire for reinforcement of PMMA provisional FPD in a study by Viswambaran M et al., it was concluded that placement of fibers in the occlusal third of the pontic was the most appropriate site to increase the fracture resistance of it. This was not in agreement with previous studies, but in the present study, it was found that occlusal and cervical reinforcement has comparable results.[28]

Another study done by Kapri Anita using Everstick glass fibers for a three-unit interim FPD made out of PMMA showed that placement in the occlusal third of the pontic had higher fracture resistance. The reason for the same could be that the fracture might stop at the point of its initiation which is the occlusal area and might not propagate through the FPD. But a more detailed methodology was required to investigate further.[29]

The effect of different pontic heights was tested and it was found that the fracture resistance of interim restorations was not affected by pontic spans and neither by pontic heights too.[30] As flexure rate varies for different lengths of the FPD, the effect of the span of the pontic must be significant which is why two spans were tested in the present study to ensure if the previous study results were any different from the present study.

Four groups with control and test of each group (PMMA with no reinforcement and PMMA reinforced with glass fibers) of 14 mm, 17 mm, 20 mm, and 24 mm pontic span were evaluated in a study by Change Min et al. These were stored in artificial saliva and were put under thermal cyclic loading followed by placement on the abutments with temporary cement. Later, these were tested using UTM machine, and it was found that FPDs of 14 mm had the highest mean fracture load. There was no significant difference between 20 and 24 mm. An altered pattern of fracture was noted with reinforcement.[31]

In the present study, 64 samples (eight groups) were evaluated for three variables: pontic span, pontic type, and fiber placement. In this study, industrial glass fibers were used to reinforce Protemp4 material. According to the mean load-bearing capacity values of comparison groups, it is clearly evident that load-bearing capacity would be the maximum for a reinforced three-unit FPD than a longer span one. Only pontic heights have been tested so far and the type of pontic and its influence on fracture after reinforcement has not been studied. In the present study, two types of pontics were studied: modified ridge lap and hygienic pontic for both three- and four-unit interim FPDs. The mean values of load-bearing capacity were greater for modified ridge lap pontics in the case of both three- and four-unit provisional bridge. A scaffold was cast to mold the industrial glass fibers into two-shaped required: cervical plus connector and occlusal plus connector. For the area of placement of fibers, there has been a varied result over the years and even in this study, a single area of placement was not found better than the other. Both cervical plus connector area as well as occlusal plus connector area had equal effect on load-bearing capacity. Furthermore, more studies would be required to evaluate the provisional FPDs reinforced by the placement of these glass fibers under clinical conditions.

LIMITATION

Interim FPDs were not tested using temporary cement. The luting agent may also have an effect on the load-bearing capacity of the FPD. Further studies on the clinical performance of the reinforced interim partial dentures using scaffold design for glass fibers are yet to be evaluated for success.

CONCLUSION

Within the limitations of this study, the following can be concluded that a three-unit reinforced interim FPD has greater load-bearing capacity than a four-unit interim FPD. Modified ridge lap pontic design has greater load-bearing capacity value than the hygienic pontics design. Fiber placement at the occlusal plus connector area as well as the cervical plus connector area has similar results and none is considered better than the other.

This *in vitro* study offers insight into various designs of the glass fiber placement to augment fracture resistance. It is possible to supply prefabricated shapes of glass fibers which can be used *in vivo* in the future utilizing the data from this study.

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