Original Article

Comparison of fiber reinforcement placed at different locations of pontic in interim fixed partial denture to prevent fracture: An *in vitro* study

Surg Cdr Anita Kapri

Department of Prosthodontics, Army Dental Centre (R and R), Delhi Cantonment, New Delhi, India

Abstract

Background: The interim restoration is an important phase in fixed prosthodontic therapy. It should provide sufficient durability to withstand the forces of mastication. A fractured interim restoration is damaging to the prosthodontic care and may lead to an unscheduled appointment for repair. Several attempts have been made to reinforce interim fixed partial dentures (FPDs). These have included the use of metal wire, a lingual cast metal reinforcement, a processed acrylic resin interim restoration, and different types of fibers, e.g., carbon, polyethylene, nylon and glass. These fibers can be placed in the occlusal, middle or cervical thirds in the FPD. There is no scientific data to evaluate the effect of fiber placement methods on the fracture resistance of clinical interim FPDs.

Purpose of the Study: Hence this study was designed to evaluate fracture load values of interim FPDs with different locations of fiber reinforcement.

Materials and Methods: 30 interim FPD samples with polymethyl methacrylate (PMMA) reinforced with fibers at three different locations mainly occlusal, cervical and middle (10 samples each) were fabricated using a metal FPD on a master die. They were tested for fracture resistance in universal testing machine.

Results: The fracture resistance was recorded and is tabulated and analyzed statistically. The results showed that the placement of the reinforcement in the occlusal third of the pontic resulted in higher fracture resistance which was significantly higher ($P < 0.05$) than all other locations.

Conclusion: The occlusal third of the pontic region from mesial to the distal end of the connector is the best site of placement of the fiber for reinforcing the PMMA interim restorative resin.

Key Words: Fiber placement, fracture resistance, interim fixed partial denture, polymethyl methacrylate, reinforcements

Address for correspondence:
Dr. Surg Cdr Anita Kapri, Department of Prosthodontics, Army Dental Centre (R and R), Delhi Cantonment - 110 010, New Delhi, India.
E-mail: a.kapri@rediffmail.com

Received: 14th August, 2014, **Accepted:** 21st December, 2014

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/0972-4052.155037

INTRODUCTION

Interim fixed partial denture (FPD) is an important phase of fixed prosthodontic therapy. In today's scenario where implant fixed prosthodontics is the need of the hour, a long-term provisional is very much essential for delayed loading protocol. Most common materials used to fabricate interim FPDs are polymethyl methacrylate (PMMA), polymethyl methacrylate (PEMA) and bisacryl composite (BAC).[1,2] The most common problem with interim FPD fabricated from these materials is fracture, and hence these materials alone cannot be used for long-term provisional restorations. These materials have been reinforced with fibers, wires or metal so as to improve their fracture strength. Various fibers which are used are glass, polyethylene, carbon, quartz, etc., These fibers can be placed anywhere in the FPD either in the occlusal third, middle third or cervical third. The effect of fiber placement methods in reinforcing the interim FPD against fracture have not been covered in the scientific literature at large in general and in the Indian scenario, in particular. Hence, a study was designed to evaluate the effect of fiber placement methods for reinforcing the interim FPD against fracture.

Federick[1] emphasized the importance of the provisional restoration for successful treatment with a FPDs. Hunter[3] described the importance of making accurate fitting provisional crowns and FPDs. Bowman and Manley[4] carried out clinical trials using upper dentures reinforced with carbon fiber/PMMA inserts and confirmed that the reinforcement with carbon fiber/PMMA inserts significantly reduces the number of breakages in the denture. Carroll and von Fraunhofer[5] conducted a study to determine the effect of wire in unlooped or looped form to reinforce autopolymerizing acrylic resin. Solnit[6] carried out a study to find the effect of methyl meth-acrylate reinforcement with silane treated and untreated glass fibers (GF). This study suggested that GF can be pretreated with silane coupling agent to obtain a chemical bond between the fibers and the acrylic resin. He also found that woven GF pretreated with silane coupling agent would significantly strengthen PMMA as compared to GF in the loose form. Unreinforced PMMA cured in a pressure device resulted in least strength. Vallittu[7] reviewed various methods of reinforcing PMMA denture base resin and found that the metal wires of various dimensions included within the resin have increased the transverse strength whereas the metal mesh had shown little effect. Vallittu[8] carried out a study to determine the load required to fracture a three-unit provisional FPD fabricated from a resin of PEMA powder and n-butyl methacrylate liquid, which had been reinforced with GF. Haselton *et al*.[9] compared the flexural strength of five methacrylate based resins and eight bis-acryl resins used to fabricate provisional crowns and FPDs. Freilich *et al*.[2] carried out a clinical evaluation of fiber reinforced fixed bridges. The type of fiber-reinforced composite (FRC) (Preimpregnated vs. nonimpregnated and glass vs. polyethylene), design and external surface characteristics of the substructure, as well as the type of particulate composite veneer are all important factors that affect clinical performance. Hamza *et al*.[10,11] studied the effect of fiber reinforcement on the fracture toughness and flexural strength of three types of resin commonly used in the fabrication of provisional restorations (PMMA, PEMA, and BAC). They concluded that the use of fibers is an effective method to increase the fracture toughness and flexural strength of provisional restoration resin. Ellakwa *et al*.[12] evaluated optimal pontic and retainer fiber positions for polyethylene FRC restorations. They suggested that different techniques of laboratory construction of fiber framework in the pontic area significantly affected the fracture resistance of fiber reinforced bridges. Freilich and Meiers[13] reviewed FRC prostheses. They found that the mechanical properties of FRC materials are primarily dependent upon fiber type, ratio of fiber to matrix resin, fiber architecture (i.e., unidirectional, woven or braided) and quality of impregnation of fiber and resin. Jindal and Brar[14] have used polyethylene fibers for treatment of nursing bottle caries. John *et al*.[15] evaluated the flexural properties of PMMA reinforced with oil palm empty fruit bunch fiber and considered it a viable alternative to existing commercially available synthetic fiber reinforced PMMA resin. Kumar *et al*. in 2014[16] compared fracture strength of 3 unit fiber reinforced FPD using different design preparations and concluded that full coverage design shows greatest fracture strength.

MATERIALS AND METHODS

In order to test the fracture resistance of fiber reinforced interim FPD placed at different location of pontic in interim FPD, it was proposed to carry out the test using specially fabricated three-unit interim FPD samples simulating the clinical situation of a missing first molar using second premolar and second molar as abutments. For the purpose of standardization interim FPD samples were fabricated using a metal FPD on a master die with two abutments [a precision die was specially fabricated in brass with dimensions as shown in the Figures 1-3]. A polyvinyl siloxane impression (3M ESPE) was then made with the cast metal FPD on the die. A total of 30 samples were made. For the purpose of comparison, the study samples were divided into three groups, with ten samples in each group. No control group

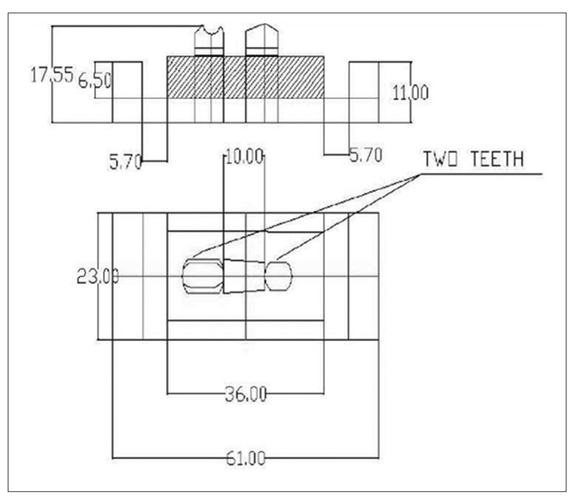


Figure 1: Line diagram of brass master die

was used for fracture strength comparison with unreinforced samples as it has already been evaluated in the literature.[6-8] Group 1 samples had the fibers placed in Occlusal third restricted from one connector to the other that is, from distal end of premolar abutment to mesial end of molar abutment, Group 2 samples had fibers placed in Middle third similarly and Group 3 samples had fibers placed in Cervical third of the pontic in interim FPD. 10 test specimens were then made in each group with the help of this impression on the same day to ensure that all interim FPDs had the same dimension under uniform conditions. By trial and error method, it was found that 1.5 g of autopolymerizing acrylic powder (DPI Self Cure Tooth Moulding Powder, Dental Products Of India, Burmah Trading Corporation Ltd., Mumbai, India) was sufficient to fill the putty index leaving slight excess. Preweighed packets of autopolymerizing resin (PMMA) with premeasured 1.5 cc of liquid were then used for each group of the samples. Since literature reveals that glass fibers (Ever stick C and B, Sticktech Company, member of GC Group, Turku, Finland) [Figure 4] has shown the highest fracture resistance,[6] they were used for this study of site of fiber placement.

Figure 2: Brass master die

Figure 3: Cast metal fixed partial denture with wax block out on the master die

Figure 4: Everstick glass fiber

Group 1: The GF was precut to 10 mm (required dimension between the connectors). This fiber was wetted with monomer before placement for 10 s. One-third part of resin was hand mixed and used to stabilize the glass fibers in the occlusal third of the pontic from one connector to the other on the blocked out die after application of a separating medium on the die. The resin was allowed to partially set so that no movement of the fibers will take place later. A second operator meanwhile mixed the remaining two third part of the resin, and this was added to the impression. Then the impression tray was inverted over the master die with the fibers in place between the connectors and left to polymerize for 15 min. It was ensured that the tray snugly fitted on the peripheral rim of the rectangular base using hand pressure. The tray with the die was then pressed with a clamp to ensure the tray remained completely seated throughout at the polymerization procedure under uniform pressure. After 15 min, the tray was removed, and the three-unit interim FPD sample was carefully separated from the impression, trimmed, polished and checked on the master die for marginal fit and absence of rocking. This resulted in the interim FPD sample with GF located in the occlusal third of the pontic

Group 2: The GF was precut to 10 mm (required dimension between the connectors). This fiber was wetted with monomer for 10 s. The fiber reinforcement was placed at the middle third portion of the pontic of the die between the connectors and stabilized with the resin mixture on both its end with the one-third part of the resin mix. The resin was then allowed to set partially. Then the second part of the resin mixed and added to fill the impression. Then the impression tray was inverted over the master die with fibers in place. Rest of the procedure was same as in Group 1. This resulted in the interim FPD sample with GF located in the middle third of the pontic

Group 3: The resin mixture was hand mixed as earlier. The fiber reinforcement was placed at the cervical third portion of the pontic of the die between the connectors and stabilized with the resin mixture on both its end. The resin was then allowed to set partially. Then the second part of the resin mixed was added to fill the impression. Then the impression tray was inverted over the master die of the abutments with fibers in place. Rest of the procedure was same as in Group 1 and 2. This resulted in the interim FPD sample with GF located in the cervical third of the pontic.

RESULTS

Fracture resistance of the samples was done using three points bending test with the help of a Universal Testing Machine (Instron Corp. 4204). Each interim FPD sample was firmly seated with hand pressure on the brass master die and held on the Universal Testing Machine (Instron Corp. 4204). It was ensured that each sample fitted snugly on the die with no rocking of the sample. The test samples were loaded with a 6.36 mm diameter steel ball placed on the machine arm loaded in the region of the central fossa of the pontic with a crosshead speed of 5 mm/min till the fracture occurred. The load causing the initial fracture was recorded [Figures 5 and 6]. Fracture resistance was then automatically calculated by the equipment software and displayed. All the data were recorded, tabulated and subjected to statistical analysis. The mean and standard deviation (SD) for each group were determined. The data were analyzed for differences using one-way ANOVA to determine statistically significant differences between the means. The fracture resistance was recorded and is tabulated in Tables 1-3, respectively. Tables 1-3 shows the maximum load value at which each FPD sample fractured in Group 1, 2 and 3, respectively, and their fracture resistance values. The results showed that the placement of the reinforcement in the occlusal third of the pontic resulted in higher fracture resistance which was significantly higher ($P < 0.05$) than all other locations [Table 4 and Graph 1]. Table 4 shows the comparison of average fracture resistance values in all the three groups and their statistically significance. The mean fracture resistance for interim fixed dental prosthesis samples in this study was greatest when the fiber reinforcements were placed in the occlusal third. The mean ± SD for Glass Fibers Occlusal Third was 14.20 ± 3.49; Glass Fibers Middle Third 10.05 ± 3.61 and Glass Fibers Cervical Third was 11.80 ± 2.13.

Figure 5: Interim fixed partial denture sample on the master die

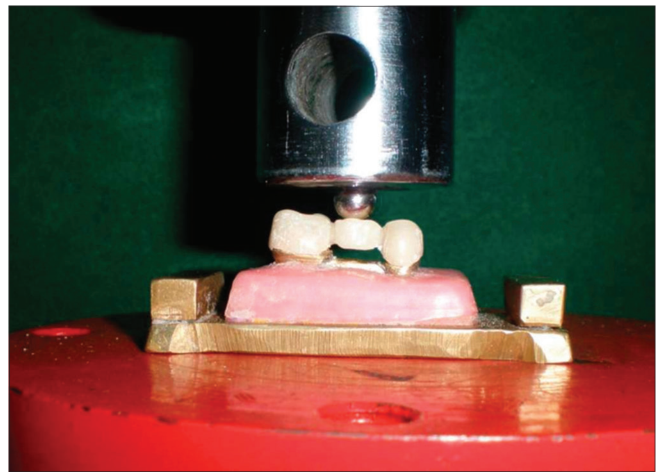
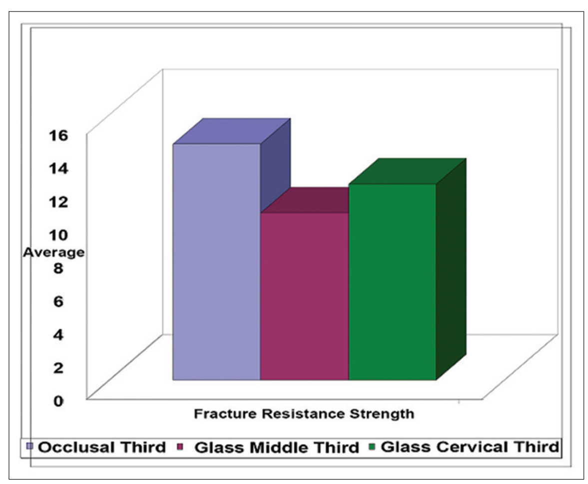


Figure 6: Testing of fracture resistance of the sample



Graph 1: Bar diagram showing comparison of fracture resistance

DISCUSSION

Glass fibers were tested as reinforcement for denture base PMMA as early as the 1960s. Since then, many studies investigated the strength of the GF-PMMA composite.[17] There is evidence from dynamic *in-vitro* tests that GF reinforcement increased fatigue resistance of dental appliance up to 100 times compared with fatigue resistance of an unreinforced restoration.[18] The GF used in the study (everStick®) are silanized E-GF preimpregnated with porous polymer and is formed of a large number of unidirectional GF. Results of the study suggested that placement of fibers in the occlusal third of the pontic region of the three-unit FPD sample showed the best fracture resistance values. Geerts, Overturf and Oberholzer[19] compared the fracture resistance of a PMMA resin and a BAC resin reinforced with stainless steel wire, glass fiber and polyethylene fiber. They concluded that when esthetic and space are of concern, GF seems to be the most appropriate method for reinforcing interim FPDs made from PMMA and BAC resins. The results of this study can be correlated with a study by Hamza *et al.*[12] who suggested that reinforcement at the cervical third of the pontic region showed higher fracture toughness values. This can be explained because interim restoration resin, like most brittle materials, has a greater compressive than tensile strength. Therefore, fracture is usually initiated in the tension side of the restoration, which will be in the cervical third of the pontic. This was not in

Table 1: Glass fiber in occlusal third

Sample number	Maximum load (*n*)	Fracture resistance (MPa)
1	507.54	16.92
2	433.16	14.44
3	344.96	11.49
4	536.84	17.89
5	366.03	12.20
6	253.33	8.44
7	297.92	9.93
8	549.58	18.32
9	467.26	15.57
10	504.50	16.82
Average	499.86	14.20

MPa: Megapascals

Table 2: Glass fiber in middle third

Sample number	Maximum load (*n*)	Fracture resistance (MPa)
1	258.81	8.62
2	315.95	10.53
3	324.47	10.81
4	373.77	12.46
5	174.05	5.80
6	500.48	16.68
7	400.33	13.34
8	317.81	10.59
9	169.19	5.57
10	183.16	6.10
Average	301.60	10.05

MPa: Megapascals

Table 3: Glass fiber in cervical third

Sample number	Maximum load (*n*)	Fracture resistance (MPa)
1	323.59	10.78
2	395.43	13.18
3	262.35	8.74
4	414.34	13.81
5	348.97	11.63
6	294.68	9.82
7	281.46	9.38
8	363.77	12.12
9	394.74	13.16
10	461.58	15.39
Average	354.09	11.80

MPa: Megapascals

Table 4: Comparison of fracture resistance strength

Methods of placement of fibers	Fracture resistance strength Mean±SD (n=10)
Glass fibers occlusal third	14.20±3.49
Glass fibers middle third	10.05±3.61
Glass fibers cervical third	11.80±2.13
F	4.38
P	<0.05

SD: Standard deviation

agreement with the results obtained in this study. The reason of getting highest fracture resistance in occlusal third in this study can be because the fracture will stop the propagation at the point of initiation (i.e. the occlusal) through the restoration. However, the reasons for this needs to be investigated using more detailed methodology. Perea *et al.*[20] evaluated the load bearing capacities of FRC fixed dental prostheses (FDP) with pontics of various materials and thicknesses. They concluded that by increasing the occlusal thickness of the pontic, the load-bearing capacity of the FRC FDPs may be increased. The highest load-bearing capacity was obtained with 4.0 mm thickness in the ceramic pontic. However, with thinner pontics, polymer denture teeth and composite pontics resulted in higher load-bearing values.

Nagata *et al.*[21] evaluated the fracture resistance of computer-aided design/computer-assisted manufacture (CAD/CAM)-fabricated for FRC denture retainers. They concluded that polymerized dentures with FRC showed greater mean final fracture load than the CAD/CAM dentures with FRC.

Statistical analysis showed significant results. The dimensions of these FPDs were identical hence their fracture load values provided preliminary estimates of the effect of reinforcement methods on the fracture resistance of a clinical interim restoration. The method used to test the fracture resistance of interim FPDs was based on the one previously described by Vallittu in 1998. The effect of the interim luting agent on fracture resistance of interim FPDs was not investigated in this study. It is likely that cementing the FPD to the abutment increase the fracture resistance of the FPD by transferring stresses more evenly to the FPD abutment system. However, these results may provide a rational clinical protocol for the fabrication of fiber-reinforced interim FPD. Further '*in vivo*' studies may be carried out to verify these results.

LIMITATIONS OF THE STUDY

The effect of the interim luting agent on fracture resistance of interim FPDs was not investigated in this study. It is likely that cementing the FPD to the abutment increases the fracture resistance of the FPD by transferring stresses more evenly to the FPD abutment system. However, these results may provide a rational clinical protocol for the fabrication of fiber-reinforced interim FPDs.

CONCLUSION

Fracture resistance of interim FPD fabricated from PMMA for areas of heavy occlusal stress can be increased with the use of metal wire, a lingual cast metal reinforcement, and impregnation with different types of fibers. The occlusal third of the pontic region from mesial to the distal end of the connector is the best site of placement of the fiber for reinforcing the PMMA interim restorative resin. Further *in vivo* studies using this methodology are recommended to substantiate these results so that the ideal restorative protocol can be determined for clinical success.

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How to cite this article: Kapri A. Comparison of fiber reinforcement placed at different locations of pontic in interim fixed partial denture to prevent fracture: An *in vitro* study. J Indian Prosthodont Soc 2015;15:142-7.

Source of Support: Nil, **Conflict of Interest:** None.