The effect of different fiber reinforcements on flexural strength of provisional restorative resins: an *in-vitro* study

Vaibhav Deorao Kamble[1]*, MDS, Rambhau D. Parkhedkar[2], MDS, Tushar Krishnarao Mowade[1], MDS

[1]Department of Prosthodontics, VSPM's Dental College and Research Center, Nagpur, India

[2]Department of Prosthodontics, Saraswati Dhanwantri Dental College, Parbhani, India

PURPOSE. The aim of this study was to compare the flexural strength of polymethyl methacrylate (PMMA) and bis-acryl composite resin reinforced with polyethylene and glass fibers. **MATERIALS AND METHODS.** Three groups of rectangular test specimens (n = 15) of each of the two resin/fiber reinforcement were prepared for flexural strength test and unreinforced group served as the control. Specimens were loaded in a universal testing machine until fracture. The mean flexural strengths (MPa) was compared by one way ANOVA test, followed by Scheffe analysis, using a significance level of 0.05. Flexural strength between fiber-reinforced resin groups were compared by independent samples t-test. **RESULTS.** For control groups, the flexural strength for PMMA (215.53 MPa) was significantly lower than for bis-acryl composite resin (240.09 MPa). Glass fiber reinforcement produced significantly higher flexural strength for both PMMA (267.01 MPa) and bis-acryl composite resin (305.65 MPa), but the polyethylene fibers showed no significant difference (PMMA resin- 218.55 MPa and bis-acryl composite resin- 241.66 MPa). Among the reinforced groups, silane impregnated glass fibers showed highest flexural strength for bis-acryl composite resin (305.65 MPa). **CONCLUSION.** Of two fiber reinforcement methods evaluated, glass fiber reinforcement for the PMMA resin and bis-acryl composite resin materials produced highest flexural strength. **Clinical implications.** On the basis of this *in-vitro* study, the use of glass and polyethylene fibers may be an effective way to reinforce provisional restorative resins. When esthetics and space are of concern, glass fiber seems to be the most appropriate method for reinforcing provisional restorative resins. **[J Adv Prosthodont 2012;4:1-6]**

KEY WORDS: 3-point bend test; Fixture; Rollers; Stress applicator rod; Provisional restorative resins

INTRODUCTION

Fixed partial dentures have become a well-established treatment modality for many partially edentulous patients. Because these restorations are made indirectly in a dental laboratory, several days or weeks are usually required for their completion. Therefore provisional restoration is an essential step in fixed prosthodontics.[1] The word provisional means 'established for the time being'. During the prosthetic rehabilitation procedures, provisional restorations are commonly used to provide both pulpal and periodontal protection until the final restorations are placed. Such temporary restorations should have good marginal integrity, esthetics and sufficient durability to withstand the forces of mastication. Material strength is important when selecting resins for provisional restorations. For patients with treatment plan which requires long-term use of provisional restorations like full mouth rehabilitation, improved mechanical properties are required. Materials commonly used to fabricate provisional restorations are polymethyl methacrylate (PMMA) resin, polyethyl methacrylate resin, bis-acryl composite (BAC) resin, and epimine. Historically, ethyl methacrylates have shown poor wear resistance and poor esthetics. Thus, the PMMA and bis-acryl resin composite materials possess a larger market value.[2] Previous studies have evaluated the marginal fit, polymerization shrinkage, periodontal response, temperature rise, color stability, and fracture resistance of the various provisional restorative materials.[3] Several methods and materials have been attempted to reinforce provisional restorative resins such as use of a stainless steel wire, cast metal on lingual side, a processed acrylic resin, and fibers such as polyethylene and glass.[4] Considering the high incidence of fractures, numerous studies have been conducted on individual reinforcement methods to improve the strength of the provisional restoration.[1,2,4] It would be worth knowing, up to what

Corresponding author: Vaibhav Deorao Kamble
Department of Prosthodontics, VSPM's Dental College and Research Center
Digdoh Hills, Hingna Road, Nagpur, Maharashtra, India
Tel. 91 9561381468: e-mail, vaibhavk056@gmail.com
Received April 27, 2011 / Last Revison January 6, 2012 / Accepted January 27, 2012

extent the fiber reinforced resin fulfills the strength requirement of an ideal provisional restorative material.

The purpose of this study was to evaluate and compare the effect of two different fiber reinforcement i.e. polyethylene fibers and glass fibers on the flexural strength of PMMA and BAC resins.

MATERIALS AND METHODS

The master die was fabricated in stainless steel with dimensions of 30 mm × 10 mm × 2 mm. The master die had one threaded hole on each end to facilitate easy removal from the investing material. After verification of the dimensions, four dies were selected for preparation of a gypsum mold.

Gypsum molds were prepared with the help of preformed metal dies. Each threaded hole of master die was filled up with modeling wax (Deepti denal products, Ratnagiri, Maharashtra, India). A thin layer of petroleum jelly was applied over the die and it was invested with Type IV gypsum product (Ultrarock; Kalabhai Karson, Mumbai, Maharashtra, India) in the dental flask (Varsity Flasks; National Dental Supply Company, New Delhi, India). Ensuring metal to metal contact between the base and its counterpart, the flask was closed under constant pressure on bench clamp. After setting, the flask was opened and the modeling wax within the holes was removed. The dies were carefully removed from the investing material. The molds were evaluated for any porosities and roughness. The prepared molds were immersed in hot water to remove any traces of impurities and to facilitate the application of separating medium (Stellon cold mould seal; Dental Products of India, Mumbai, Maharashtra, India). The mold cavities obtained were used for the preparation of test specimens.

For control group test specimens of PMMA resin (DPI Heat cure, 792, Mumbai, Maharashtra, India), polymer and monomer in the ratio of 2:1 by weight was mixed and allowed to reach dough stage. It was kneaded and packed in the mold. The trial closures were performed and excess was removed. The flask was clamped and a constant pressure of 500 gm was maintained for 20 minutes to allow bench cure and even flow of material in the molds. The flask was kept for polymerization in water at 90℃ for 2 hours. After completion of polymerization cycle, the flask was allowed to cool in water bath to room temperature. Specimens were finished and polished after deflasking. BAC resin specimens (Protemp 4 Garant; 3M ESPE, B008, Seefeld, Germany) were prepared with similar procedure, except it was supplied in an auto mixing syringe. The mix was packed directly into the mold using application tips supplied with the kit. Using this procedure, 15 specimens of PMMA and BAC resin were prepared.

Polyethylene fibers (Lotus polytwist; 30805-43, Daman, India) were soaked in monomer for 10 minutes in a petridish for improved adhesion of the fibers with PMMA resin matrix.[4,5] The fibers were removed from the monomer and excess liquid was allowed to dry. Polymer and fibers were mixed thoroughly to disperse the fibers. The monomer and polymer containing fibers was mixed in the ratio of 2:1 by weight and allowed to reach the dough stage. Mix was packed into the prepared mold. The specimens were polymerized and retrieved in the same manner as the control group. For BAC resin specimens, bonding agent (Adper™; 3M ESPE, 4 AR Seefeld, Germany) was applied on polyethylene fibers and cured for 40 seconds with halogen light cure unit (Megalux CS; Megadenta, Radeberg, Germany). With Garant dispenser, both base and catalyst pastes were dispensed on the mixing pad. The mix was hand-spatulated after incorporation of polyethylene fibers for 30 seconds and immediately transferred to applicator syringe for placement into the mold and the mold was assembled.[5]

Glass fibers (Saint Gobain Vetrotex International; 1652060, Chambery, France) used in this study had the length of 48 mm and a thickness of 8 to 12 μm. These fibers were rolled in an aluminium foil to form the bundles and these bundles of fibers were chopped into 6 mm length using a sharp scalpel blade. 2% by weight of 6 mm length glass fibers were soaked in silane (Ultradent products; B0DMV, South Jordon, USA) for 5 minutes in a petridish for better bonding of these fibers with the resin matrix.[6] The fibers were removed from silane and allowed to air dry completely. The specimens were polymerized and retrieved. The exposed fibers at the peripheral border of specimens were trimmed by diamond point at slow speed to avoid delamination of the reinforcement. Specimens were stored in saline at 37℃ for 24 hours in an incubator before testing. Specimens were labeled on each end prior to testing so that fractured pieces could be reunited and examined after testing.

Total 90 specimens were tested to measure the flexural strength of PMMA and BAC resin. Specimens were distributed into 6 groups.

- Group I - Control group (Unreinforced PMMA)
- Group II - Reinforced with monomer impregnated polyethylene fibers.
- Group III - Reinforced with silane impregnated glass fibers.
- Group IV - Control group (Unreinforced BAC)
- Group V - Reinforced with monomer impregnated polyethylene fibers.
- Group VI - Reinforced with silane impregnated glass fibers

For flexural strength, specimens were tested by 3-point bend test on Universal Testing Machine (Instron 4467; Buckinghamshire, England) at a cross head speed of 1 mm/min. For the 3-point bend test, a fixture was fabricated with the dimensions of 50 mm × 30 mm × 30 mm. On top of the fixture two plates were welded at a distance of 15 mm from the centre on either side. A roller with diameter of 5 mm was placed on top of each plate. A customized "T" shaped stress applicator

rod with the dimension of 80 mm × 20 mm was fabricated, by which stress can be applied in the centre of specimen.

The specimen was placed on the rollers in such a way that the centre of the specimen coincided with the centre of the distance between the two rollers. This whole unit was mounted on the lower jaw of the universal testing machine and the stress applicator rod was fixed on the upper jaw. A load was applied with "T" shaped rod on the centre of specimen until fracture occurred and peak force (F) values were recorded at this point in Newtons. Diagrammatic representation of 3-point bend test (Fig. 1) illustrates 'C' as the compressive stress applied on the specimen via the applicator rod, 'T' as the tensile stress acting on the under surface of the specimen, and 'S' as the shear stress acting on the junction of the roller and the specimen.[7]

The peak force (F), from the stress strain curve of each specimen, was recorded and used to calculate the flexural strength in MPa from the following equation[2]:

$$\delta\beta = \frac{3FI}{2Bh^2}$$

Where,

$\delta\beta$ = Flexural strength in MPa

F = Maximum applied load in newtons

I = Supporting width in millimeters

B = Breadth of test specimens in millimeters

h = Height of the test specimen in millimeters

The data was tabulated and analyzed by Statistical Package for Social Science© 10.0 (SPSS, Inc; Chicago, IL, USA). The mean difference, standard deviation and standard error were calculated for each variable. The data of each resin type were analyzed for difference by use of one-way analysis of variance (ANOVA) followed by Scheffe analysis, using a significance level of 0.05 to determine the mean differences. As the intent of this study was to make comparisons between the different materials tested, independent samples t-test was used for analysis.

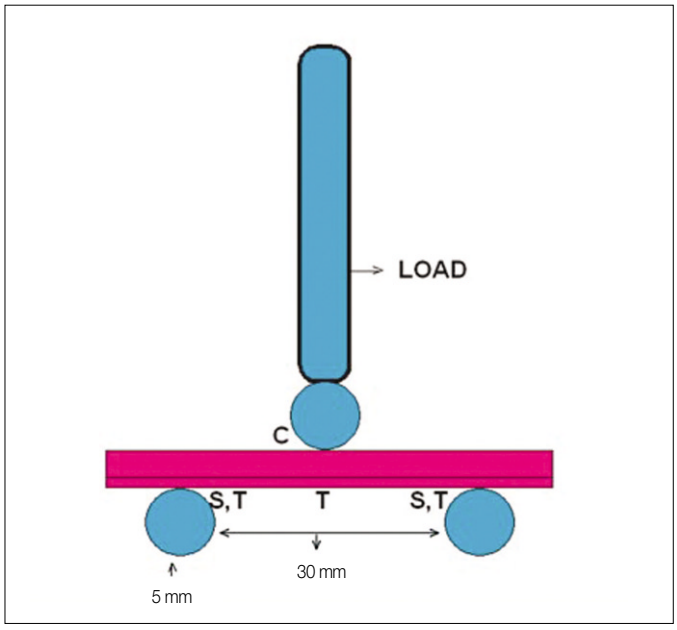

Fig. 1. Diagrammatic representation of 3-point bend test.

RESULTS

The results for mean flexural strength values are shown in Table 1. One-way ANOVA was used to study whether reinforcement with polyethylene and glass fibers significantly improved flexural strength when compared to unreinforced (control) group. The hypothesis of means was rejected at 5% level of significance with *P* value =.0000 and the means of 3 groups differs significantly. This shows that group III specimens were superior to group I and II and group VI specimens were superior to group IV and V. As the means were not equal, a pair wise comparison of means was carried out using Scheffe analysis. Group III showed significantly higher flexural strength than group I but no significant difference was found between group I and II. Similarly, group VI showed significantly higher flexural strength than group IV but no significant difference found between group IV and V (Table 2).

Table 1. Mean flexural strength values of polymethyl methacrylate and bis-acrylic composite resin (control group and fiber-reinforced group)

PMMA and BAC resin groups	Mean flexural strength (MPa)	SD
Group I	215.53	2.8414
Group II	218.55	2.7604
Group III	267.01	7.6431
Group IV	240.09	2.2812
Group V	241.66	4.6080
Group VI	305.65	13.2844

PMMA- Polymethyl methacrylate resin, BAC- Bis-acryl composite resin.

Table 2. Multiple comparisons by Scheffe analysis between control and fiber-reinforced group

PMMA and BAC resin groups		Mean difference	*P* value	Result
Group I	Group II	-3.024	.261	not significant
Group I	Group III	-51.4773	.000	Significant*
Group II	Group III	-48.4533	.000	Significant*
Group IV	Group V	-1.5733	.872	not significant
Group IV	Group VI	-65.5667	.000	Significant*
Group V	Group VI	-636.9933	.000	Significant*

PMMA- Polymethyl methacrylate resin, BAC- Bis-acryl composite resin.
Symbol * indicates the statistical significant difference between groups.
Symbol shows significant improvements in the fiber reinforced groups and comparison.

Table 3. Independent samples t-test: Comparison of flexural strength between fiber-reinforced polymethyl methacrylate and bis-acrylic composite resin

	N	Mean	SD	t value	*P* value	Result
Group II	15	218.5533	2.7604	16.660	.0000	Significant*
Group V	15	241.6600	4.6080			
Group II	15	218.5533	2.7604	24.862	.0000	Significant*
Group VI	15	305.6533	13.2844			
Group III	15	267.0067	7.6431	10.999	.0000	Significant*
Group V	15	241.6600	4.6080			
Group III	15	267.0067	7.6431	9.766	.0000	Significant*
Group VI	15	305.6533	13.2844			

Symbol * indicates the statistical significant difference between groups.
Symbol shows significant improvements in the fiber reinforced groups and comparison.

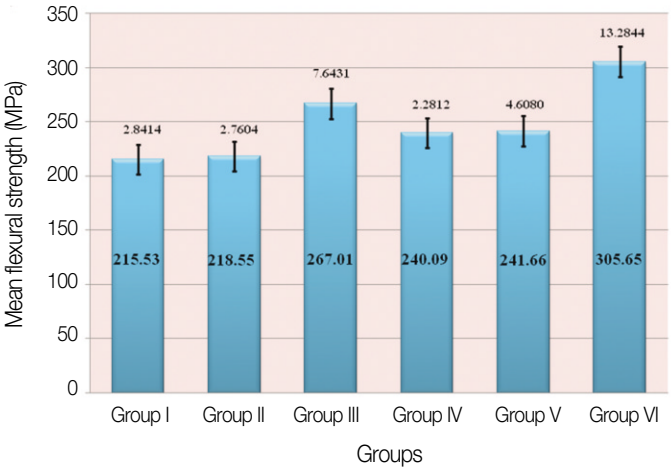

Fig. 2. Graph showing mean flexural strength of control and fiber-reinforced polymethyl methacrylate and bis-acrylic composite resin. (n = 15), *P* value<.05.

By using independent samples t-test, the results revealed statistically significant difference between flexural strength of fiber reinforced PMMA and BAC resin group. Group VI showed highest flexural strength followed by group III, V and group II in order (Table 3). The comparative mean values of the flexural strength of group II, III, V and VI are presented in Fig. 2.

DISCUSSION

The use of fibers to reinforce a provisional restoration has an acceptable success rate mainly because of the advancements in fiber-reinforcing materials.[5] Reinforcement with fibers enhances the mechanical strength characteristics such as transverse strength, ultimate tensile strength, and impact strength.[8] Although laboratory flexural strength values under static loading may not reflect intraoral conditions; these values are nevertheless helpful as useful predictors of clinical performance.[4]

Glass fiber is an inorganic substance, which has been cooled to a rigid condition without crystallization. 'E' glass fibers, based on an alumina-lime-borosilicate composition are considered the predominant reinforcement for polymer matrix due to their high mechanical properties like strength and fracture resistance, low susceptibility to moisture, resistance to chemicals, thermal stability, and high melting point. Polyethylene fibers are naturally crystalline polymers, which are drawn at temperature below their melting point to produce materials of enhanced modulus in the axial direction. Characteristics of these fibers include light weight, high strength, high modulus, abrasion resistance, resistance to moisture absorption, and resilience.[8,9]

BAC resins are supplied in automixing cartridge, presumably providing more homogeneous mix than hand mixing the PMMA resin.[10] However this is not supported by Haselton *et al*.,[3] who found no lower standard deviations for the BAC resins compared to hand mixed PMMA resin. This study confirms the higher flexural strength of the control BAC resin as compared to PMMA resin. Traditional PMMA resins are monofunctional and have low molecular weight linear molecules that exhibit reduced strength and rigidity. In contrast, BAC resins are difunctional and have ability to cross- link with monomer chains; resulting in greater toughness and strength.[11]

BAC resin has been marketed as Protemp 4 Garant. This includes a newly modified monomer system, not with the rigid intermediate chain characteristic of BAC resin, but with flexible chain in comparison to other synthetic resins. This modification allows a balance between high mechanical strength and limited elasticity of the BAC resin resulting in a material that can withstand higher stresses until fracture and that can tolerate brief deformation.[2]

The reinforcing effect of fibers on different polymer types increased the mechanical properties of provisional restorative

resins.[11] The possible reason for the increase was the transfer of stress from the weak polymer matrix to the fibers that have high tensile strength. The stronger the adhesion between the fiber and the matrix, the greater the strengthening effect. One approach to increase the adhesion of fibers is resin impregnation of the fibers before application. An effective impregnation procedure allows the resin to come into contact with the surface of each fiber. Wetting the fibers with monomer is commonly used method but may impair other properties because of residual monomer.[4]

In the present study, polyethylene fibers did not produce higher flexural strength in either material than unreinforced group which may be attributed to poorly bonded fibers, thus creating the equivalent of voids. Improper impregnation also increases water sorption that might result in a detrimental hydrolytic effect and decreases the mechanical properties of reinforced resin. To increase the reinforcing effect of polyethylene fibers, different surface treatments should be carried out that includes plasma spraying, chemical, flame, and radiation treatments.[4] There was a statistically significant improvement in flexural strength of silane impregnated glass fiber group, which may be attributed to the effect of silane coupling agent that chemically bonds inorganic glass fibers to the organic resin matrix and may make the mixture more homogenous resulting in strong PMMA and BAC resin.[6] Kolbeck *et al*. stated that the reinforcing effect of glass fibers was more effective than polyethylene fibers, and was attributed to the difficulty of obtaining good adhesion between polyethylene fibers and the resin matrix.[12,13] This study showed that significant effect is produced by random orientation of fibers in the specimens of most groups. The ease and simplicity of their inclusion would make this technique more acceptable for widespread use, avoiding the necessity of interruption of packing procedures and time consuming placement of oriented fibers or woven filaments. Fiber incorporation beyond 3% by weight will affect the flow of the dough and represents a large volume of material to be wetted by monomer during mixing and produce dry friable dough. This will provide no beneficial effect on strength. For this reason, 2% by weight of each type of fiber was added to each specimen.[8] Glass fiber reinforcement provides the best esthetic qualities for dental applications though more research is necessary to determine whether glass fibers are carcinogenic in the mouth, attract more plaque, or cause gingival disorders.[13,14]

During the specimen preparation some variability is introduced in the selection of the materials, storage of the specimens, finishing and polishing of the specimens. *In vitro* static load tests differ from the dynamic oral conditions. No cyclic loading in a moist environment was performed in the present study, and this is a study limitation. It is important to note that flexural strength is only one of the behaviors in response to a particular stress and that strength is just one property of provisional crown materials. A strong material may possess other less desirable characteristics such as tendency to strain, lack of polishability, difficult manipulation, or poor esthetics. A provisional crown placed on single anterior tooth will have different clinical requirements than a long span provisional fixed partial denture. The clinician must be aware of all attributes of various materials and choose the provisional material appropriate for each patient.[2]

The clinical implication of this study is that glass and polyethylene fibers used did not compromise esthetic qualities of provisional restoration and strength achieved exceeded the normal strength of PMMA and BAC resin. Fiber reinforcement is a potential technique for strengthening provisional fixed partial dentures at the connector sites to avoid fractures which may be used for extended periods.

CONCLUSION

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

1. PMMA resin has significantly lower flexural strength than BAC resin.
2. Reinforcement with 2% by weight of glass and polyethylene fibers improved the flexural strength of the specimens compared to unreinforced PMMA and BAC resin. This shows that use of fibers is an effective method to increase mechanical properties of provisional restorative resins.
3. Silane impregnated glass fiber reinforcement produce significantly higher flexural strength for both PMMA and BAC resin compared to monomer impregnated polyethylene fiber reinforcement. This shows that silanized glass fibers seems to be the most appropriate method for reinforcing provisional restorative resins where esthetics and space are of concern.

REFERENCES

1. Rosenstiel SF, Land MF, Fujimoto J. Contemporary fixed prosthodontics. 3rd ed. St. Louis; Mosby; 2001. p. 380-6.
2. Osman YI, Owen CP. Flexural strength of provisional restorative materials. J Prosthet Dent 1993;70:94-6.
3. Haselton DR, Diaz-Arnold AM, Vargas MA. Flexural strength of provisional crown and fixed partial denture resins. J Prosthet Dent 2002;87:225-8.
4. Hamza TA, Rosenstiel SF, Elhosary MM, Ibraheem RM. The effect of fiber reinforcement on the fracture toughness and flexural strength of provisional restorative resins. J Prosthet Dent 2004;91:258-64.
5. Vallittu PK. Flexural properties of acrylic resin polymers reinforced with unidirectional and woven glass fibers. J Prosthet Dent 1999;81:318-26.
6. Solnit GS. The effect of methyl methacrylate reinforcement with silane-treated and untreated glass fibers. J Prosthet Dent 1991;66:310-4.
7. Dagar S, Pakhan A, Tunkiwala A. An in-vitro evaluation of flex-

ural strength of direct and indirect provisionalization materials. J Indian Prosthodont Soc 2005;5:132-5.
8. Uzun G, Hersek N, Tinçer T. Effect of five woven fiber reinforcements on the impact and transverse strength of a denture base resin. J Prosthet Dent 1999;81:616-20.
9. Gutteridge DL. The effect of including ultra-high-modulus polyethylene fibre on the impact strength of acrylic resin. Br Dent J 1988;164:177-80.
10. Koumjian JH, Nimmo A. Evaluation of fracture resistance of resins used for provisional restorations. J Prosthet Dent 1990;64: 654-7.
11. Geerts GA, Overturf JH, Oberholzer TG. The effect of different reinforcements on the fracture toughness of materials for interim restorations. J Prosthet Dent 2008;99:461-7.
12. Vallittu PK. Ultra-high-modulus polyethylene ribbon as reinforcement for denture polymethyl methacrylate: a short communication. Dent Mater 1997;13:381-2.
13. Kolbeck C, Rosentritt M, Behr M, Lang R, Handel G. In vitro study of fracture strength and marginal adaptation of polyethylene-fibre-reinforced-composite versus glass-fiber-reinforced-composite fixed partial dentures. J Oral Rehabil 2002;29: 668-74.
14. Stipho HD. Effect of glass fiber reinforcement on some mechanical properties of autopolymerizing polymethyl methacrylate. J Prosthet Dent 1998;79:580-4.