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 prosthetics. 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. Previous studies have evaluated the marginal fit, polymerization shrinkage, periodontal response, temperature rise, color stability, and fracture resistance of the various provisional restorative materials. 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. Considering the high incidence of fractures, numerous studies have been conducted on individual reinforcement methods to improve the strength of the provisional restoration. It would be worth knowing, up to what
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 dental 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; Kalabhari 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 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. 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.

Glass fibers (Saint Gobain Vetrotex International; 1652060, Chamberry, 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 aluminum 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. 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°C 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:

\[ \delta = \frac{3FI}{2Bh^2} \]

Where,
- \( \delta \) = 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.

**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.
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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. Reinforcement with fibers enhances the mechanical strength characteristics such as transverse strength, ultimate tensile strength, and impact strength. Although laboratory flexural strength values under static loading may not reflect intraoral conditions; these values are nevertheless helpful as useful predictors of clinical performance.

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.

BAC resins are supplied in automixing cartridge, presumably providing more homogeneous mix than hand mixing the PMMA resin. However this is not supported by Haselton et al., 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.

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.

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

### 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 | 2.7064 | 16.660 | .0000 | Significant* |
| Group V  | 15 | 241.6600 | 4.6080 | 24.862 | .0000 | Significant* |
| Group VI | 15 | 305.6533 | 13.2844 | 9.766 | .0000 | Significant* |

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.
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The flexural strength is only one of the behaviors in response to a test, and this is a study limitation. It is important to note that ing in a moist environment was performed in the present tests differ from the dynamic oral conditions. No cyclic load- was added to each specimen. Glass fiber reinforcement pro- friable dough. This will provide no beneficial effect on the flow of the dough and represents a large volume of mate- rials. Fiber incorporation beyond 3% by weight will affect 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 fil- aments. Fiber incorporation beyond 3% by weight will affect the flow of the dough and represents a large volume of mate- rial 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. Glass fiber reinforcement pro- vides 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. During the specimen preparation some variability is intro- duced 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 load- ing 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 pro- visional 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. The clinical implication of this study is that glass and poly- ethylene 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 poly- ethylene 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 poly- ethylene fiber reinforcement. This shows that siliconized glass fibers seems to be the most appropriate method for rein- forcing provisional restorative resins where esthetics and space are of concern.

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