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ORIGINAL RESEARCH

Effect of Glass Fiber Length on Flexural Strength of Fiber-reinforced Composite Resin

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ABSTRACT

The aim of this study was to determine experimentally maximum fracture load of fiber-reinforced composite with different span lengths and to determine the effect of glass fiber on this parameter.

Materials and methods: Six fiber-reinforced groups (n = 10) were made with three different lengths (10, 15, 20 mm) with or without glass fiber in split mold. The specimens were early cured and then post-cured with a labolite unit, then specimens were subjected to three-point flexural test by a universal testing machine. Data were analyzed with ANOVA and LSD post-hoc test ($p < 0.05$).

Results: Maximum fracture load of specimens increased with decreasing lengths ($p < 0.001$) and fiber-containing group showed significantly higher fracture load than fiberless groups ($p < 0.001$).

Conclusion: It was concluded that by increasing the span length, the maximum fracture load values (N) decreased incorporation of fiber results in higher fracture strength values.

Keywords: FRC, Glass fiber, Flexural strength.

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INTRODUCTION

When two or mores materials are combined, the resulting composite will have a combination of properties that neither of the components possesses individually. While they achieve certain intermediate properties between the two components, some components, especially toughness, can be significantly superior in the composite compared with either of the two materials. In fiber-reinforced polymers, the main function of fibers is generally to increase the stiffness and strength.[1]

The matrix acts to protect the fibers and fix their arrangement in a predetermined position that provides optimum reinforcement. It should be strong enough to support a significant load with minimal elastic distortion. This is called the flexural strength or modulus of the material. The toughness of the material is also an index of the resistance of the material to rapid crack propagation.[1]

The missing teeth can be replaced with any of a variety of tooth supported fixed prostheses and among all these choices traditional porcelain fused to metal substructures continue to be a mainstay of fixed prostheses.[2] Although they have demonstrated excellent clinical results over the years but they have disadvantages, such as unesthetic metallic framework, and may corrode to allergic components which may tattoo the gingival tissue, also laboratory procedures are time-consuming and expensive and porcelain veneers may be prone to fracture or may wear the opposing teeth.[2-5]

In recent years, developments in resin and fiber technology and patient demand for more esthetic tooth-colored restorations led to the increased use of resin-bonded fiber-reinforced fixed partial dentures (FPDs).[4] Bundles of long continuous glass or polyethylene fibers impregnated with resin matrix are now replacing the metallic frame works, they are translucent and also maintain the physical properties required to support masticatory forces.[2]

Previous studies showed acceptable survival rates over extended periods of service (73.4% over, 4.5 years[6] and 81.8% over 8 years).[4]

The desirable properties for fiber-reinforced composites are strength, toughness, minimal water sorption, good optical properties, biocompatibility, bond ability and manageability.[7]

For this technique, according to Wijlen, the selection criteria should closely resemble those for a Maryland bridge. He also recommended short spans, not exceeding than 8 to 10 mm. He concluded that 'the rather surprising early success is due to conservative case selection and to the inherent flexibility or resilience of the resin-fiber substructure'.[5]

In dental applications, such as bridges, FRCs are usually susceptible to flexure or bending in clinical service. So these materials are often tested in flexure in the laboratory.[1] The span length is an important factor in a successful and durable FRC bridge placement.[8]

Creugers et al stated that the treatment success primarily relies on the prosthetic space. They offer that the distance should not be larger than 15 mm because the FPD would suffer a higher deflection and thereby fails. This is very important and they said that 'a large prosthetic space in the mandible might increase the failure rate in three times'.[9]

Alender et al fabricated FRC specimens with circular and rectangular cross section. They used the three-point bending test to estimate the ultimate flexural strength and flexural modulus of specimens with different length (10, 14, 17, 20 mm). They concluded that: By increasing the length, the flexural strength and flexural modulus values in MPa increased and the maximum fracture load values in N decreased. It is also cruscial to report the L/D ratio for interpretation of flexural strength and flexural modulus values of small size test specimens.[10]

Despite the known effect of the span length on the maximum fracture load, it is not yet clear which length of FRC bridges should be fabricated to withstand the functional load. This is an important factor in case selection for RFC bridges.

The aim of this study was to determine experimentally the flexural strength and maximum fracture load of fiber-reinforced composite with three different lengths.

MATERIALS AND METHODS

In this study six experimental groups (N = 10) were prepared. First three split steel molds with 2 × 2 × 10 mm, 2 × 2 × 15 mm, 2 × 2 × 20 mm spaces for specimen fabrication were prepared. For group 1, 2 and 3, pieces of glass ribbon fiber (Angelus, Brazil) preimpregnated in Bis GMA and urethane dimethacrylate with the width of 2 mm were cut in the lengths of 10, 15 and 20 mm respectively. Each one was placed at the bottom of the mold with the same size and the remaining spaces were filled with indirect composite (Gradia GC, Japan) (Fig. 1).

For groups 4 to 6, the control groups, no fiber was incorporated and the whole mold spaces were filled with composite resin. Then shim stock was placed over the mold and a glass slab was pushed over the shim stock to flatten the top of the specimen, after that specimens were cured by an LED unit (LED, Demetron, Kerr) with the power of 1200 mw/cm.[2] Specimens with 10 or 15 mm length were cured at two points and specimens with 20 mm length at three points, each for 40 seconds. After the removal of the mold the specimens were postcured in a labolite unit (GC, Japan) for 15 minutes then finished and polished with finishing diamond bur and polishing rubber point.

The specimens were subjected to three point loading test (Zwick/Roell Z020, Germany) with cross head speed of 1 mm/minutes and the fracture loads (N) were measured. Data were analyzed with the two-way ANOVA and LSD post-hoc tests.

RESULTS

The mean fracture load of the groups with 10 mm length (groups 1 and 4) showed statistically significant difference with the 15 mm length groups (groups 2 and 5) and 20 mm length groups (groups 3 and 6) ($p < 0.001$), and it was also significant between 15 mm length groups (groups 2 and 5) and 20 mm length groups (groups 3 and 6) ($p < 0.001$). The mean fracture loads was 131.68 ± 63.97 N for 10 mm groups (groups 1,4) and 86.845 ± 48.63 N for 15 mm groups (groups 2 and 5) and 57.27 ± 32.65 N for groups with 20 mm length (groups 3 and 6) (Fig. 2).

In analyzing the differences between groups with LSD post-hoc test significant differences were observed between all the groups. In groups with 10 mm length the mean fracture load for the group with glass fiber (group 4) was 190.60 ± 29.15 N and showed statistically significantly higher with the similar group without fiber (group 1) with the mean fracture load of 72.76 ± 8.69 N ($p < 0.001$).

The mean fracture load for group 5 (15 mm length with fiber) was 133.60 ± 10.31 N and showed statistically significantly higher with group 2 (15 mm length without fiber) with the mean fracture load of 40.09 ± 5.46 N ($p < 0.001$). For 20 mm length groups, the mean fracture load for the group with fiber (group 6) was 87.43 ± 14.94 N

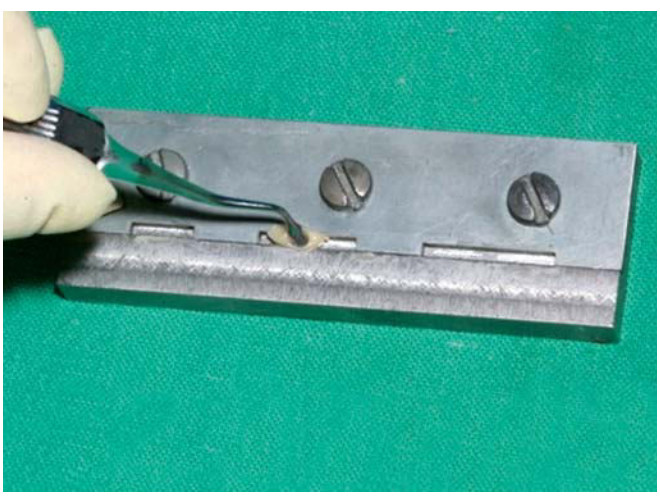

Fig. 1: Specimen making

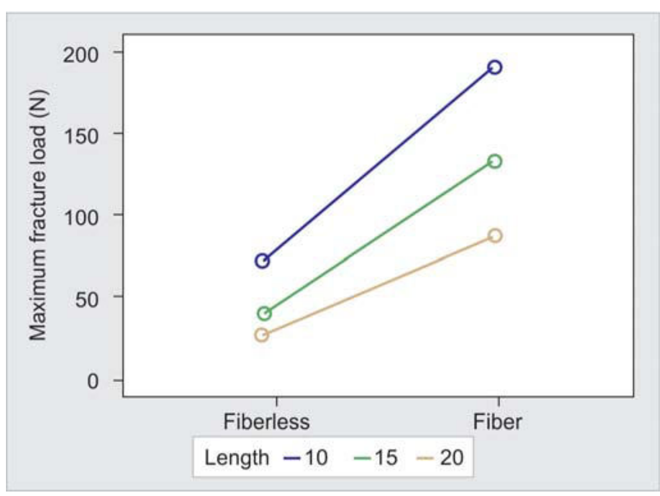

Fig. 2: Fracture load of specimens with or without fiber

Table 1: Fracture load of different groups

Groups	Length	Fiber	Number	Mean (N)	Standard deviation
1	10	No	10	72.760	8.698
2	15	No	10	40.090	5.464
3	20	No	10	27.120	2.712
4	10	Yes	10	190.600	29.159
5	15	Yes	10	133.600	10.319
6	20	Yes	10	87.430	14.947
Total			60 (total)	91.933	58.093

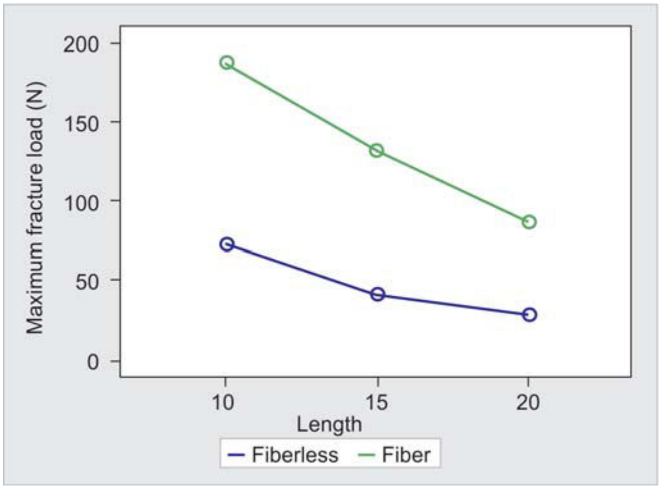

Fig. 3: Fracture load of fiber containing and fiberless groups with different lengths

and was significantly higher ($p < 0.001$) in comparison with the similar group without fiber (group 3) with the mean of 27.12 ± 2.7 N.

The mean fracture load for all groups with fiber (groups 4, 5 and 6) was 137.21 ± 46.99 N and the mean for all groups without fiber (groups 1, 2 and 3) was 46.65 ± 20.40 N the difference was also significant ($p < 0.001$) (Fig. 3 and Table 1).

DISCUSSION

The aim of this study was to determine the fracture strength of FRC specimens with different lengths.

Bae et al analyzed the flexural strength and flexural modulus of fiberless and fiber containing FRC specimens with three-point bending test. In their study, they used polyethylene (ribbond) and three different glass fibers (glass span, vectris, fiberkor). They concluded that most of fibers resulted in higher flexural strengths. Furthermore, fibrekor and glass span resulted in higher flexural modulus.[11] Glass fibers are composed of glass interlaced filaments and increase the impact strength of composite resin structures.[12] Garoushi also stated that glass fibers are best fibers for reinforcing dental materials.[13] So, we used glass fibers in this study.

Soares showed that adding glass fibers to composite bridges would increase flexural strength.[14] In the present study, also specimens with fiber had higher fracture load than fiberless groups. While junior observed that although increasing glass fibers results in increased strength but using too much fiber results in decreased amount of resin matrix and decreased strength.[2] Sadeghi had emphasized on reinforcing effect of fibers and advised that fiber content should be less than 60% for maximum results.[15] In the present study, the specimens were bars with 2 × 2 mm cross-section and different lengths and a layer of 2 × 0.5 mm fiber was placed at the bottom of the specimens, when the resin matrix involved in the fiber layer is taken into account the fiber content is estimated between 20 and 25% which results in increased fracture load of specimens in fiber-containing groups.

Having placed fibers in three different positions (top, middle, bottom) in FRC bars, Fuji noticed that placing fibers at the bottom portion led to the best reinforcing effects[16] then inline with previous reports, in the present study, fiber was positioned at the bottom portion of mold.

As Freilich believed, the flexural strength value is an important factor in dental applications.[1] Numerous studies have reported that in a three point bending test, the distance between supports (L), the diameter of the specimen (D) and the resulting L/D ratio can affect flexural properties of the specimens.[17-22] Creugers et al found that the prosthetic space is a significant factor to determine the treatment success. They indicated that the distance should not be larger than 15 mm, because the FPD would suffer a higher deflection and could fail. They said that 'a large prosthetic space in the mandible might increase the failure rate by three times'.[9]

About the prerequisites for successful results Edelhoff said that the maximum mesiodistal extension of the interdental gap should be less than 12 mm.[23]

In the present study in fiber-containing groups, the 20 mm length group showed lower strength than 15 mm length group, and both showed decreased strength compared to the 10 mm length group. Similar results were obtained in fiberless groups with different lengths.

This study also showed that adding a layer of fiber to composite specimens increased the maximum fracture load ($p < 0.001$). This was observed in all L/D rations tested in this study, as a result of instant cross section (2 × 2), L is the only diametric variable.

Another interesting findings of the present study was that by increasing the L/D ratio, the maximum load values decreased although the material and its polymerization remained the same, but it should be noted that the relation between L/D ratio and the maximum load values is not linear. It seems that increasing the length results in rapid decrease in strength and fibers would not cause such reinforcing effects in larger spans.

This was exactly inline with what Alander et al observed in their study. They tested different lengths (10, 14, 17 and 20 mm) with cross-section of 2×2; they also showed that increasing the L/D ratio results in decreased maximum load.[10]

In contrast Rosentritt et al found increased fracture strength of the four unit FPDs as compared to the three unit system. They explained it to be the result of higher flexibility which can possibly cause a higher deformation in the center of the four-unit FPDs. This deformation in comparison to the stiffer three-unit FPDs may contribute to a mechanical protection of the pontic – abutment areas during artificial mastication and also during fracture testing.[24]

Eckrote stated that 'as L/D is decreased, the load is supported by the fibers in tension and compression as well as the matrix in shear. The clinically important maximum load and load at the elastic limit increase with decreasing L/D'.[21]

Grande et al on their investigation about 'the effect of custom adaptation and span—diameter ratio on the flexural properties of fiber—reinforced composite posts' showed that an increase in the L/D ratio decreased the maximum load values, but flexural strength and flexural modulus values increased[22] which is coordinate with our results.

There are few articles on using different FRC bridge lengths in clinical situations. Piovesan et al for instance, fabricated 19 FRC bridges in cases with prosthetic spaces less than 15 mm, after the mean evaluation time of 41.15 months FPDs were 94.75% retained in their study. They believe the span length as an important factor in their experience of durable FRC bridge placement.[8]

The present study, considering the findings of preciding studies, made an effort to find the ultimate results which could be compared with occlusal forces mentioned in prosthodontic references for determining the acceptable values, which may be given to clinicians or dental technicians to determine the needed reinforcing fibers in pontic area of fixed partial dentures in different span lengths. Further investigations are needed with different FPD models with different span lengths.

Within the limitations of this *in vitro* study it was concluded that glass fiber has a reinforcing effect on composite resin and the fracture strength of the FRC structures is increasing with decreasing FRC length and this relation is not linear.

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