Original Article

Fracture Strength and Bending of Fiber-Reinforced Composites and Metal Frameworks in Fixed Partial Dentures

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Abstract:

Objective: This *in vitro* study evaluated the fracture strength and bending amount of two types of fiber reinforced composite (FRC) and cast metal frameworks used for fabrication of inlay fixed partial dentures (IFPDs).

Materials and Methods: Seventy-two extracted first maxillary premolars and molars (36 each) were embedded in acrylic resin to represent a missing of second maxillary premolar. FRC IFPDs were fabricated using Stick and Fiber-Braid fiber bundles and IFPDs using cast metal alloy (12 for each group). The specimens were stored for 2 weeks at 37°C (SD=1) in distilled water, thermocycled (5-55°C, x 2500) and statically loaded to fracture. The initial bending prior to fracture was evaluated. The data were analyzed using paired t-test and ANOVA test.

Results: The fracture strength was significantly higher in the FRC groups ($P<0.05$); also, the fracture strength was significantly higher in Stick group than Fiber-Braid group ($P<0.05$). The amount of bending was significantly greater in the FRC groups ($P<0.05$). The amount of difference in bending between the two groups of FRC was not statistically significant.

Conclusion: Within the limits of this *in vitro* study, the results suggest that the FRC IFPDs can be used as a conservative, esthetic alternative to the IFPDs with cast metal frameworks. The results of this study should be confirmed by long-term clinical investigations.

Key Words: Denture, Partial, Fixed, Resin-Bonded; Inlays; fiberglass reinforced polymers

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INTRODUCTION

Minimal tooth preparation of abutment teeth is desirable fixed partial dentures (FPDs). Resin-bonded FPDs with metallic frameworks are considered practical and conservative but have not exhibited long-term success, especially when replacing posterior teeth [1,2]. They have demonstrated problems like debonding, graying of abutment teeth due to metal show-thought and over contoured retainer components, secondary caries and loss of retention [3-5]. The quest for tooth-colored and metal-free frameworks led to all-ceramic restorative designs; however, the brittleness of ceramic materials has limited their clinical indications [1].

In 1996, fiber reinforced composites (FRCs) were introduced for the fabrication of individual crowns and short-span FPDs. Physical data on these materials suggest that they are best suited for conservative Inlay FPDs (IFPDs). FRC IFPDs are a less invasive treatment, have excellent esthetics, ease of fabrication and repair and are biocompatible [2,6-8]. A higher volume fraction of fibers in the resin matrix is believed to improve the mechanical properties. Therefore, fiber volume fraction of FRCs is relatively high, up to 60 vol%. However, in dental applications fiber fractions are considerably lower [9].

Generally, FRC IFPDs have been used for 3-unit FPDs replacing a single premolar or molar when the intra-abutment span is not more than 15 mm [7]. Furthermore, the following prerequisites must be met for successful results: good oral hygiene, low susceptibility to caries, parallel alignment and immobility of abutment teeth, minimum height of abutment teeth ≥5 mm, maximum mesiodistal extension of the inter-dental gap (12 mm) [5]. Careful patient selection, adequate planning of the design, precise preparation, correct choice of materials and meticulous bonding techniques are important factors as well [10].

Behr et al [6] reported high fracture strength of approximately 700 N for FRC IFPDs even after thermocycling and mechanical loading.

Stick glass fibers (everStick, Stick Tech Ltd, Turku, Finland) are preimpregnated continuous unidirectional with polymethylmetacrylate, resulting in strength properties comparable to those of metal alloy. An additional benefit of polymethylmethacrylate-preimpregnated Stick glass fiber is improved bond strength of resin composite luting cement by interpenetration and polymer network formation [9-12].

According to the claim of the manufacturer, Fiber-Braid (NSI, Dental Pty, New South Wells, Australia) is a non-impregnated material with high modulus and high strength polyethylene fibers, molecularly orientated, for use in splinting, immobilization procedures and all bridges and other high stress restorations where fiber reinforcement is required.

A major disadvantage of the current fiber materials is their lack of radiopacity. Radiographs serve as baseline reference information for comparison at subsequent recall visits, identifying extra luting cement, and detecting early development of caries [11]. The first clinical reports confirmed the *in vitro* results. After one year of observation, an investigation of IFPDs reported that there were no fractures, surface defects, or excessive wear. SEM analysis of the margin exhibited 92% excellent margins at the tooth-luting composite interface and 86% excellent margins at the luting composite-restoration interface [13]. Another study concluded that resin-bonded glass-fiber-reinforced FPDs may be an alternative for resin-bonded FPDs with a cast metal framework [14].

The aim of this *in vitro* study was to determine and compare the fracture strength and bending amount of IFPDs made of two different FRCs (Stick and Fibre-Braid) and metal base frameworks on based on the hypothesis that IFPDs made of FRCs have higher fracture strength as frameworks than cast metal.

MATERIALS AND METHODS

Seventy-two freshly extracted intact and caries-free maxillary first premolars and first molars (36 for each) with no cracks were disinfected, cleaned, polished, and stored in distilled water. Each sample included a first premolar and a first molar tooth embedded 1.0 mm apical to the CEJ in a 50×30×20 mm^3 cold-cure acrylic resin block (Acropars, Marlic Medical Industries Co, Tehran, Iran). The distance between the abutments was nine millimeters, to represent the loss of a maxillary second premolar.

The specimens were randomly divided into three groups (n=12) with a proximal preparation on each abutment adjacent to the edentulous area. For the molars, the isthmus was four millimeters wide, six millimeters long, and 2.5 mm deep with the proximal box extending two millimeter apical to the isthmus floor 1.5 mm in width. The only difference in tooth preparation for the premolars was in the isthmus length, which was four millimeter. Both buccolingual and mesiodistal convergence angles were 10 degrees. All enamel margins were beveled 0.25 mm.

In Stick and Fiber-Braid groups, the FRC IFPDs were made using direct technique according to the manufacturers' instructions. In the both groups, the pontics were built up, layer by layer with hybrid composite (Tetric Ceram, Ivoclar Vivadent, Amherst, NY, USA). In the cast metal group, cast metal frame works in nickel-chromium alloy (VeraBond, AlbaDent, Cordelia, CA, USA) with porcelain (Noritake, Kizai Co. Ltd, Nagoya, Japan) contoured on them were cemented to the abutment teeth with a dual cure cement (Panavia F2.0, Kurary Medical Inc, Japan), according to the manufacturer's instructions. After adjustments, final glazing, polishing and sandblasting of the metal retainers was carried out. The size of pontics in the three groups was similar.

The samples were stored in distilled water at 37°C (SD=1) for two weeks, then thermocycled for 2500 cycles in two water baths at 5-55°C. The IFPDs were continuously loaded until fracture occurred using a universal testing machine (Zwick Z010; Zwick GmbH, Ulm, Germany) with a crosshead speed of one millimeter per minute. The vertical force was applied to the central part of the occlusal surface of the pontic with a round-ended steel rod six millimeter in diameter. In order to reduce the local force peaks, a piece of 0.5 mm thick tin foil was inserted between the steel rod and the pontic. The maximum force (Newton) at fracture point was recorded. The amount of bending (millimeter) was also evaluated by measuring the distance the rest rod moved from the 10 N preload point to fracture point.

The data were analyzed using one-way analysis of variance (ANOVA) and paired t-test. The level of significance was set at $\alpha=0.05$.

RESULTS

The mean and standard deviation for fracture strength and bending amount were recorded in Newton (N) and millimeter, respectively, for the three groups (Table 1).

The results of one-way ANOVA and paired t-test indicated that fracture strength was significantly higher in FRC groups ($P<0.001$). Among the FRC materials, Stick group had greater fracture strength ($P<0.001$). In addition, the results showed that the bending amounts were significantly greater in FRC groups ($P<0.05$) and not significantly different in the two FRC group ($P>0.05$).

DISCUSSION

The results of this *in vitro* study demonstrate that FRC IFPDs have significantly more fracture strength than IFPDs made with cast metal framework ($P<0.001$). Fiber-reinforced materials have highly favorable mechanical properties and their strength-to-weight ratios are superior to those of most alloys. When compared to metals they exhibit many other advantages including non-corrosiveness, translucency, good bonding properties, and ease of repair. They also have the potential for chair side and laboratory fabrication. Thus, FRCs are expected to gain increasing application and popularity in dentistry [4,14-16].

The outcomes of this study should be viewed in the context of clinical evaluation of IFPDs with cast metal framework. These results are

Table 1. Mean (SD) of fracture strength and bending for each groups.

Groups	Force (N)	Bending (mm)
IFPDs with Stick	1866 (284)	1.02 (0.34)
Fibre-Braid	1273 (145)	1.13 (0.35)
Cast Metal	581 (203)	0.63 (0.24)

SD=Standard Deviation, N=Newton, mm=millimeter, IFPDs=Inlay fixed partial dentures in agreement with many studies on the use of FRC IFPDs as an alternative to conventional metal IFPDs. Jain and Cobb [14] evaluated an inlay bonded FPD in a patient with a missing maxillary right second premolar for 4-years. They stated that the restoration has served satisfactorily for more than four years and can be considered as a conservative, esthetic alternative to the conventional FPD in certain clinical cases [14]. After one year, all 20 fiber-reinforced IFPDs investigated at base line were intact. SEM analysis revealed 92% excellent margins at the tooth-luting resin interface and 86% excellent margins at the luting resin-resin composite interface. Undue wear on the occlusal surfaces of the laboratory-fabricated prostheses was not observed [12].

Scurria et al [17] conducted a meta-analysis of nine conventional bridge studies, which showed a survival rate of 95% after four years. After 10 and 15 years, this analysis demonstrated survival rates of 87% and 69%, respectively. Other clinical studies reported the survival rate 69% after 13 years, 70.6% after 10 year and 86.4% after 35.3 months [16-19]. Sadeghi and Richards suggested that fiber reinforced composite materials can be used in the fabrication of 3-unit maxillary anterior FPDs with excellent esthetic qualities [2,3]. Vallittu [20] evaluated the survival rate of 29 resin-bonded glass fiber reinforced composite (GFRC) FPDs in a clinical study for periods of up to 42 months and Kaplan-Meier survival probability at 63 months was 75%. Three of the failed FPDs were rebonded or repaired in situ, producing a functional survival rate of 93% after rebonding or repairing. It was suggested that GFRC FPDs may be a possible alternative to cast metal resin bonded FPDs [20].

The data from this study also have shown that the difference in fracture strength between the two FRC groups was statistically significant ($P<0.001$); FRC IFPDs made with Stick glass fiber-reinforced had greater fracture strength than FRC IFPDs made with Fibre-Braid.

In addition, the data have shown that the difference in the bending amounts between the two FRC groups was not statistically significant; although FRC IFPDs made with Stick glass fiber-reinforced exhibited a lower bending amount than those made with Fibre-Braid. These results are supported by Vallittu's [21] who suggested that the bonding of the GFRC FPDs made from Stick and StickNet fiber reinforcements is adequate for long span resin-bonded FPDs.

Several factors may increase fracture resistance of FPDs fabricated from glass-fiber reinforced materials systems. In addition to the type of fibers used, their quantity, toughness, orientation, and the type of impregnation may considerably influence the fracture resistance. Therefore, preimpregnated fiber systems with defined fiber concentrations, carefully determined and coordinated material combinations, recommended by the manufacturers, should be used [22].

In contrast to the results of this study, Behr and colleagues concluded in a clinical report that FRC restorations need further improvement of the veneering composites. Because of the increasing wear, discoloration, fractures of the facings and fiber exposure, FRCs should only be used for provisional restorations [13]. In addition, Bohlsen and Kern [16] evaluated the clinical outcome of 83 FPDs made from the GFRC material Targis/Vectris. After three years, the survival rate was 59.9% and 67.9% for FPDs cemented with temporary cement and zinc phosphate or glass ionomer, respectively. Therefore, the use of this material to fabricate FPDs as permanent restorations cannot be recommended [17]. However, the cements they used were not recommended for cementation of IFPDs [5,10,13].

Visually, the main weak point of FRC IFPDs was seen to be the veneering material as the veneer fracture was initiated before debonding of the fiber under load. Debonding of the restorations was observed only in the premolar abutment regardless of the type of FRC IFPDs. This result was similar to that reported by Song et al [7] who concluded that the debonding in the premolar location appeared to be due to the smaller bonding area and the narrow connector dimensions. Thus, as a clinically possible and important means of improving the FPD adhesion, it is recommended that the bonding area and connector dimensions be increased.

CONCLUSION

FRC can be favorably used in the fabrication of 3-unit IFPDs. So, FRC IFPDs may be used as a conservative, esthetic alternative to the IFPDs with cast metal frameworks, although the results of this study needs to be confirmed by long-term clinical investigations.

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