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Comparison Between Tub and Box Shaped Tooth Preparation of Fiber Reinforced Composite Fixed Partial Denture Replacing First Molar Tooth

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Abstract: ***Background:*** Fiber-reinforced composite (FRC) fixed partial dentures (FPDs) offer a cost-effective, minimally invasive, and less technique-sensitive alternative for replacing missing teeth. Among the commonly used designs, box-shaped and tub-shaped tooth preparations are frequently applied to restore posterior teeth. Identifying the more effective design can enhance the clinical success of FRC FPDs. ***Objective:*** This study aimed to compare the fracture strength and bending behavior of box-shaped and tub-shaped tooth preparations in FRC FPDs replacing a first molar. ***Materials and Methods:*** This in vitro experimental comparative study was conducted in the Department of Prosthodontics, BMU, over six months. Extracted premolar and molar teeth were mounted in polymethyl methacrylate resin blocks with an 11 mm edentulous span to simulate clinical conditions. Eighteen specimens were divided equally into two groups: box-shaped and tub-shaped preparations. After tooth preparation, impressions were taken, casts poured, and FRC FPDs fabricated and cemented. All specimens were stored in distilled water for 24 hours before testing. Fracture strength and bending amounts were measured using a universal testing machine, and fracture sites were evaluated radiographically. ***Results:*** The box-shaped preparation demonstrated significantly higher fracture strength (509.67 ± 24.02 N) than the tub-shaped preparation (449.56 ± 46.09 N) ($p = 0.003$). Bending amounts were also greater in the box-shaped group (1.24 ± 0.20 mm) than in the tub-shaped group (0.87 ± 0.25 mm) ($p = 0.003$). Most fractures occurred in the veneering material with no significant difference between groups ($p > 0.99$). ***Conclusion:*** Box-shaped tooth preparation provides superior strength and flexibility and may be preferred for FRC FPDs replacing first molars.

Keywords: Ret Fiber Reinforced Composite, Fixed Partial Denture.

Research Paper

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INTRODUCTION

The replacement of missing teeth can be achieved through removable or fixed prostheses. Among these options, fixed prostheses are generally preferred by both clinicians and patients due to their superior comfort, function, and aesthetics. Fixed prosthodontic restorations allow for the reconstruction of teeth severely damaged by caries or trauma, as well as the replacement of missing teeth using crowns, onlays (for single-tooth restoration), or bridges (for multiple missing teeth). Metal–ceramic restorations have long been the most used material for fixed partial dentures (FPDs). Although these restorations provide acceptable strength and durability, their aesthetic outcomes are often inadequate. Additionally, metal–ceramic prostheses can cause wear to the opposing dentition and require precise tooth preparation to achieve proper retention and resistance form, which demands significant clinical expertise. Another limitation is that a considerable amount of tooth structure must be removed to accommodate the porcelain layer. While full-metal FPDs require less tooth reduction and provide excellent strength, they lack aesthetic appeal—particularly when restoring anterior or premolar teeth—and may cause allergic reactions in patients sensitive to metal alloys. With advances in dental materials, all-ceramic FPDs have become increasingly popular for their superior translucency and aesthetic quality. However, they require extensive tooth reduction to provide adequate ceramic thickness and depend heavily on operator skill and laboratory precision. Despite their advantages, their relatively low flexural strength limits their use to single-unit restorations [1]. Moreover, their abrasiveness against opposing enamel remains a concern. The introduction of implant-supported restorations has provided a more conservative and functional alternative for single-tooth replacement. Nevertheless, many patients decline implant therapy due to its high cost, surgical nature, or systemic health contraindications [2]. Consequently, fiber-reinforced composite (FRC) prostheses have emerged as an attractive alternative. FRC fixed partial dentures combine aesthetics, low wear on opposing teeth, and the ability to bond directly to abutment teeth, minimizing the need for extensive tooth preparation. They consist of two main components: the fiber composite that forms the substructure and the particulate composite that creates the veneering surface [3]. Although long-term clinical data are limited, several studies have reported promising short-term outcomes and satisfactory fracture resistance of FRC FPDs [4]. The success of an FPD depends on several factors, including the elastic modulus of the substructure, restoration thickness, luting agent, and preparation design [5]. Additionally, the type, quality, and bonding efficiency of the fibers within the resin matrix significantly influence the overall strength and performance [6]. Previous research has shown that FRC FPDs can withstand masticatory forces in both premolar and molar regions, demonstrating fracture strengths around 700 N after thermocycling and mechanical loading [7,8]. Compared with full-coverage restorations, inlay-type FRC FPDs are less invasive [9]. Optimal fiber placement and retention are typically achieved with box-shaped preparations [10]. However, when teeth are tilted or when space is limited, tub-shaped preparation may be more appropriate[8]. Despite these clinical adaptations, the ideal preparation design for inlay FPDs has not been fully established. Although some authors have proposed theoretical designs [11,12], further in vitro and in vivo studies are necessary to validate their effectiveness. Therefore, the present study aims to compare the fracture strength, bending behavior, and fracture sites of fiber-reinforced composite fixed partial dentures using box-shaped and tub-shaped tooth preparations in the replacement of first molar teeth.

MATERIALS AND METHODS

This experimental in vitro study was conducted in the Department of Prosthodontics, Faculty of Dentistry, Bangladesh Medical University, Shahbag, Dhaka, and in the Pilot Plant and Process Development Centre, Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka. The study period spanned six months, from March 2022 to August 2022. The research focused on evaluating the performance of fiber-reinforced composite (FRC) fixed partial dentures (FPDs) replacing the mandibular first molar. A total of 18 mandibular premolar and 18 molar teeth were collected according to the selection criteria. Only extracted permanent mandibular posterior teeth were included, while anterior teeth, deciduous teeth, congenitally malformed, grossly decayed, fractured teeth, and those with short anatomical crowns (<4 mm) were excluded. The independent variable of the study was the shape of proximal preparation (box-shaped and tub-shaped), whereas the dependent variables included fracture strength, bending amount, and site of fracture. All extracted teeth were cleaned with curettage instruments and stored in 0.9% normal saline at room temperature for 24 hours before use. One premolar and one molar were embedded vertically in polymethyl methacrylate (PMMA) resin blocks, leaving 1 mm of the root surface below the cementoenamel junction. The teeth were positioned 11 mm apart to simulate the clinical loss of a mandibular first molar. A total of 18 specimens were prepared, each containing one molar and one premolar, and then divided equally into two groups: Group I with box-shaped preparations and Group II with tub-shaped preparations, both maintaining a span length of 11 mm. All tooth preparations were performed by the same operator using rotary cutting instruments under continuous water coolant. The criteria for both preparation designs followed standard guidelines illustrated in figures 1 and 2. Each prepared tooth pair was duplicated using addition silicone impression material in a custom tray, and two definitive stone dies were produced with type IV dental stone. The dies were treated with separating media, including the prepared areas, to facilitate subsequent framework fabrication. For each specimen, a two-layer FRC framework (Ever Stick C&B, GC) was constructed by placing the fibers into the prepared cavity with a thin layer of flowable composite resin in between, followed by light polymerization for 15 seconds. The remaining cavity space was incrementally filled with packable composite resin (Filtek P-60, 3M ESPE) in layers less than 2.5 mm, each cured for 20 seconds. After polymerization, the framework was removed and trimmed to ensure uniform dimensions across all specimens. Pontics were built incrementally on the framework using packable composite, each layer being less than 2.5 mm thick and polymerized for 20 seconds. Final finishing and polishing were completed with a composite finishing kit. Before cementation, the enamel surface of each preparation was etched for 10 seconds and dentin for 5 seconds with 35% phosphoric acid. Both surfaces were then treated with an adhesive bonding system. The FRC FPDs were cemented using a dual-cure composite luting agent, and excess cement was carefully removed. All specimens were stored in distilled water at room temperature for 24 hours prior to testing. Mechanical testing was performed using a universal testing machine at a crosshead speed of 1 mm/min until fracture occurred. The vertical load was applied at the central fossa of the pontic with a round-end steel rod, and a 0.5 mm thick tin foil was interposed between the rod and pontic to prevent localized force concentration. The bending amount (in mm) was measured as the distance the test rod traveled from a 10 N preload to fracture. The fracture load and bending value for each specimen were recorded, and fracture sites were examined visually and radiographically to determine the fracture mode—whether within the veneering composite, FRC framework, tooth structure, or a combination thereof. Quantitative data were expressed as mean ± standard deviation, while qualitative data were expressed as percentages. Normality of the data distribution was assessed, and as the data followed a normal distribution, unpaired t-tests were used to compare mean values between groups. The Chi-square test was applied for categorical variables. All statistical analyses were performed using SPSS software (version 22.0; IBM Corp., USA), with a significance level set at $p < 0.05$.

RESULT

Fiber-reinforced composite fixed prostheses are prioritized for the replacement of missing teeth due to their many advantages. Because inlay preparation is less invasive than full coverage preparation, inlay preparation is preferred for fiber-reinforced fixed partial dentures. In posterior teeth, both box-shaped and tub-shaped inlay proximal preparations are commonly used. To predict the success of the clinical application of the fiber-reinforced composite fixed dental prosthesis, it was necessary to identify superior alternatives between the two. Considering this, this study compared tub- and box-shaped tooth preparations for fiber-reinforced composite fixed partial dentures on the first molar tooth.

Table 1: Comparison of fracture strength between proximal preparations

Fracture strength	Box shaped n=9	Tub shaped n=9	P value
Mean ±SD	509.67±24.02	449.56±46.09	0.003
Median (Range)	510 (468-544)	450 (350-501)	

Independent sample T test was done
S=significant, NS=non-significant
Data was expressed as mean ±SD, median (Range)

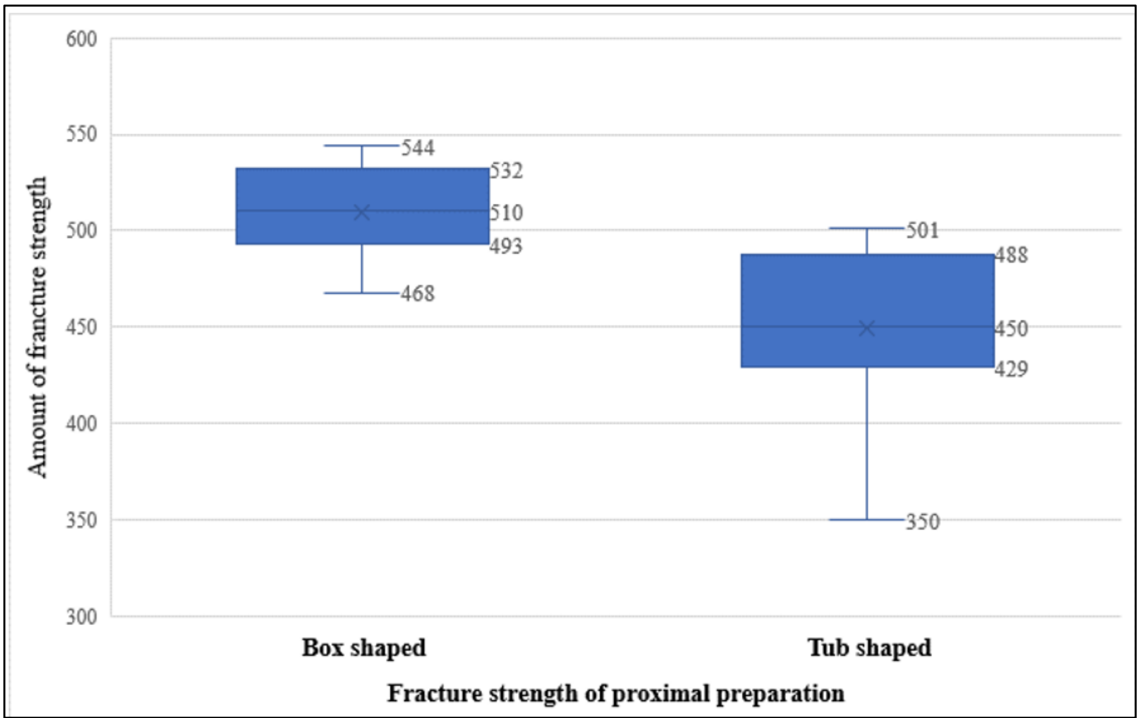

Figure 1: Box plot showing the fracture strength of proximal preparations

Table I and Figure I show that the mean ±SD fracture strength of the box shaped tooth preparation was 509.67±24.02 and tub shaped tooth preparation was 449.56±46.09. The fracture strength was found significantly higher in box shaped tooth preparation than tub shaped tooth preparation (p value: 0.003)

Table 2: Comparison of bending amount between proximal preparations

Bending amount	Box shaped n=9	Tub shaped n=9	P value
Mean ±SD	1.24±0.20	0.87±0.25	0.003
Median (Range)	1.25(0.96-1.54)	0.80(0.53-1.26)	

Independent sample T test was done
S=significant, NS=non-significant
Data was expressed as mean ±SD, median (Range)

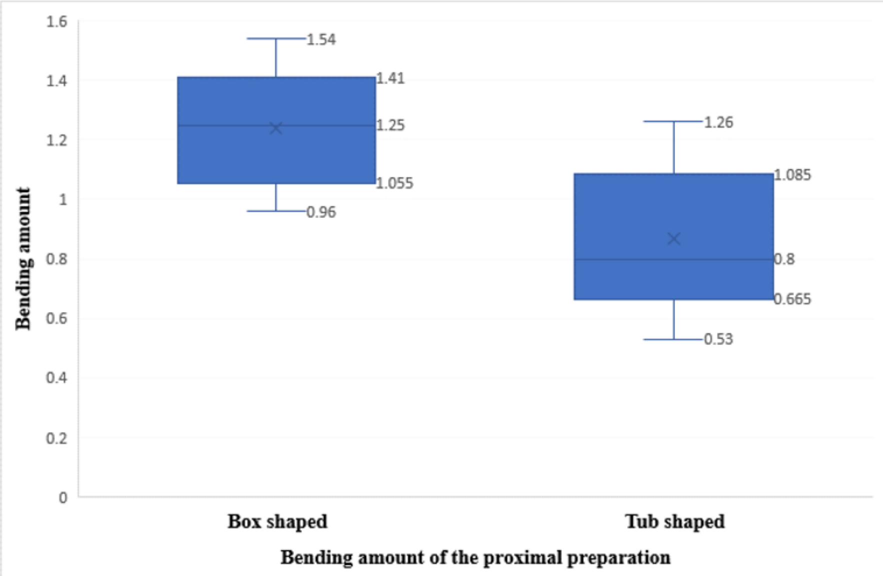

Figure II: Box plot showing the bending amount of proximal preparations

Table II and Figure II is showing that the mean ±SD bending amount of the box shaped tooth preparation was 1.24±0.20 and tub shaped tooth preparation was 0.87±0.25. The bending amount was found significantly higher in box shaped tooth preparation than tub shaped tooth preparation (p value: 0.003).

Table 3: Distribution of fracture site according to proximal preparation

Fracture site	Proximal preparation		Total	P value
	Box shaped	Tub shaped		
Veneer material	8 (88.9)	7 (77.8)	15 (83.3)	>0.99
Combination fracture	1 (11.1)	2 (22.2)	3 (16.7)	
Total	9 (100.0)	9 (100.0)	18 (100.0)	

Fisher's Exact Test
S=significant, NS=Non significant
Data was expressed as frequency, percentage

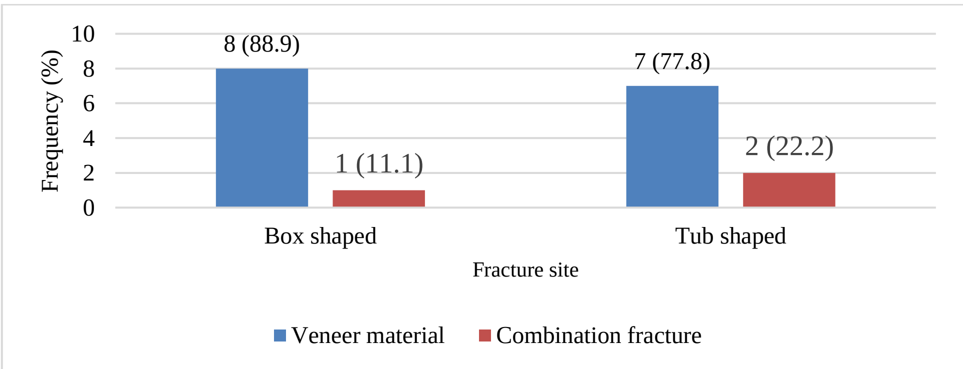

Figure III: Distribution of fracture site according to proximal preparation

Table III and Figure III show that in both proximal preparation, fracture predominantly occurred in the veneer material. And no significant difference of fracture site was observed between box shaped and tub shaped preparation (p value: >0.99).

DISCUSSION

In this study, the effects of box-shaped and tub-shaped tooth preparations on the fracture strength and bending behavior of fiber-reinforced composite fixed partial dentures (FRC FPDs) were evaluated. The fracture sites were also examined to identify the predominant failure modes. The findings revealed that the box-shaped preparation demonstrated significantly higher fracture strength (509.67 ± 24.02 N) compared with the tub-shaped design (449 ± 46.09 N). This outcome contrasts with the results reported by Behr et al. [8], who found greater fracture resistance in the tub-shaped preparation. However, the present findings align closely with those of Song et al. [13]. The difference from Behr et al. [8] could be attributed to variations in preparation dimensions. In their study, the tub-shaped preparation was extended more mesiodistally, providing increased fiber reinforcement at the connector regions. In contrast, the current study utilized a narrower tub-shaped design to preserve pulpal vitality, which may have limited the amount of fiber reinforcement. The box-shaped design, by providing a broader surface area and larger connector dimensions, may have enhanced stress distribution and resistance to bending forces. Shi et al. [14] also reported that fibers placed near the tensile side of the pontic offer greater mechanical advantages. Since the box-shaped design contained more fiber content near the bottom of the pontic, it likely produced stronger reinforcement and higher fracture strength. The primary goal of any dental prosthesis is to restore functional masticatory efficiency. For clinical success, an FRC FPD should withstand approximately 500 N in the premolar region and 500–900 N in the molar region [15]. Reported load-bearing capacities of FRC FPDs ranged from 524 N [6] to as high as 2500 N [16], reflecting differences in materials, pontic dimensions, retainer designs, and testing protocols [17]. Ozcan et al. [18] observed significantly lower fracture resistance in FRC FPDs with deep pontic anatomy (598 ± 240 N) compared with shallow ones (1186 ± 224 N). The relatively lower fracture strength observed in the present study may similarly be influenced by the deep anatomic form of the pontic used. The bending amount in the current study was lower in the tub-shaped group compared to the box-shaped one. Although bending deflection is typically proportional to the cube of span length and inversely proportional to the cube of thickness [19], this finding did not align with theoretical expectations. A plausible explanation is that veneer fracture initiated before complete bending of the fiber framework, preventing full deflection, as also suggested by Song et al. [13]. Further studies are needed to clarify this phenomenon. Most fractures in this study occurred within the veneering composite (Filtek P60), with no statistically significant difference between the two preparation designs. The failure mode of FRC FPDs generally occurs in two stages: cracking or chipping of the veneering composite, followed by adhesive separation between the veneering layer and the fiber framework [20] In this study, fracture lines were commonly observed between the fiber framework and veneering material, and in some specimens, complete debonding was evident. This adhesive failure can be attributed to the difference in elastic modulus between Ever Stick C&B (559 MPa) [21] and Filtek P60 (157.98 MPa) [22], which creates interfacial stress under loading. The present study had several limitations. Physiologic tooth movement was not simulated, which could have been achieved using a polyether coating, as suggested by Behr et al. [23]. Additionally, no artificial aging was performed; thermocycling and mechanical fatigue might have influenced the outcomes. Finally, only mandibular first molars were used as pontics, and including other tooth positions could yield broader insights into the performance of FRC FPDs.

CONCLUSION

Within the limitations of this in vitro study, it can be concluded that fiber-reinforced composite fixed partial dentures (FRC FPDs) with a box-shaped preparation design demonstrated significantly higher fracture strength and greater bending compared to those with a tub-shaped design. The tooth preparation design, however, did not significantly influence the fracture site or mode, as most failures involved cracking or chipping of the veneering composite followed by adhesive separation from the fiber framework. Based on these findings, the box-shaped preparation can be considered more suitable and is recommended for the fabrication of FRC inlay FPDs in clinical practice.

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