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Research Article

Effect of Short and Long Fiber-Reinforced Composite Resins Used as Post and Core on Fracture Resistance of Premolars: An *in vitro* Study

Manal Hussain Abd-alla[1]*, Tuqa Jameel Ebrahim[2], Ahmed Sleibi Mustafa[1]
[1]*Department of Conservative Dentistry, College of Dentistry, Mustansiriyah University, Baghdad, Iraq;* [2]*Department of Dentistry, Al Hikma University College, Baghdad, Iraq*
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Abstract
Background: Endodontically treated (ET) premolars with a compromised tooth structure have been recorded to end with a high prevalence of catastrophic fracture. ***Objective***: To compare the fracture resistance (FR) of ET premolars with MOD cavities restored with two fiber-reinforced composites as cores or post-cores. ***Methods***: 60 premolars were divided into six groups (n=10): five experimental groups (A-E) and one control group with sound teeth (F). The experimental groups with MOD cavities were endodontically treated and restored differently. Group A was restored with a core of one bulk fill composite resin (OBF). Groups B and C were fixed with either a core of EverX flow short fiber-reinforced composite (SFRC), a layer of Ribbond polyethylene fiber, or OBF. In order to fill a 6 mm post space within the palatal roots, groups D and E first underwent direct layering with SFRC or Ribbond and OBF coverage. Samples were thermocycled and subjected to a fracture resistance test using an Instron machine at 0.5mm/min. ***Results***: The highest FR value was recorded for the sound teeth (1789N), and the least was for group A (938N). All the experimental groups recorded significantly lower FR compared with sound teeth ($p<0.05$). A significantly higher FR was recorded for both groups D and E compared with group A ($p<0.05$). ***Conclusions***: Both SFRC and Ribbond, when used directly as post-core for ET premolars, enhanced the fracture resistance compared with a core of OBF only.

Keywords: Endodontically treated; Fracture resistance; Post-core; Ribbond; SFRC.

تاثيرالراتنجات المركبة المعززة بالالياف القصيرة أو الطويلة المستخدمة كمادة حشوية داخل اللب والجذر على مقاومة الكسر للضواحك: دراسة مختبرية
الخلاصة
الخلفية: أن الضواحك المعالجة لبياً(ET) تكون ذات بنية متضررة وعادة ما تنتهي نسبة كبيرة منها بكسور كارثية. **الهدف**: مقارنة مقاومة الكسر (FR) للضواحك المعالجة لبياً ذات تجاويف نوع MOD المُرمَّمة باستخدام نوعين من الحشوات المركبة المدعمة بالألياف كحشوات داعمة للب و الوتد. **الطرائق**: تم تقسيم 60 سن من الضواحك إلى ست مجموعات :(n=10) خمس مجموعات تجريبية (A-E) ومجموعة ضابطة واحدة ذات أسنان سليمة .(F) خضعت المجموعات التجريبية ذات تجاويف نوع MOD للمعالجة اللبيّة والترميم بطرق مختلفة. رُمِّمت المجموعة A بحشوة أساسية من راتنج مركب نوع .(OBF) رُمِّمت المجموعتانB و Cبحشوة أساسية داخل اللب فقط من مركب EverX flow المدعم بالألياف القصيرة (SFRC) أو بطبقة من ألياف الطويلة البولي أثيلين (Ribbond) وغُطِّيت بحشوة OBF. جُهِّزت المجموعتان D وE أولاً برفع مسافة 6 مم من مادة حشوة الجذر (Gutta Percha) من داخل الجذر، ثم مُلئت هذه القنوات بطبقات مباشرة من SFRC أو Ribbondلتكون كوتد ولب ثم ُغطِّيت بحشوة OBF وخضعت العينات لدورات حرارية واختبار مقاومة الكسر باستخدام جهاز إنسترون بسرعة 0.5 مم/دقيقة. **النتائج**: سُجّلت أعلى قيمة لمقاومة الكسر للأسنان السليمة (1789N)، وأدناها للمجموعة A(938N)، سجّلت جميع المجموعات التجريبية قيمًا أقل بكثير لمقاومة الكسر مقارنةً بالأسنان السليمة (p<0.05) . كما سُجّلت قيم أعلى بكثير لمقاومة الكسر في المجموعتين E وD مقارنةً بالمجموعة A(p<0.05). **الاستنتاجات**: كلٍّ من مادة SFRC و Ribbond عند استخدامها بشكل مباشر كوتد داعم لجذورالضواحك المعالجة لبيا, عززا مقاومة الكسر مقارنةً باستخدام حشوة OBF فقط.

* ***Corresponding author***: Manal H. Abd-alla. Department of Conservative Dentistry, College of Dentistry, Mustansiriyah University, Baghdad, Iraq; Email: manaer11@uomustansiriyah.edu.iq
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INTRODUCTION

Endodontically treated premolars are at risk of fracture due to weakening that is caused by the removal of tooth structure during treatment [1,2]. Besides, they are highly subjected to both shear and compressive loadings during mastication due to their position in the oral cavity [3,4]. Increasing the fracture resistance (FR) of ET premolars with extensive loss of tooth structure and preventing their catastrophic fracture have been the focus of many clinicians in order to extend their clinical longevity. Several approaches have been used to restore the ET premolars with large cavities by direct or indirect restorations with or without the use of prefabricated posts. Aurelio *et al*. [5] reported that including posts within the restoration of ET premolars resulted in a higher survival rate when cuspal coverage is not planned for the final restoration. Rippe *et al*. [6] stated that using fiber posts, with their elastic modules comparable to that of dentin, when submitted to stress tends to produce less catastrophic irreparable fracture. It has been reported that incorporating the fiber posts within the final restoration can increase the fracture resistance of premolars by distributing the stress and load applied to the core [7]. However, preparing a post space within the root canal with drills can cause not only additional removal of radicular dentin but also increase the chance for crack formation that may increase tooth fracture [8,9]. Also, the complex units made up of post-luting-radicular dentin could be more stressed because of how they are bonded together [10], since these materials have different levels of elasticity and flexural modules [11]. Incorporation of contemporary types of composite resins with fibers was intended to produce fiber-reinforced composite resins with enhanced mechanical properties. Different types of fibers, such as short glass or long polyethylene fibers, were used that resulted in different properties of reinforced composite resins depending on the fiber's own properties [12]. Researchers suggested that ET premolars be made stronger with short fiber reinforced composite resin (SFRC) or long polyethylene fiber (Ribbond) as a core [13–15] and as post-core materials [16,17]. However, the use of these materials to achieve the best clinical results can be related to the correct selection for each particular clinical situation. The use of SFRC to assess the FR of ET teeth has been studied with no conclusive results. While the majority of researchers adopted SFRC (EverX posterior), fewer studies used SFRC (EverX flow). EverX flow is a flowable type of SFRC that was first marketed in 2019. It has been reported to have good adaptability in limited spaces, which makes it a possible option to be used as intra-canal material. Ranka *et al.* in 2022 compared, in a clinical study, EverX posterior and EverX flow when used as cores with ET molars [18]. The researchers reported better performance of EverX posterior; however, both were statistically equivalent in their clinical performance. Molnár *et al.* [19] reported higher FR with EverX flow but with no significant differences compared with EverX posterior when used for ET molars. The reinforcement of premolars by direct layering with fiber-reinforced composite was reported by some studies [20-22] without consensus on their effect on FR. According to a recent systematic review and meta-analysis by Fousekis *et al.* in 2025 [23] on SFRC used as post-core material, they suggested that further studies are required since evidence on the performance of SFRCs within the canal space without extra removal of dentin is still limited. Therefore, this study was conducted to investigate the effect of two types of fiber-reinforced composites, SFRC (EverX flow) and Ribbond (long polyethylene fiber), when used by direct layering as core or post-core on the FR of ET premolars with MOD cavities. The null hypotheses tested in this study were: 1. No differences in FR of sound teeth compared with ET premolars would be recorded whether restored by direct layering with SFRC or Ribbond as a core or post-core, and 2. There would be no differences in modes of failure for sound teeth compared with the other experimental groups.

METHODS

Study design and sample selection

Sixty upper first premolars, extracted for orthodontic purposes, were selected for this study. The inclusion criteria were teeth with no caries, restoration, or cracks as examined by trans-illumination with the aid of magnification (X4) [21,22]. The teeth had normal occlusal anatomy and comparable mesio-distal and bucco-lingual dimensions (± 0.5 mm). All teeth had two roots with no curvature and with a comparable root length of 15 ± 1.0 mm. The teeth were cleaned from any remaining soft tissue with hand scalars. They were immersed in 5.25% NaOCl for 5 min and then stored in 0.9% normal saline at room temperature [21]. The teeth were divided into 6 groups (n=10), one positive control and five experimental groups. The required sample size was calculated a priori using G*Power 3.1 (Heinrich-Heine-Universität Düsseldorf, Germany). A one-way ANOVA (fixed effects, omnibus) was selected as the primary statistical test, with five experimental groups. An effect size (f) of 0.40 was assumed based on data from a previous in-vitro study evaluating fracture resistance of fiber-reinforced restorations (20). The significance level (α) was set at 0.05, and statistical power (1–β) at 0.80. The calculation indicated a minimum of 8 specimens per group; this number was increased to 10 specimens per group to compensate for any potential specimen loss or unexpected exclusions.

Endodontic preparation

Access cavity preparation was carried out with a round-end, and endo Z bur with high speed and water cooling at the center of the occlusal surface. The working length was established with the direct method by subtracting 1 mm from the actual root length determined after introducing #10 K-file until it was visible through the apical foramen. The canals were instrumented using rotary ProTaper Universal files (Dentsply, Maillefer, Ballaigues, Switzerland). The sequences used for ProTaper were S1, S2, F1, and F2 for the preparation of the root canals [21,22]. Irrigation was performed by filling the canal space between each file with 2 ml of 2.5% NaOCL and a final irrigation with normal saline [22]. Then, the canals were dried with paper points, and root canal obturation was performed with a matched single-cone F2 gutta-percha (Maillefer-Dentsply) and a calcium-hydroxide based sealer (Sealapex, Kerr, USA). After root canal obturation, the access cavity was filled with Teflon and a temporary filling. The teeth were stored in deionized distilled water for 24 hours prior to the final restoration. Each sample was placed inside a 2*2 cm dimension acrylic base to a level of 2 mm below the CEJ. Then, prior to setting, they were removed, and a silicon light body was injected between the tooth and the acrylic base before reinserting to simulate the periodontal ligament [24].

Restorative procedure

All the samples of the experimental groups received standardized MOD cavity preparation with a 1/3 intercuspal width and 5 mm depth slot design using a flat-end parallel fissure bur [13]. A digital caliper was used to check the cavity for standardization. The restorative materials and their compositions used for the experimental groups are shown in Table 1.

Table 1: The tested materials, types, and their components

Material (Company)	Type of composite	Components
Filtek One Bulk Fill (3M ESPE, St. Paul, USA)	Nano-filled	Resin matrix: UDMA, AUDMA, DDMA, proprietary AFM Inorganic fillers: A combination of a non-agglomerated/non-aggregated 20nm silica filler, a non-agglomerated/non-aggregated 4 - 11nm zirconia filler, the agglomerated ytterbium trifluoride (YbF3) is 100 nm in size. 76.5 % by weight
EverX flow (GC, Europe)	Flowable short fiber reinforced Bulkfill	Resin matrix: Bis-MEPP, TEGDMA and UDMA. Inorganic fillers: E-glass fibers and barium glass. Average length of fibers 140µm diameter 6 µm. 70% by weight
Ribbond (Ribbond Seattle, WA, USA)	Polyethylene fiber	Leno weave ultra-high modulus polyethylene fiber ribbon

A selective etching using a 37 % phosphoric acid (SDI) was used for all groups. The etching procedure with or without a post was performed for enamel for 15 seconds and rinsed for 5 seconds. Then, all the walls of the cavity and canals were rubbed with a self-etch dual-cure adhesive (Gradia Core Self-etching Bond, GC Europe) with a micro brush and then light-cured for 10 seconds with an LED light-curing unit (Radii Plus SDI, Australia) with an intensity of 1500 mW/cm². All the experimental groups were restored by transforming the MOD cavity into a class I cavity [21] using One bulk-fill composite (Filtek™ One Bulk, 3M). The remaining coronal restoration of the experimental groups was completed as follows (Figure 1): Group A, the cavity was restored by 2 mm horizontal layering with One bulk fill composite resin (OBF).

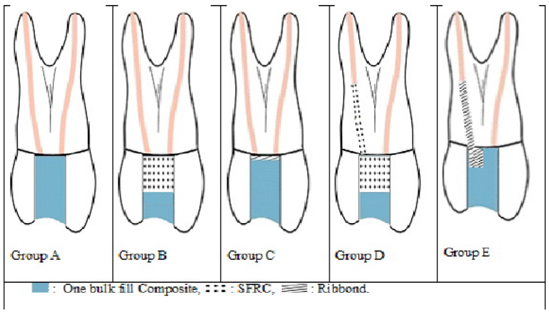

Figure 1: The experimental groups; Group A: Core with OBF composite, Group B: Core with SFRC, Group C: Core with Ribbond, Group D: Post and core with SFRC, Group E: Post and core with Ribbond.

Group B, the core was restored with EverX Flow™ (SFRC, GC Europe, Leuven, Belgium) in a single layer leaving 2 mm occlusally that was filled with OBF [22], and group C, the core was filled using Ribbond (Ribbond-Ultra; Ribbond Inc., Seattle WA, USA). A 5 mm length was cut from the 4 mm wide Ribbond sheet using a Ribbond scissor and inserted into the floor of the cavity in a buccolingual direction [25]. Before its application, the Ribbond was dampened with the wetting resin (Ribbond wetting resin, Ribbond Inc., Seattle WA, USA). The excess wetting resin was squeezed out of the Ribbond fiber using a plastic instrument. The Ribbond piece was then covered with a thin layer of a flowable composite (Ribbond Securing Composite, Ribbond Inc., Seattle WA, USA) and adapted well to the floor of the cavity and light-cured for 40 seconds. Then, the cavity was restored with horizontal layers of OBF as in group A. Before restoring groups D and E, a 6 mm post space was prepared for the palatal roots with a Gates Glidden burs fiber post drill (#2) using a slow-speed handpiece, leaving a minimum of 6 mm of gutta-percha as an apical seal of the canal. Then, the post space was washed, dried with paper points, and etched with the dual-cure self-etch adhesive system as recommended by the manufacturer. Group D: The palatal canal of each tooth was directly layered with SFRC EverX flow. The material was inserted inside the canal in a 2 mm increment using a disposable micro brush. After each increment, a light-transmitting fiber post (1.2 mm) was inserted into the post space to enhance light transmission to the apically positioned layers. To avoid direct contact with the uncured SFRC layer, the light transmitting post was retracted 0.5-1 mm from its surface [22]. The top layer was then light-cured for 80 secconds through the fiber post. After that, the rest of the cavity was filled in with a thick layer of SFRC. The material was placed at a level that matched the position of dentin, leaving a 2 mm that was restored with OBF. In group E, the palatal canal post space was filled with Ribbond to form an intracanal post as recommended by the manufacturer. Using a 16-mm length of 2-mm-wide Ribbond was wetted and protected from exposure to light until its use. A dual-curing resin cement (Panavia; Kuraray Medical) was used to lute the Ribbond within the canal. The wetted Ribbond was inserted apically within the canal with a fine plugger till touching the gutta-percha. To increase the amount of Ribbond fiber to the greatest volume possible and reduce the amount of cement, the prepared length of Ribbond was folded and inserted into the canal from the middle area [16]. The 2 mm protruding ends of the Ribbond outside the canal were cured for 80 sec and covered with ribbon flowable resin. Then, the rest of the cavity was restored with OBF. After that, all the samples were thermocycled using a thermocycling device for 500 cycles between 55°C to 5°C (±5) with a dwell time of 30s. To measure the fracture resistance, all groups were subjected to a compressive loading using a universal testing machine (Computer controlled universal testing machine, Laryee Technology, China) at a speed of 0.5 mm/min. The active tip with an 8 mm diameter metal sphere was positioned at the center of the occlusal surface of each tooth, touching the two slopes of the cusps. The vertical loading of the testing machine was applied until tooth fracture, and the force was recorded for all the groups in Newton (N). The fracture patterns of the teeth for all groups were evaluated under a stereomicroscope. The type of mode of failure was classified according to the location of the fracture to be either above the CEJ to be considered repairable or irreparable when the fractured part extended below the CEJ [26].

Ethical consideration

This research study was approved by the Research Ethical Committee at the related institution in Mustansiriyah University (certificate ID: MUOPR29 in May 2023).

Statistical analysis

The data were analyzed using IBM SPSS statistics (version 26.0). Shapiro-Wilk test was used for determining the normality distribution of the data. One-way ANOVA and post hoc tests (Dunnett t and Tukey HSD) were used for multiple comparisons among and between the groups. Chi-Square Non-parametric Test was used to analyze the data of modes of failures. All the tests were set at a level of significance at $p< 0.05$.

RESULTS

Mean values (SD) of fracture resistance with the minimum and maximum values are shown in Table 2. The highest fracture resistance values were recorded for sound teeth (1789 N), and the lowest values were for group A (938 N). The mean values of FR for groups B (core of SFRC) and C (core of Ribbond) were 1049 N and 1274 N, respectively.

Table 2: Values of FR for all groups

Groups	n	Mean±SD	Range
A	10	938.3±238.7	675-1335
B	10	1049.6±294.8	672-1592
C	10	1274.5±176.4	918-1487
D	10	1319.9±349.0	815-1773
E	10	1458.6±317.0	907-1908
F	10	1789.2±201.4	1459-2141

A: One bulk fill; B: Core with SFRC; C: Core with Ribbond; D: Post-core with SFRC; E: Post-core with Ribbond; F: Sound Teeth.

While those groups with posts and cores (D and E) recorded higher FR than the other three groups (1319 N and 1458 N, respectively). According to the one-way ANOVA test, the results recorded a significant difference among the groups ($p= 0.001$). Using the post hoc Dunnett t-test to compare the sound teeth (control group) with the experimental groups individually, the result showed that all the experimental groups recorded significantly lower FR than the control group ($p< 0.05$). Multiple comparisons between the experimental groups were performed with the post hoc Tukey HSD test. The results showed that the FR of group A was significantly lower than both groups D and E ($p< 0.05$); however, it was not significantly different compared with groups B and C ($p> 0.05$). Group E showed a significantly higher value compared with group B ($p= 0.018$). Groups D and E were not significantly different from each other ($p= 0.805$) (Table 3).

Table 3: Dunnett t and Tukey post hoc tests for multiple comparisons of the FR values for all groups

Dunnett t <control				Tukey's Test			
Groups		Mean diff.	*p*-value	Groups		Mean diff.	*p*-value
F	A	850.9	<0.0001	A	B	111.3	0.902
					C	336.2	0.075
	B	739.6	<0.0001		D	381.6	0.032
	C	514.7	<0.0001		E	520.3	0.001
				B	C	224.9	0.395
	D	469.3	0.001		D	270.3	0.220
					E	409.0	0.018
	E			C	D	45.4	0.996
		330.6	0.035		E	184.1	0.593
				D	E	138.7	0.805

Values were expressed as mean difference. A: One bulk fill; B: Core with SFRC; C: Core with Ribbond; D: Post-core with SFRC; E: Post-core with Ribbond; F: Sound Teeth.

The number and percentage of the modes of failure for all the groups expressed as: repairable or irreparable are represented in Table 4. The chi-square test revealed a statistically significant difference among the groups ($p= 0.02$). Sound teeth (group F) showed the highest percentage of repairable failure (90%), while group A showed the highest percentage of irreparable failure (80%). For the experimental groups, B, C, and D showed 30% and 70% of repairable and irreparable types of fracture, respectively. Group E, on the other hand, recorded the least percentage of irreparable failure (60%) among the experimental groups.

Table 4: The distribution of modes of failure for all groups

Groups	Repairable	Irrepairable
A	2(20)	8(80)
B	3(30)	7(70)
C	3(30)	7(70)
D	3(30)	7(70)
E	4(40)	6(60)
F	9(90)	1(10)
	$p= 0.02$*	

Values were expressed as frequency and percentage. A: Core with One Bulk fill; B: Core with Ever X flow; C: Core with Ribbond; D: Post-core with Ever X flow; E: Post-core with Ribbond; F: Sound Teeth. * Chi square test.

DISCUSSION

Fiber-reinforced composite resins, whether with short fibers or long polyethylene fibers, have been encouraged to be used as cores or posts and cores to reinforce ET teeth and to prevent their catastrophic fracture. However, the selection of restorative material and the application technique are crucial, as they can produce a direct influence on the clinical outcome. The results of the present study recorded a significantly higher FR for the sound teeth compared with all the experimental groups. Hence, the first null hypothesis of this study was rejected. Both materials (EverX Flow and Ribbond), whether used as core or post-core, did not significantly increase the FR of ET premolars with MOD cavities to reach that of sound teeth. This result is in agreement with Dalkiliç *et al.* [27] and Mahmoud *et al.* [28]. However, Ozsevik *et al.* [29] and Garlapati *et al.* [13] reported that SRFC (EverX posterior), when used as a coronal restoration underneath conventional composite resin, produced FR values with no significant difference with intact teeth. However, the selected teeth in the later studies were ET molars, whilst in the current study they were ET premolars. The results of this study showed that the FR of premolars with SFRC EverX flow cores (group B) was not significantly higher than OBF composite resin (group A). This result is in agreement with the results of Atalay *et al.* (2016) [30] using EverX posterior and Frater *et al.* (2021) [22] using two SFRCs (EverX flow and posterior). Ribbon cores (group C), on the other hand, also produced an increase in FR values, although it was not significantly different either from OBF cores (group A) or from SFRC cores (group B). These results are in agreement with the results reported by Dalkiliç *et al.* (2019) [27] and Abdulamir and Majeed (2022) [31]. Interestingly, group C also recorded insignificant differences in FR with those with the highest values of FR (groups D and E). The use of Ribbond within a core of resin to internally reinforce weak ET teeth was suggested by de Toubes *et al.*, in 2025 [32]. They have stated that such a technique can improve the chemical bond between the two materials and inhibit fracture propagation. Besides, although the use of Ribbond did not increase the FR significantly for these teeth, it could block and bridge the cracks between the fibers and hence reduce the cohesive fracture within the cores [25]. The results of direct layering of post-core with both SFRC (group D) and Ribbond (group E) recorded an increase in the FR with a significant difference compared with group A (OBF) without any significant difference between them. This result is in accordance with Bharati *et al.* in 2025 [17] using ET premolars with extensive loss of tooth structure. They have stated that incorporation of pre-impregnated fibers within the restoration of these teeth could enhance the flexural strength of the whole structure. Restoring ET premolars with post-cores of SFRC EverX flow significantly increased the FR compared with those with cores of conventional composite resin [22]. The increase in FR produced by SFRC EverX flow can be attributed to its composition. This material consists of fibers of micrometers in length and a fiber ratio of 30-94 that can provide good reinforcement due to close adaptation with a maximum number of fibers to the canal wall and the critical cervical area. This enhanced behavior was attributed to many factors, such as the number, location, orientation, and aspect ratio of fibers in addition to the resin used and fiber impregnation into it, among other factors [14]. EverX flow with its high number of randomly oriented short fibers may produce an isotropic performance and multidirectional reinforcement inside the cavity [33]. This result is inconsistent with the results of Forster *et al.* (2016) [20] using EverX posterior as a direct post-core since the FR of premolars had increased to a higher value than sound teeth. However, in the later study, the used ET premolars were with small access cavities. Teeth with simple standard access cavities have been shown to possess no significant difference in FR from intact teeth [34]. It is well known that with the removal of the marginal ridges, weakening of premolars reaches about 63% [35]. Ribbond, on the other hand, is a long type of polyethylene fiber with a continuous ultra-high molecular weight and a spectrum of 215 fibers. The fibers within the Ribbond are designed with a lock-stitch leno weave pattern. Such a design could prevent slipping of fibers within the resin matrix; hence, under loadings can reinforce the restoration in multiple directions [35]. This material, when used as direct layering post-core within the root canal, would produce a monoblock between the root dentin and the restoration [36]. It has been reported that when receiving a high number of loads, Ribbond may enhance stress modification by absorbing and distributing the forces to the teeth [37]. According to the result of types of failure, none of the experimental groups could decrease the incidence of irreparable fracture to that of sound teeth. The difference between the types of modes of failure was statistically significant among all groups. Hence, the second null hypothesis was also rejected. Sound teeth produced the least percentage of irreparable fractures, while the highest percentage of irreparable fractures was recorded by those restored with a core of OBF. Irreparable fracture was recorded with 70% percentage for those restored with SFRC with or without post and for those with a core of Ribbond. However, Ribbond, when used as a post-core, recorded a 60% percentage of irreparable fractures. Less irreparable fracture with Ribbond as post and core was attributed to the multiple directions of the fibers when placed within the canal that come into close contact with the radicular dentin [38]. This result is supported by a recent systemic review by Vartak *et al.*, as a better percentage of irreparable fractures was recorded with Ribbond than glass fiber reinforced and other types of prefabricated posts [37]. However, teeth with MOD cavities are more prone to cuspal fractures [39], and their fracture under high loading is inevitable; hence, the results of this study are not unexpected.

Study limitations

It is worthwhile to mention that comparisons with other studies cannot be completely reconciled due to lack of protocol standardization. Several factors that can influence and affect the results need to be taken into consideration. It has been mentioned that factors such as type of materials, technique, tooth type, the amount of the remaining tooth structure have different influences on FR of ET teeth. Therefore, further studies with similar or close protocols are still needed.

Conclusion

Both EverX flow (SFRC) and Ribbond (long polyethylene fiber), when used as core only or as post-core, increased the fracture resistance of endodontically treated maxillary premolars with MOD cavities; however, none of them could reach the values of sound teeth. Using EverX Flow or Ribbond as post-core with a direct layering technique can increase the fracture resistance significantly compared with one bulk-fill composite resin. The mode of failure for all the experimental groups was a high prevalence of irreparable fracture.

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Conflict of interests

The authors declared no conflict of interest.

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Data sharing statement

Supplementary data can be shared with the corresponding author upon reasonable request.

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