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Research Article

Evaluation of bond strength between various types of fiber posts and resin cements: An in vitro comparative study

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Abstract: The current study aimed to compare the tensile bond strength (TBS) between different types of fiber posts and resin cement. **Materials and methods**: Sixty-three human lower premolars with similar root dimensions were randomly assigned to three groups, each consisting of 21 teeth belonging to a specific type of fiber post. The teeth were prepared by removing the coronal portion and mounted in acrylic blocks, leaving 2mm of the coronal tooth exposed. Endodontic therapy and post-space preparation were performed on the root canals of all specimens. The text describes a study where groups were divided into subgroups based on the type of resin cement used for luting fiber posts. Each subgroup consisted of 7 teeth. The bond strength between the fiber post and resin cement was measured using a universal testing machine, and the mode of failure was analyzed using a stereomicroscope. **Results:** The results of the study indicated significant differences among the groups and showed that the group using quartz fiber posts and RelyX U200 resin cement had the highest mean TBS (387.43±6.924), while the group using glass fiber posts and TOTAL C-RAM resin cement had the lowest mean TBS (176.29±3.039). **Conclusion**: The type of fiber post used in conjunction with a specific luting agent has an impact on the bond strength between the post and the resin cement. The study suggests that higher bond values can be achieved when using quartz fiber posts luted with RelyX U-200 cement. However, it is important to note that these findings are based on the limitations of the study.

Keywords: Fiber post, Resin cement, Tensile strength

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INTRODUCTION

Fiber-reinforced posts emerged as a promising alternative to prefabricated metal posts in the early 1990s, specifically designed to provide support for coronal restoration in teeth with significant structure loss following endodontic treatment [(1)]. These fiber posts not only offer mechanical benefits but also enhance the aesthetic appeal of restorations by improving optical effects. The mechanical advantages of fiber posts include a close-to-dentin elastic modulus, high flexural strength, compatibility with bis-GMA-based resin, biocompatibility, and corrosion resistance [(2)]. However, the retention of a post, which refers to its ability to withstand vertical dislodging forces, depends on various factors. The length, diameter, tapering, luting cement, surface treatment, and whether the post is active or not all contribute to its retention capabilities [(3)]. Fiber posts are passively engaged within the root canals and are held in place by the luting agent that adheres to both the fiber post and the intraradicular dentin. Despite their many advantages, debonding has been a common cause of failure with fiber posts [(4)].

The bonding capacities of these posts are influenced by several factors, including the design and composition of the post systems, which directly impact their retention. Consequently, post-dislodgement with its coronal restoration may occur as a result of reduced bonding capability [(3)].

The retention of fiber posts in root canals is crucial in dental procedures. The resin cement must adhere to both the dentin and the post to achieve even stress distribution and a monoblock-like effect [(4)]. Dental professionals have various options for posts based on their shapes and materials. By understanding these factors and making informed decisions, dentists can enhance the success and durability of their restorative treatments, benefiting their patients' oral health [(3)].

The everStick post is a glass fiber post that can easily adapt to the shape of the root canals, reducing voids and ensuring complete filling. It maximizes the adhesive surface and strength of the tooth. The post is particularly beneficial for curved, oval, or large root canals. The research objective is to assess the tensile bond strength between various types of fiber posts and resin cement [(5-8)].

MATERIALS AND METHODS

Preparation of specimen

In this study, 63 mandibular premolars were being taken from individuals aged 18 to 24 years undergoing orthodontic treatment. All of the root surfaces, canals, and apices of the teeth are completely formed and in good shape. At 10X magnification, a stereomicroscope is used to inspect each root for cracks. Pre-operative radiographs are performed in the mesial-distal and bucco-lingual directions to confirm a type I root canal system, no (internal or external) resorptions or calcifications are evident. During the collecting period, the teeth are kept in a screwed glass container with distilled water at room temperature (9). Then the teeth were cleaned by using a scaler to remove calculus, then an ultrasonic bath with 2% NaOCl for 5 minutes to dissolve any remaining soft tissues, and finally, rinse with distilled water, and then effectively sterilized for 30 minutes in an autoclave at 121ºC and 15 IPS (10,11). Then, keep in distilled water till the next step.

Preparation of root canals

Using a long, straight, flat-end diamond bur of size 016 in a high-speed handpiece equipped with a cooling system, we sectioned the teeth 2 mm above the cement-enamel junction, leaving about 13 mm of root for easily grasping and handling of specimen during pouring, then (11mm) of each root was inserted at a right angle inside cold cure acrylic poured PVC mold with the aid of a dental surveyor, as seen in Figure (1).

Figure (1): Placement of specimen inside acrylic mold with aid of dental surveyor

Then, a barbed broach is used to get access to the root canals and scrape out the pulp tissues. To determine the working length manually, take the length at which the No. 15 K-file can be seen at the end of the root with digital radiography (12). After that, rotary ProTaper gold NiTi files ranging in size from S1 to F3 were inserted into the canals at the recommended 250 rpm and 3.0 Ncm of torque. Root canal preparation is accomplished in a crown-down mode using a gentle in-and-out motion of the instruments, with alternating applications of (1 ml) of 2% NaOCl, (2 ml) of distilled water, (1 ml) of 17% EDTA solution, and then (2 ml) of distilled water, for irrigation and lubrication [(9)]. Using a single cone obturation technique and AH plus sealer, the root canals were obturated with F3 ProTaper gutta-percha to the full planned working length, and the roots coronally were sealed with glass ionomer cement (Vitremer, 3M ESPE, St. Paul, MN, USA) and stored for a week at 100% humidity and 37°C [(13)].

After that, the sixty-three root samples were randomly separated into three groups (n=12) according to the fiber post types as follows:

In this study, the focus is on different groups of root fillings and the types of fiber posts used in each group.

Group F1: consists of roots filled with smooth, translucent glass fiber posts, specifically the Rely XTM -3M from ESPE.

Group F2: on the other hand, involves roots filled with serrated, translucent quartz fiber posts, specifically the 3A from China. Finally,

Group F3: comprises roots filled with everStick® fiber posts from GC, Europe N.V. To further investigate the effects of different luting cements, each group is subdivided into three subgroups, each containing seven samples.

Group C1: This focuses on samples where fiber posts are cemented with "RelyX U200 Automix," a dual-cure resin cement.

Group C2: explores samples where fiber posts are cemented with "U-Cem premium," a self-adhesive universal resin cement.

Group C3: examines samples where fiber posts are cemented with "TOTAL C-RAM," a dual-cure resin cement.

The materials used in the research are listed in Table 1.

Table (1): Materials and their compositions used in this study.

Materials	Composition
RelyX U200 Automix, (3M ESPE, St. Paul , MN, USA)	Base: Stabilizers, methacrylate monomers containing phosphoric acid groups, methacrylate monomers, rheological additives, initiators. Catalyst: Silanated filler, methacrylate monomers, Alkaline filler, stabilizers, initiator components, rheological additives, pigments. Silica fillers of zirconia.
U-Cem premium (Vericom Co., Ltd. Korea)	Base: Bis-GMA, fluorinated barium, pigments, fumed silica, stabilizer, dimethacrylate. Catalyst: fumed silica, MDP, barium silicate, dimethacrylate catalyst, stabilizer.

TOTAL C-RAM (ITENA, FRANCE)	Resin matrix: UDMA, Bis-GMA, TEGDMA. Monomers adhesive acides: esters di acid phosphoric methacrylates 4-META, nanosilica, Silane coupling agent.
Rely X™ fiber post (3M, ESPE, Germany)	Smooth translucent glass fiber post: Fibers: S-glass fibers (60–70% by weight); Matrix: Epoxy-resin; Fillers: Zirconia filler.
Quartz fiber post (3A, China)	Serrated translucent quartz: Fibers: quartz fibers "65% by weight" which is pure silica in a crystallized form; Matrix: Epoxy-resin and bis-GMA, Fillers: no filler.
everStick fiber post Europe N.V)	Fibers: Silane coated, unidirectional E-glass fibers (61.5% by weight); Fillers: no filler. Matrix: Polymer network of Semi-interpenetrating, PMMA, and Bis-GMA.

Preparation of post space

The coronal sealing was removed following storage with the aid of #245 carbide bur (Brasseler, Savannah, GA, USA) in a high-speed handpiece. Then by employing the F4 rotary device, the obturating material was removed from each root sample at (9 mm) [13] . uniform post space of the same size was prepared using the Peeso Reamer #3, manufactured by Dentsply Maillefer in Ballaigues, Switzerland [14] as seen in Figure (2).

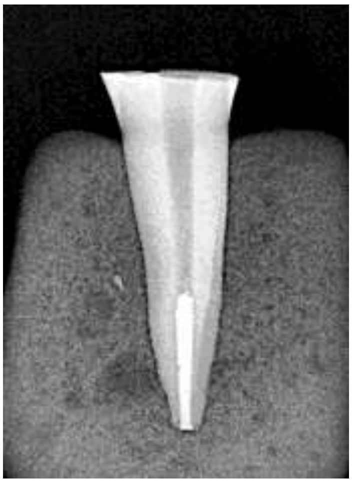

Figure (2): An x-ray for post space preparation and

The reamer was chosen as a tool for creating the post space due to its efficiency and reliability. To ensure optimal performance, the drill was swapped out after every five preparations to maintain its effectiveness. After the post space preparation, the canals were rinsed with a 2% NaOCl solution for 1 minute [15]. This step was crucial in disinfecting the canals and removing any debris or bacteria present. Following the NaOCl rinse, a 5% sodium thiosulfate solution was used for 1 minute to neutralize the effect of the NaOCl solution. This precautionary measure was taken to prevent any adverse effects that the NaOCl solution may have on the dental structure [16]. To further cleanse the canals, a rinse with 5 ml of distilled water was performed, followed by the application of 2 ml of 17% EDTA solution for 1 minute. The EDTA solution served the purpose of chelating any remaining debris and facilitating the removal of the smear layer. To conclude the procedure, a final rinse with 5 ml of distilled water was carried out, ensuring the complete removal of any residual substances. The area was then aspirated using endodontic cannulae, and the excess moisture was eliminated with the help of absorbent paper points. This meticulous process aimed to create a clean and well-prepared post space, free from any contaminants or debris, thus promoting successful dental treatment outcomes [2].

1. **Placement of post and luting application**

Before use, each fiber post (glass and quartz) undergoes a thorough cleaning process. First, the post is cleaned with 70% ethanol for 30 seconds to ensure any contaminants are removed according manufacturer's instructions. After that, it is washed with distilled water to eliminate any remaining ethanol residue. Once the cleaning process is complete, the post is dried thoroughly to ensure proper adhesion[17].

Following the manufacturer's instructions is crucial when it comes to dental procedures, particularly those involving resin cement and root canals. In the case of inserting resin cement into the root canal, it is important to ensure accuracy and precision. The process begins with the careful insertion of the resin cement using an intracanal tip. This specialized tool allows for the controlled and targeted placement of the cement within the root canal, ensuring optimal bonding and stability. Once the cement is in place, the next step involves inserting the post into the resin cement-filled post space. This step requires a delicate touch and attentiveness to detail, as the post must be positioned correctly to achieve proper tooth restoration. To avoid any potential complications, any excess cement is promptly removed within 30 seconds of placement. Finally, to ensure the post remains securely in place, finger pressure is applied for the first seven minutes while the cement initially sets [18].

Next, the cervical end of the fiber posts is exposed to a light-curing unit called Valo, manufactured by Ultradent Products Inc. This unit emits a high-intensity light with an output of 1000 mW/cm2 and falls within the wavelength range of 395 to 480 nm. The cervical end is exposed to the light for 40 seconds, ensuring the resin cement is properly cured. Alternatively, the material is light-cured from every side for a minimum of forty seconds [17,18].

To prevent premature polymerization, the soft unpolymerized everStick sheet is handled away from direct light. The sheet is cut to a predetermined length (9mm), condensed to fit the prepared post space, and shaped accordingly. The shaped post is then reinserted into the root canal and initially light polymerized with light-curing unit called Valo, manufactured by Ultradent Products Inc. This unit emits a high-intensity light with an output of 1000 mW/cm2 and falls within the wavelength range of 395 to 480 nm. for 20 seconds according manufacturer's instructions, following removal from the root canal, it is further light polymerized for 40 seconds, following the manufacturer's instructions [19].

For the EverStick posts, another cleaning step is necessary. They are cleaned for 30 seconds using 70% ethanol, followed by rinsing with distilled water. Once cleaned, the posts are well-dried to ensure optimal adhesion with the resin cement.

The process of cement application and EverStick post insertion is carried out as previously mentioned for other types of fiber posts. After completion, the specimens are stored at 37ºC and 50% humidity for one week, allowing for proper setting and stabilization of the cemented posts [18].

Tensile strength test

After one week of preparation, to minimize the occurrence of non-axial stresses during the measurement of tensile strength, each sample was individually secured to a specialized apparatus designed to tightly hold the sample in a vertical position. This setup ensures that the samples are in an optimal position for accurate measurements. To carry out the tests, the Universal Testing Machine GESTER GT-KO3B, manufactured by GESTER INTERNATIONAL Corporation, was utilized. The force was applied to the samples at a crosshead speed of 1.0 mm/min until the point of dislodgement, which was recorded in Newton [20]. By recording the force required for dislodgement, the bond strength of each sample could be determined. To draw meaningful conclusions from the data, the bond strength values were subjected to statistical analysis using the SPSS Statistical Software version 20. The analysis employed the "two-way ANOVA" method, which helps to determine the significance of different factors on the bond strength. Additionally, "Duncan's multiple range test was utilized to identify any significant differences between the bond strength values. The significance level chosen for this analysis was set at 0.05, ensuring that only results with a high level of statistical confidence were considered. Overall, these testing methods and statistical analyses provide a robust and reliable approach to evaluating the bond strength of the samples.

Analysis of Failure Mode

In the field of materials science and dentistry, tensile testing is a widely used method to evaluate the mechanical properties of fiber posts. Once the tensile testing is completed, it is crucial to examine the mode of failure of each fiber post. This examination is typically carried out using a stereomicroscopy, specifically the Optika microscope from Italy, which provides a magnification of 35X. By closely observing the failures, valuable insights can be gained regarding the performance and reliability of the fiber posts.

The mode of failure is classified into four distinct categories. The first category is an adhesive failure between the post and the luting material, which is characterized by the absence of any visible resin cement around the post. This type of failure indicates that the bond between the post and luting material has failed, resulting in a weakened connection. The second category is adhesive failure at the dentin-cement interface, where the bond between the dental cement and the dentin is compromised. This type of failure suggests that the adhesion between the dental cement and the tooth structure is not strong enough to withstand the applied tensile forces.

The third category of failure is the cohesive failure of the luting material. This means that the luting material itself has fractured or separated internally, without any involvement of the post or the dental cement. This type of failure indicates that the luting material may not possess sufficient strength or durability to withstand the tensile forces exerted during function. Finally, the fourth category is referred to as a mixed type, which is a combination of two or more of the previously mentioned failure modes. This type of failure highlights the complexity and variability of the failure mechanisms involved in fiber posts [21].

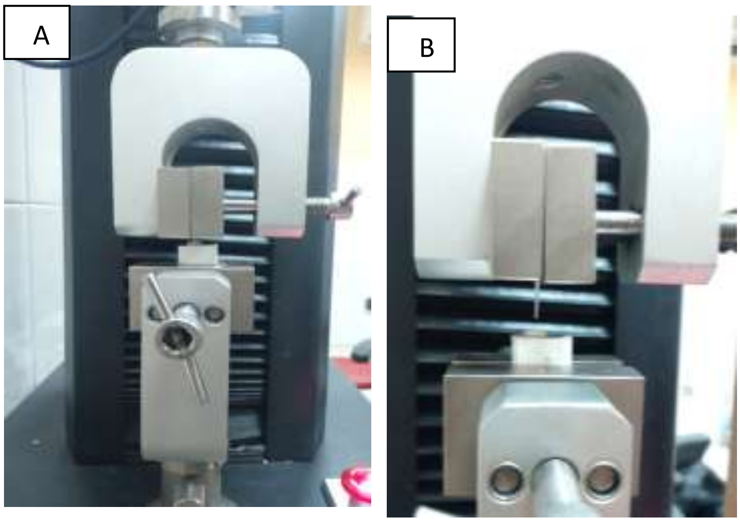

Figure (3): Universal testing machine with specimen. Engagement of fiber post in machine (A), dislodgement of fiber post (B).

RESULTS

The means and standard deviations of tensile bond strength (in N) of the three kinds of posts were calculated and represented in Table (2). Table 2 presents an extensive overview of the calculated means and standard deviations of the tensile bond strength, measured in Newton, for three specific types of posts that are currently being analyzed. This table serves as a valuable resource for researchers and engineers involved in the study of bond strength. The means displayed in the table represent the average bond strength exhibited by each post type, providing a useful reference point for understanding the performance of these posts in terms of their tensile bond strength. By examining the means, one can gain insights into the relative strength of each post type and make informed decisions based on this information. Additionally, the standard deviations presented in Table 2 offer a measure of the variability or dispersion of the bond strength values within each group. This statistical measure is essential in assessing the consistency and reliability of the bond strength results obtained for each post type. A lower standard deviation suggests that the bond strength values within a particular group are closely clustered around the mean, indicating a higher level of uniformity and predictability. On the other hand, a higher standard deviation signifies a greater dispersion of bond strength values, suggesting a wider range of performance outcomes for that specific post type. In summary, Table 2 provides a comprehensive representation of the means and standard deviations, enabling researchers and engineers to gain valuable insights into the average bond strength and its variability across the three types of posts under consideration.

Table (2): The mean and standard deviations of tensile bond strength for all tested groups

Fiber post	Resin cement	N	Minimum	Maximum	Mean	Std.
F1	c1	7	288.00	308.00	296.43	8.059
	c2	7	184.00	190.00	187.29	2.138
	c3	7	171.00	180.00	176.29	3.039
F2	c1	7	378.00	396.00	387.43	6.924
	c2	7	340.00	365.00	353.57	8.960
	c3	7	195.00	222.00	208.14	10.636
F3	c1	7	315.00	335.00	323.14	6.866
	c2	7	200.00	225.00	211.43	8.772
	c3	7	185.00	198.00	192.43	4.685

F1 refers to glass fiber posts, F2 represents quartz fiber posts, and F3 stands for everStick fiber posts. Each of these fiber posts offers unique characteristics and benefits, catering to the diverse needs of patients. C1 refers to RelyX U200 dual cure resin cement, C2 represents U-Cem premium dual resin cement, and C3 stands for TOTAL C-RAM dual cure resin cement.

Table (3) displays the results of a "two-way ANOVA" for various fiber post and resin cement types as well as their interactions. This statistical analysis provides valuable insights into the bond strength of different test groups. The significance of these findings lies in the fact that they indicate whether there are any meaningful differences among the groups being compared. In this case, the results of the ANOVA revealed a statistically significant difference among the groups ($P \leq 0.05$). This means that there is a strong likelihood that the observed variations in bond strength are not due to random chance, but rather, they can be attributed to the different fiber post and resin cement types being tested. The significance level of $P \leq 0.05$ is commonly used in scientific research to determine if the observed differences are statistically meaningful. Therefore, these findings suggest that the choice of fiber post and resin cement can have a significant impact on the bond strength of dental restorations. Overall, the results of the two-way ANOVA presented in Table (3) provide valuable insights into the relationship between various fiber post and resin cement types and their impact on bond strength.

Table (3): "Two-way Analysis of Variance" (ANOVA) for resin-cements, levels of fiber posts, and their interactions.

"Source of variance "	***Type III sum squares**	**df**	**mean square**	**F**	**sig.**
(F) Fiber post	106897.810	2	53448.905	1.032	.000
(C) Resin cement	218304.667	2	109152.333	2.107	.000
Fiber post × Resin cement (F × C)	40307.810	4	10076.952	194.540	.000
Error	2797.143	54	51.799		
Total	4613079.000	63			
Corrected Total	368307.429	62			

"Duncan's multiple range test" for the various fiber post types, independent of the types of cement used, and their relationship (table 4) revealed that the glass fiber post had statistically the lowest mean of tensile bond strength (220.00 ±55.780), from other side the quartz fiber post group had the highest mean of tensile bond strength (316.38±80.147). Despite not showing a statistically significant variance ($p>0.05$) in the tensile bond strength from the ever stick post (242.33 ± 59.458).

Table (4): "Duncan's multiple range" Test for the influence of types of fiber post upon tensile bond strength.

Types of Fiber post	**(N)**	**"Mean ± std"**	**Duncan groups**
F1 (smooth, glass)	21	220.00 ± 55.780	B
F2 (serrated, quartz)	21	316.38 ± 80.147	A
F3 (everStick)	21	242.33 ± 59.458	B

The study conducted on different types of cement, specifically comparing the RelyX U200 resin cement and the TOTAL C-RAM cement, revealed interesting findings regarding tensile bond strength. According to the results, the RelyX U200 resin cement groups displayed the highest mean tensile bond strength of 335.66 ± 39.743. This result indicates that the RelyX U200 resin cement exhibits superior bonding properties compared to other types of cement analyzed in the study. On the other hand, the TOTAL C-RAM cement groups demonstrated the lowest mean tensile bond strength of 192.28 ± 14.863. This finding suggests that the TOTAL C-RAM cement may not provide as strong of a bond as the RelyX U200 resin cement or other types of cement evaluated in the study. These results were obtained through the application of "Duncan's multiple range test, which is a statistical method used to assess significant differences among multiple groups. Importantly, the statistical analysis accounted for various factors, such as fiber post types and their interaction, ensuring a comprehensive evaluation of the different cement types.

Table (5): "Duncan's multiple range" Test for the influence of types of resin cement on tensile bond strength.

types of Resin cement	(N)	Mean ± SD
C1 (Rely-X U200)	21	335.66 ±39.743
C2 (U- Cem premium)	21	250.76 ±75.496
C3 (TOTAL C-RAM)	21	192.28 ± 14.863

The results of Duncan's multiple range" test for the interactions of fiber posts with resin cement, as presented in Table 6, provide valuable insights into the tensile bond strength means of different groups. Among the tested groups, F1C3 (glass fiber post + TOTAL C-RAM cement) and F2C1 (quartz post + RelyX U200 cement) stood out as having statistically significant differences in their bond strength means. Group F1C3 exhibited the lowest mean tensile bond strength at (176.29±3.039), while group F2C1 showcased the highest mean tensile bond strength at (387.43±6.924). These results highlight the varying performance of different fiber posts and resin cement combinations when it comes to their ability to withstand tensile forces. To visualize these findings, a bar graph was created, which can be seen in Figure 4. This graph provides a clear representation of the tensile bond strength means for all the assessed groups, demonstrating the disparities between them. The utilization of Duncan's multiple range test and the subsequent analysis of the results have contributed to a deeper understanding of the interactions between fiber posts and resin cement in terms of their tensile bond strength.

Table (6): "Duncan's multiple range" Test for the interaction between "fiber post "and "resin cement" on the tensile bond strength

Groups	N	Mean ± Std	Duncan Grouping
F2C1	7	387.43±6.924	A
F2C2	7	353.57±8.960	B
F3C1	7	323.14±6.866	C
F1C1	7	296.43±8.059	D
F2C3	7	208.14±10.636	E
F3C2	7	211.43±8.772	E
F3C3	7	192.43±4.685	F
F1C2	7	187.29±2.138	f
F1C3	7	176.29±3.039	g

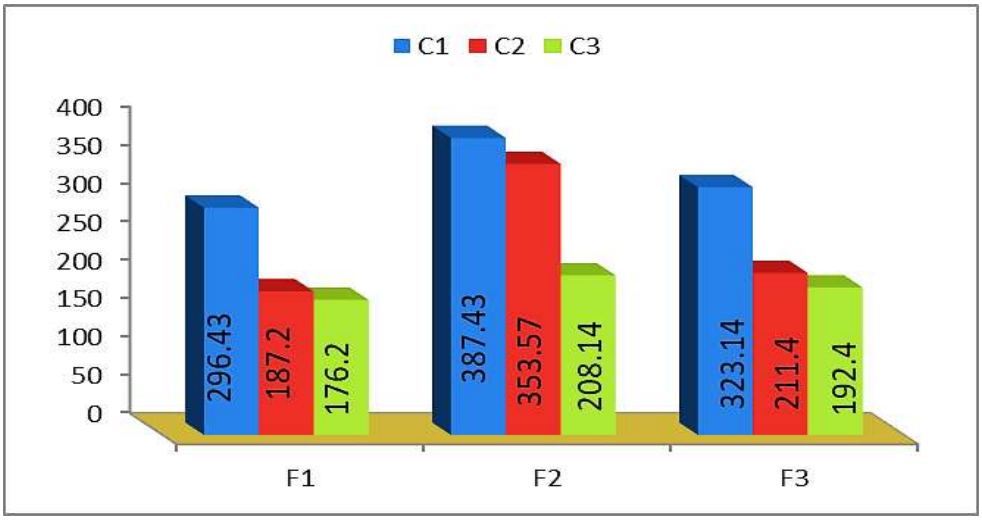

Figure (4): Bar chart illustrating the mean tensile bond strength and Duncan's multiple range test for all tested groups.

Mode of failure analysis

The results presented in Table (7) provide valuable insights into the adhesive failure rates observed among different groups. Among all the groups, the one consisting of quartz fiber post + Rely X U-200 cement exhibited the lowest adhesive failure rate, recording an impressive 0%. In comparison, the group utilizing glass fiber post + Total C-RAM displayed a relatively higher adhesive failure rate of 28.5%. The adhesive failure rates increased further in the groups employing glass fiber post + U-cem premium (71.4%) and ever stick post + Rely X U-200 cement (71.4%), marking them as having the highest adhesive failure rates among the tested groups. On the other hand, the group using quartz fiber post + Rely X U-200 cement displayed the highest rates of cohesive and mixed failure, accounting for 14.2% and 85.7%, respectively. These findings indicate the superior adhesive properties of the quartz fiber post + Rely X U-200 cement combination. Furthermore, Figure (5) in the research provides representative samples of different types of failure observed under the stereomicroscope at a magnification of 35X.

Table (7): Distribution of the failure modes following the tensile strength test

Mode of failure	F1C1	F1C2	F1C3	F2C1	F2C2	F2C3	F3C1	F3C2	F3C3
Adhesive (type 1)	57%	71.4%	28.5%	0%	43%	57%	71.4%	57%	28.5%
Adhesive (type 2)	0	0	0	0	0	0	0	0	0
Cohesive (type 3)	0	0	0	14.2%	0	0	0	0	0
Mixed (type 4)	43%	28.5%	71.4%	85.7%	57%	43%	28.5%	43%	71.4%

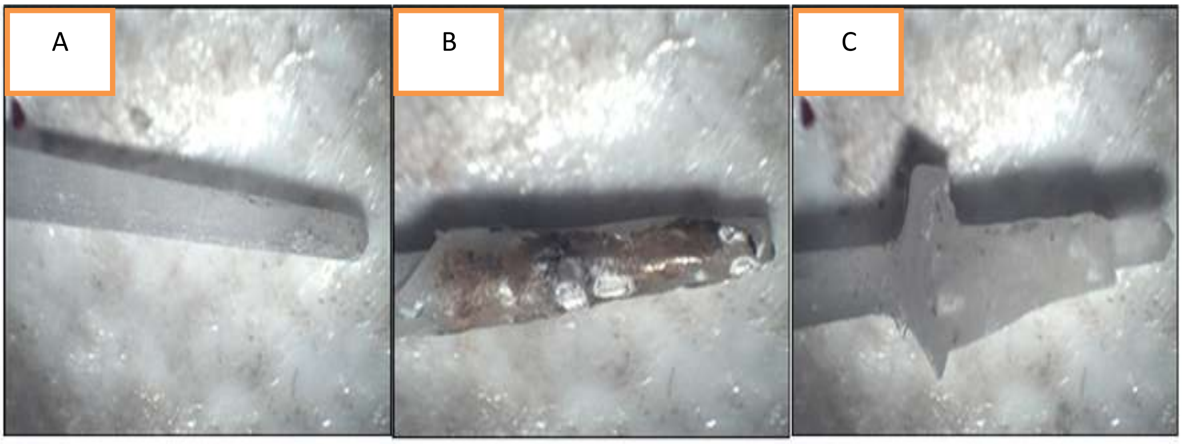

Figure (5): mode of failure under stereomicroscope: (A) Adhesive, (B) cohesive, (C) mixed type.

DISCUSSION

Fiber-reinforced resin posts have emerged as the most recent alternative for the repair of teeth that have undergone endodontic treatment. While there may be a paucity of experimental and research laboratory investigations on fiber posts, it is crucial to underline the remarkable success rate and the near absence of root fractures associated with their use. These posts hold significant potential in strengthening frail roots without increasing the risk of fracture. With their unique composition and properties, fiber-reinforced resin posts offer a promising solution for restoring the structural integrity of treated teeth. Unlike traditional metal posts, fiber posts provide a more aesthetically pleasing and natural-looking outcome. Their ability to bond with the surrounding tooth structure enhances the overall stability and longevity of the restoration. Moreover, the flexibility of fiber posts allows them to distribute stresses more evenly, reducing the likelihood of root fractures that often occur with rigid metal posts. This innovative approach in dental treatment opens up new possibilities for preserving and enhancing the functionality of endodontically treated teeth. As further research and advancements are made in this field, fiber-reinforced resin posts are expected to play a vital role in ensuring successful and durable restorations (21).

The outcomes of the present study revealed significant findings regarding the bond strength of different post and cement combinations. The group consisting of quartz fiber post and RelyX U-200 cement exhibited the highest bond strength, whereas the group comprising glass fiber post and TOTAL C-RAM cement demonstrated the lowest tensile bond strength compared to the other groups. Interestingly, the results also indicated that glass fiber posts had the lowest average value of tensile strength, while the groups utilizing quartz posts had the highest average value of tensile strength, regardless of the cement type used.

The study suggests that the increased bond strength of quartz (serrated) posts can be attributed to the micromechanical interlocking of the resin cement with the surface imperfections of the post. This finding indicates that the bonding of cross-linked posts in the study is mainly reliant on micromechanical bonding mechanisms. This is further supported by another study, which demonstrated that serrated titanium posts, when cemented with resin cement, exhibited the highest pull-out force. In this context, it becomes evident that chemical adhesion is unlikely between crosslinked fiber posts and epoxy-based or dimethacrylate-based matrices. Therefore, the adhesion observed in this study is primarily a result of mechanical factors, specifically the interlocking of the adhesive cement into the irregularities present on the post's surface. These findings highlight the significance of surface characteristics and imperfections in achieving stronger bond strengths between resin cement and quartz posts, emphasizing the importance of micromechanical interlocking in dental restorations (22,23).

Additionally, the everStick post displayed higher bond strength compared to glass fiber posts. This can be attributed to the fact that the everStick post is fully adapted to the root canal, resulting in better adaptation with fewer gaps and lower cement thickness, ultimately leading to higher bond strength. Furthermore, the semi-IPN polymer matrix of the prefabricated glass post is another contributing factor. The everStick post contains linear and cross-linked polymer portions, with the linear phase being polymethylmethacrylate (PMMA). This linear phase can dissolve and interact with HEMA, Bis-GMA, and TEGDMA-based monomers, which further enhances adaptability, reduces gap formation, and increases bond strength. Conversely, tests have shown that previously made cross-linked epoxy-based fiber posts cannot be penetrated by monomers like HEMA, Bis-GMA, and TEGDMA (1,18,24). These findings shed light on the complex interplay between different post materials and cement types, providing valuable insights for dental professionals in selecting the most suitable combination for optimal bond strength in clinical applications.

The luting cement plays a crucial role in the retention of posts due to its strong mechanical qualities and its ability to adhere to the root dentine and fiber posts. Resin luting cement, in particular, fulfills both of these requirements, offering significant advantages for the luting of fiber posts. However, despite these beneficial characteristics, extensive clinical and in vitro research has indicated that the weak link lies at the interface between the fiber post and resin-luting cement. This discovery may suggest that the adhesive luting technique is sensitive when applied to root canals, considering the various challenges involved. These challenges include properly treating the dentine's surface, managing humidity, allowing adhesive solvents to evaporate, inserting the luting cement into the canal without trapping air, and ensuring appropriate cement polymerization. All of these factors have a direct impact on the interaction between fiber posts and the luting cement. Therefore, it is essential for dental professionals to carefully consider these aspects and strive for optimal techniques to enhance the longevity and stability of luted fiber posts (25).

A resin luting agent plays a crucial role in dental procedures, particularly in the context of post spaces. However, it is important to consider the potential challenges that may arise when using such materials. One significant issue is the creation of polymerization shrinkage stresses within the post space, which can have implications for the overall success of the procedure. These shrinkage stresses are closely linked to the concept of the C factor, which refers to the ratio of bonded to unbonded surface areas in root canal dentin. In some cases, the C factor in post spaces can be exceptionally high, reaching values as high as 200 (26). This high C factor, coupled with the use of light-polymerizing materials, can result in intense polymerization stress within the geometrically adverse configuration of the post space. As a consequence, resin composites used in these situations may detach from the dentin walls, leading to the creation of interfacial gaps. To address these challenges and ensure proper polymerization, it is crucial to maximize the strength and adhesion of the cement used in post spaces. One effective approach is the incorporation of a chemically activated component within a dual-catalyst system. By doing so, the cement can achieve optimal physical properties and enhance the bond between the post and dentin (22). Achieving a high conversion rate is also essential in maximizing the performance of luting cement. Researchers such as Le Bell et al. have investigated the use of polymerizing glass fiber-reinforced resin composite material (FRC) in post spaces. Their work focused on determining the depth of light-initiated polymerization of the FRC and its potential application in enhancing the overall success of resin-luting agents.

In a study comparing the bond strength of different resin cements used with various fiber post types, it was found that the RelyX U-200 cement exhibited the highest mean value of bond strength, while the TOTAL C-RAM showed the lowest. The RelyX U-200 cement is known for its low viscosity, excellent flowability, and minimal polymerization shrinkage, which reduces the likelihood of gaps forming during application (27). This is attributed to the presence of salinated fillers in the cement. Additionally, the bonding mechanism of RelyX cement involves both micromechanical retention and chemical bonds to hydroxyapatite, further enhancing its bond strength.

The manufacturer has replaced polyacrylic with functional monomers of 4-META and modified esters, resulting in increased bond strength. The addition of an extra monomer and a new rheology modifier to the RelyX U-200 cement formulation, along with optimized processing of filler particles, contributes to its improved mechanical properties and overall adhesion performance (28). The self-adhesive nature of U200 resin cement is also beneficial, as the application method using a commercial delivery system allows for improved monomer dentinal tissue interaction. The decreased viscosity of the cement enables enhanced diffusion of reacting species, leading to a higher rate of reticulation during polymerization.

Moreover, the ability of self-adhesive resin cement to effectively diffuse and decalcify the underlying dentin is attributed to the increasing viscosity resulting from an acid-based reaction that occurs after paste-to-paste mixing (29). In contrast, the rapid working and setting times, as well as substantial polymerization shrinkage, of the TOTAL C-RAM cement may have detrimental effects (30). While U-cem premium contains the phosphate-based functional monomer 10-MDP, which chemically interacts with hydroxyapatite, it exhibits moderate tensile strength.

This finding is similar to the adhesives used in Panavia 21 and Clearfil Esthetic Cement, both of which are "mild" self-etch adhesives and contain the phosphate-based functional monomer 10-MDP. The stability of the bond between MDP and hydroxyapatite is attributed to the low solubility of MDP-calcium salt in water. The slightly higher acidity of ED Primer II in Clearfil Esthetic Cement compared to ED Primer in Panavia 21 may account for the subtle difference in bonding effectiveness between the two types of cement. The predominant failure mode observed in the study was adhesion between the fiber post and the resin cement (31).

CONCLUSIONS

Within the limitations of this study, it can be concluded that the bond strength between fiber posts and resin cement can be affected by various factors. The choice of fiber post and resin cement plays a crucial role in determining the overall bond strength. Different types of fiber posts, such as carbon, glass, or quartz, can have varying effects on the bond strength. Similarly, the selection of resin cement, whether self-adhesive or adhesive, can also impact the bond strength. It is important to consider these factors when choosing the appropriate combination of fiber post and resin cement for dental restorations. Furthermore, the study revealed that the most prevalent mode of failure observed in the tested samples was adhesive failure. Adhesive failure refers to the failure that occurs either between the dentin and cement or between the fiber post and cement. This finding suggests that the interface between the dentin, cement, and fiber post is critical in determining the overall bond strength. Factors such as surface preparation, application technique, and material properties can influence the bond strength and the occurrence of adhesive failure. However, it is important to note that this study has its limitations. The findings are based on a specific set of conditions and materials used in the study. The results may not be directly applicable to all clinical scenarios. Additionally, the study did not investigate other potential factors that could influence bond strength, such as the tooth structure or the presence of any underlying pathology. Therefore, further research is needed to validate and expand upon these findings.

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Ethical statement: This study involved the use of human teeth that had previously been extracted, requiring the researcher to obtain ethical approval from the Research Ethics Committee at the Faculty of Dentistry at Mosul University, Iraq. The clearance number for this study was REC reference no. UoM.Dent/H.DM.2/23.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript

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تقييم قوة الرابطة بين أنواع مختلفة من أعمدة الألياف والأسمنت الراتنجي: دراسة مقارنة في المختبر

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الملخص

الاهداف: تم إجراء دراسة بحثية لمقارنة قوة رابطة الشد (TBS) بين أنواع مختلفة من أعمدة الألياف والإسمنت الراتينج. **المواد وطرائق العمل:** تم تقسيم ثلاثة وستين ضواحك بشرية ذات أبعاد جذرية متشابهة بشكل عشوائي إلى ثلاث مجموعات ، تتكون كل منها من 21 سنًا حسب نوع المستخدم من دعامات الألياف. تم تحضير الأسنان عن طريق إزالة الجزء الإكليلي وتثبيتها في كتل أكريليك ، وترك 2 ملم من الأسنان الإكليلية مكشوفة. تم إجراء العلاج اللبي والتحضير بعد الفراغ على قنوات الجذر لجميع العينات. من ثم تم تقسيم المجموعات إلى مجموعات فرعية بناءً على نوع أسمنت الراتينج المستخدم في لصق أعمدة الألياف. تتكون كل مجموعة فرعية من 7 أسنان. تم قياس قوة الرابطة بين الدعامة الليفية والإسمنت الراتينج باستخدام جهاز الفحص العام، وتم تحليل طريقة الفشل باستخدام جهاز ستيريوميكروسكوبي **النتائج :** اشارت نتائج الدراسة الى وجود فروق ذات دلالة احصائية بين المجموعات واظهرت ان المجموعة التي استخدمت دعامات الياف الكوارتز والاسمنت الراتينج (Rely X_U 200) كان لها اعلى متوسط لقوة الترابط (387.43 ± 6.924) بينما كانت المجموعة التي استخدمت دعامات الالياف الزجاجية والاسمنت الراتينج (Total C-Ram) كان لها ادنى متوسط لقوة الترابط (176.29 ±3.039). **الاستنتاجات :** ان نوع عامود الالياف المستخدم مع عامل تكسير معين له تاثير على قوة الرابطة بين الدعامة والاسمنت الراتينج تشير الدراسة الى انه يمكن تحقيق قيم رابطة اعلى عند استخدام اعمدة الياف الكوارتز مع اسمنت الراتينج (Rely X_U 200) ومع ذلك من المهم ذكر ان هذه النتائج تستند الى قيود الدراسة .