Effect of Accessory Fiber Post on Fracture Resistance of Endodontically Treated, Non-ferruled Teeth

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Abstract

The aim of this study was to evaluate the effect of accessory fiber posts on fracture resistance of non-ferruled endodontically treated teeth after five years fatigue loading. Twenty uniradicular lower first premolars were decoronated and endodontically treated. The specimens were randomly divided into two groups (n=10): single glass fiber-reinforced resin composite (FRC) post and flowable resin composite core (Group I) and glass FRC post with an accessory fiber post and flowable resin composite core (Group II). The specimens were then restored with Ni-Cr alloy crowns. The specimens were subjected to a cyclic loading test for 1.2 million cycles to simulate five years of clinical service followed by a static loading test. The specimen failure loads were recorded and statistically analyzed using independent t-test at the 95% confidence level. All specimens survived the fatigue loading test. The mean (SD) fracture resistance was 676 N (105 N) for Group I and 652 N (148 N) for Group II. There was no significant difference in fracture resistance between the control group (Group I) and the other experimental group ($P > 0.05$). Both restorative methods showed similar fracture resistance and resulted in fracture resistance above the average maximum bite force of lower first premolar after five years of clinical simulation.

Keywords: *FRC post, accessory fiber post, compromised endodontically treated teeth, fracture resistance*

1. Introduction

A common clinical problem in endodontically treated teeth (ETT) is the extensive loss of tooth structure (Saupe, Gluskin & Radke, 1996). ETT require a post and core to provide sufficient restoration retention and support. Cast metal posts have a long history of being used to provide the required retention and support (Heydecke & Peters, 2002). Although using a cast metal post provides high fracture resistance due to its high modulus of elasticity, many studies reported unfavorable root fractures after using this type of restoration (Aggarwal et al., 2012; Silva et al., 2011).

Prefabricated fiber posts were first introduced in the 1990s (Duret, Reynaud, & Duret, 1990). The modulus of elasticity of these posts are similar to dentin, creating a uniform stress distribution to root dentin and reducing the incidence of root fracture compared with custom cast posts (Galhano et al., 2005; Novais et al., 2009). Fiber posts should fit in the root canal to provide a uniform and thin cement layer so that the stresses are evenly transmitted from the fiber post to the root dentin, resulting in a decreased incidence of post debonding (Grandini et al., 2005). Due to the variation in the shape of root canal systems, round fiber posts do not fit well in an ovoid or triangular root canal anatomy (Coniglio et al., 2011). The existing spaces between the fiber post and root canal walls fill with thick luting cement (Boksman et al., 2011). These large amounts of luting cement in the root canal produce high stress at the adhesive interfaces because of high polymerization shrinkage, leading to a dislodged post (Braga et al., 2006; Zogheib et al., 2008). From these reasons, accessory fiber posts in addition to the main fiber post have been used to achieve a better fit to decrease the incidence of failure (Alkumru et al., 2013; Li et al., 2011). However, previous studies reported that the use of accessory fiber posts resulted in decreasing fracture resistance because insertion of the small diameter of accessory fiber posts created a large number of empty spaces which were filled by luting cement. Thus, the thick layer of luting cement increased the incidence of bubbles or voids resulting in reduced cohesive strength of the luting cement (Clavijo et al., 2009). Therefore, there is still controversy on the effect of accessory fiber post on fracture resistance of compromised ETT.

2. Objective

To evaluate the effect of the addition of an accessory fiber post to the main fiber post on fracture resistance of non-ferruled ETT after five years of in vitro fatigue loading.

3. Materials and Methods

3.1 Study sample

The protocol for this study was approved by the Ethics Committee of Chulalongkorn University (011/2018). The study samples consisted of twenty lower first premolar teeth extracted for orthodontic reasons. Teeth with restorations, crack lines, caries, or dilacerated roots were excluded. Radiographic images of the samples were obtained to determine root canal morphology. The length of the root was 14.5±0.5 mm from the cementoenamel junction (CEJ) to the apex. At the CEJ, the buccolingual and mesiodistal width of the teeth were 7.5±0.5 mm and 5.0±0.5 mm, respectively. All teeth dimensions were measured using a digital vernier caliper (Mutitoyo, Tokyo, Japan). Each tooth was decoronated at the CEJ perpendicular to the long axis of tooth using a high-speed no.837L cylindrical diamond bur (Jota AG, Switzerland).

3.2 Root canal preparation

All teeth were endodontically treated using a 017-050 rotary file (Protaper Next, Dentsply/Maillefer Insruments SA, Switzerland). During instrumentation, the root canals were irrigated with 2.5% sodium hypochlorite. The root canals were rinsed with 17% EDTA and dried with paper points before root canal obturation. The root canals were obturated using lateral condensation technique with a main cone and lateral cone gutta-percha filling (Sure-endo, Sure Dent Coporation, Korea) with root canal sealer (CU Product, Bangkok, Thailand). The root canal orifices were filled with 2 mm of provisional filling (Cavit, 3M ESPE, USA) and the specimens were stored in humidified 37°C incubator for 7 days before post-space preparation.

3.3 Post and core preparation

The gutta percha was removed using #1 and #2 Peeso reamers (Jota AG, Switzerland) to 4 mm from the root apex. The root canals were shaped with a #0 reamer (Ivoclar Vivadent AG, Liechtenstein). After post space preparation, the remaining dentinal wall thickness was 1.75±0.25 mm for mesial and distal surface and 2.75±0.25 mm for buccal and lingual surface. The specimens were randomly divided into two groups (n=10) and restored using their respective group's fiber post and core method (Figure 1).

3.3.1 Group I (Single FRC post): A glass fiber post (FRC Postec Plus, Ivoclar Vivadent AG, Liechtenstein) was tried into the root canal. The size and length of fiber post were corresponded to the #0 reamer which was used to prepare the post space. The fiber post was cut using a high-speed no.837L cylindrical diamond bur 15 mm from the tip of post, with 5 mm to retain the core and 10 mm inside the root canal. The fiber post was applied with silane (Monobond N, Ivoclar Vivadent AG, Liechtenstein) for 60 sec and any excess silane was removed using a strong stream of air. Before post cementation, the root dentin was etched with 37% phosphoric acid (N-Etch, Ivoclar Vivadent AG, Liechtenstein) for 15 sec and rinsed with normal saline for 15 sec. The root canal was dried with air and paper points. The root dentin was applied with adhesive (ExciTE F DSC, Ivoclar Vivadent AG, Liechtenstein) for 10 sec and the excess adhesive in the root canal was removed using paper points. Flowable resin composite core material (MultiCore Flow, Ivoclar Vivadent AG, Liechtenstein) was placed into the root canal, followed by gentle insertion of the fiber post into root canal. The core build-ups were standardized in size and shape using a 6 mm high transparent mold fabricated from a vacuum sheet. The flowable resin composite core was polymerized for 40 sec holding the light curing machine (Elipar DeepCure-L LED curing light, 3M ESPE, USA) adjacent to the post. The core build-up was trimmed to remove any excess core material and a 0.5 mm chamfer finishing line was created with a high-speed no.847R taper diamond bur (Jota AG, Switzerland). All specimens confirmed the adaptability between resin composite core material and root canal walls by the radiographic evaluation.

3.3.2 Group II (FRC post with an accessory fiber): The main glass fiber post was placed into the center of the root canal and an accessory glass fiber post (Reforpin, Ace Dental Group Inc., USA) was placed next to the main fiber post. The main fiber post and accessory fiber post were cut with a high-speed no.837L cylindrical diamond bur to leave 5 mm exposed to retain the core. The prepared fiber post and accessory fiber post were cemented and the core build-up was performed as in Group I.

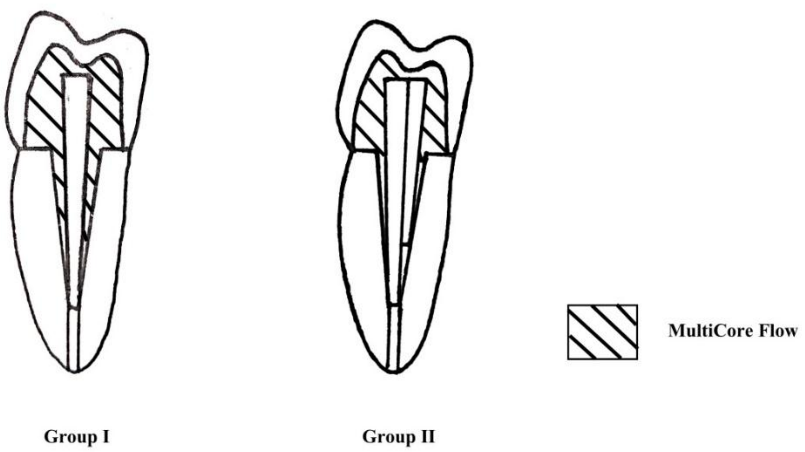

Figure 1 Schematic illustration of the experimental groups

3.4 Coronal restoration fabrication

The full metal crowns with a 3 mm diameter positioning notch on the buccal surface were fabricated with Ni-Cr alloys (Argeloy N.P., Argen, USA) in all specimens. Prior to cementing the crown, the fit-checking silicone paste (Fit Tester, Tokuyama Dental Corporation) was used to evaluate crown adaptation. The full metal crowns were prepared by applying silane for 60 sec and any excess silane was removed using a strong stream of air. The specimens were etched with N-Etch for 15 sec and rinsed with water for 15 sec, followed by applying the adhesive for 10 sec. The prepared full metal crowns were cemented with Variolink N (Ivoclar Vivadent AG, Liechtenstein). Each surface was light polymerized for 20 seconds. To simulate the periodontal ligament, the specimens were dipped into melted wax 2 mm below the CEJ to create the space for the artificial periodontal ligament. The specimens were embedded in self-curing acrylic resin (Formatray, Kerr, Romulus, MI, USA), 2 mm below the CEJ, in polyvinyl chloride rings. After acrylic resin polymerization, the specimens were removed from the acrylic resin and the wax was removed using a scalpel blade. Silicone light body (Amcoflex, Amcorp, USA) was used for simulating the periodontal ligament and loaded into the acrylic resin space followed by immediately inserting the specimen. Any excess light-body silicone was removed using a scalpel blade. The materials and their instruction for use are summarized in Table 1.

3.5 Fatigue loading and fracture resistance test

The specimens were mounted on a custom stand at 45^{o} to the long axis of the tooth assembled on the universal fatigue testing machine (E1000 ElectroPuls, Norwood, US). A 2.5 mm diameter custom-made stylus head on the universal testing machine applied a 140 N load 6 Hz to the prepared notch on the buccal surface of the crown for 1.2 million cycles. Subsequently, a compressive load was applied to the specimens with the same angulation and position as in the fatigue loading test using the universal testing machine (Instron 8872, Norwood, US) at a crosshead speed of 1.0 mm/min until specimen failure. The failure load of each specimen was statistically analyzed using independent t-test at the 95% confidence level.

Table 1 Materials and Instruction

Material	Components	Company	Instruction
Etchant (N-Etch)	37% phosphoric acid	Ivoclar Vivadent AG	- Apply etchant to the root canal for 15 sec and rinse with normal saline
Primer (Monobond N)	Alcohol solution of saline methacrylate Phosphoric acid methacrylate Sulphide methacrylate	Ivoclar Vivadent AG	- Apply Monobond N to the restoration for 60 sec then disperse any remaining excess with a strong stream air.
Adhesive (ExciTE F DSC)	HEMA Dimethacrylate Phosphonic acid acrylate Highly dispersed silicone dioxide Initiators Stabilizers Potassium fluoride in an alcohol solution	Ivoclar Vivadent AG	- Apply ExciTE F DSC to the enamel and dentin and agitate the adhesive on the prepared surfaces for at least 10 sec
Resin cement (Variolink N)	bis-GMA Urethane dimethacrylate Triethylene glycol dimethacrylate Barium glass Ytterbium trifluoride Ba-Al-fluorosilicate glass Spheroid mixed oxide	Ivoclar Vivadent AG	- Mix Variolink N Base and Catalyst in a 1:1 ratio for 10 sec before application. - The working time of the mixed Variolink N is approximately 3.5 min 37 °C
Main fiber post (FRC Postec Plus)	Glass fibers Aromatic and aliphatic dimethacrylates Ytterbium trifluoride	Ivoclar Vivadent AG	-
Accessory fiber post (Reforpin)	Glass fiber post 80% Epoxy resin 20%	Ace Dental Group Inc.	-
Flowable resin composite core (MultiCore Flow)	Dimethacrylate Barium glass Ytterbium trifluoride Ba-Al-fluorosilicate glass Highly dispersed silicone dioxide	Ivoclar Vivadent AG	- The base and catalyst pastes of MultiCore Flow are mixed at a ratio of 1:1 by pressing pastes through the static mixing tip.

4. Results and Discussion

The mean fracture resistance and standard deviation of each group are presented in Figure 2. There was no significant difference in fracture resistance between the single FRC post and flowable resin composite core (676 N±105 N) and FRC post with an accessory fiber post and flowable resin composite core (652 N±148 N)($p > 0.05$).

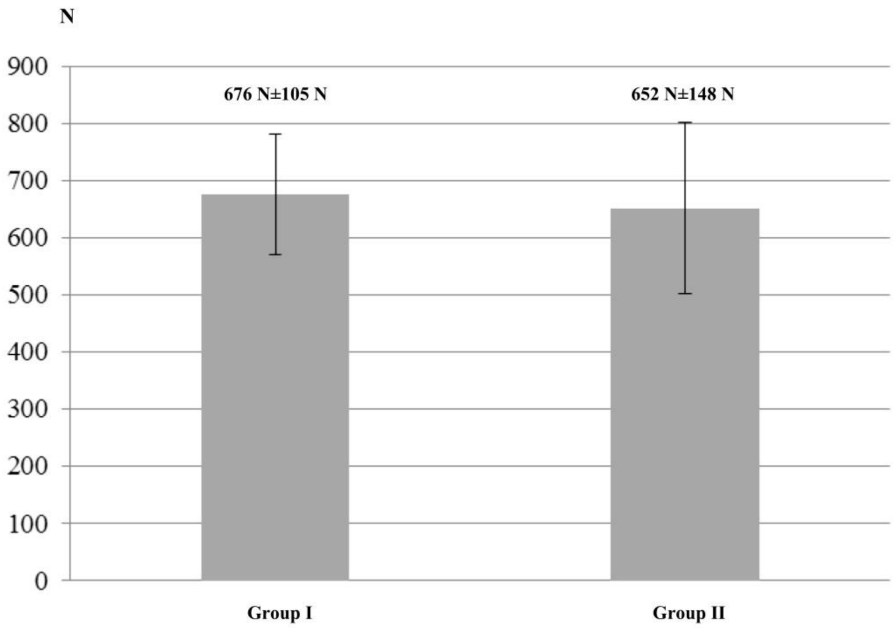

Figure 2 Mean and standard deviation values of fracture resistance (N)

Previous studies have shown that the use of accessory fiber posts can increase the total post diameter, creating better stress distribution and higher resistance to fracture compared with using a single FRC post (Li et al., 2011). However, in the present study, the fracture resistance in the single FRC post (Group I) and the accessory fiber post technique (Group II) was not significantly different. This result may be because the specimens were restored using an FRC post with or without an accessory fiber post in combination with MultiCore Flow (MC) which utilizes resin composite core materials. MC was used for luting the fiber posts and core build-up at the same time without the need for resin cement. In contrast, Silva et al. (2011) demonstrated that the fracture resistance of non-ferruled and flared ETT restored with a single FRC post was significantly lower compared with those of teeth restored with an FRC post with accessory fiber posts. However, this study used flared ETT, which may have resulted in a larger cement space compared with the present study. Because the spaces between the root canal walls and the single FRC post are filled by luting cement, which is the weakest point between the tooth and post-core complex, a large amount of luting cement compromises the long-term success of a restoration (Silva et al., 2011; Zogheib et al., 2008).

In compromised ETT, the strength of the core material affects the long-term success of a restoration (Ahn & Sorensen, 2003). The manufacturers describe MC as a dual-curing, fluoride-containing composite with a low consistency. The amount of filler in MC is 70 wt%. The amount of filler is positively correlated with the flexural modulus and fracture resistance of resin composite core materials (Panitiwat & Salimee, 2017; Silva et al., 2011). Thus, both methods resulted in similar fracture resistance.

The use of a highly filled flowable resin composite core material can strengthen the remaining root structure (Panitiwat & Salimee, 2017; Puengpaiboon, Padipatvuthikul, & Vetviriyakul, 2015). These materials integrate better with the FRC post by reducing the incidence of bubbles and voids within the post-core interface and/or within the core structure (Monticelli et al., 2005). Moreover, they also penetrate into undercut root canal areas. The bubbles and voids in the post-core complex compromise the integrity of the post and core restoration (Akkayan & Gulmez, 2002). Because this was an in vitro study, all restorative methods were optimally performed to restore the specimens followed by radiographic evaluation to ensure that the material and root canal walls were well adapted in each specimen.

In the present study, the specimens were decoronated at the CEJ with a uniform remaining dentinal wall thickness to eliminate the effect of a crown ferrule followed by different FRC post techniques so that effect of the post and core complex on the fracture resistance of the specimens could be isolated. However, the similar fracture resistance for both restorative methods might be the consequence of the similar remaining dentinal wall thickness of the specimens (de Oliveira et al., 2008; Zogheib et al., 2008). The thickness of the remaining dentin is the predominant factor in maintaining fracture resistance (Zogheib et al., 2008). A crown ferrule does not influence the fracture resistance when using an FRC post in combination with resin bonding techniques because the similarity of the elastic modulus between resin, FRC post, and dentin enhanced the potential for stress distribution to the remaining dentin (al-Hazaimeh & Gutteridge, 2001; de Oliveira et al., 2008). Without a crown ferrule, the remaining dentinal wall thickness is more important in strengthening the remaining tooth structure compared with the restorative method (de Oliveira et al., 2008).

To simulate clinical restoration aging, the specimens were fatigued using a cyclic loading of 1.2 million cycles, simulating five years of clinical service (DeLong & Douglas, 1983; Nie et al., 2012). No specimens failed during cyclic loading. The average maximum bite force for lower first premolar in healthy young adults is 254 N for males and 178 N for females (Ferrario et al., 2004). However, the failure loads of all specimens were higher compared with average maximum bite force of lower first premolar.

The limitation of the study is that the type of loading does not simulate actual loading of mastication. For this reason, the results of this study should be carefully interpreted. Prospective clinical studies comparing these groups should be observed to confirm these results.

6. Conclusion

All specimens restored with either single FRC post or FRC post with an accessory fiber post survived the fatigue loading test and resulted in similar fracture resistance.

7. Acknowledgements

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8. References

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