Effect of Adapting Resin Composite to Fiber Post on Fracture Resistance and Fracture Mode In Endodontically Treated Teeth with Flared Root Canal

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Abstract

This in-vitro study was designed to determine the influence of post adaptability on fracture resistance and fracture mode of endodontically treated teeth (ETT) with a flared root canal. Extracted human single-root mandibular premolars were selected according to inclusion criteria. A total of twenty-four teeth were selected. Teeth were assigned into 3 groups of 8 each. After endodontic treatment, experimental groups received restorations according to their restorative approaches: ETT restored without fiber post (Control group), ETT restored with prefabricated D.T. Light-Post (Prefabricated group), and ETT restored with D.T. Light-Post, relined with resin composite (Anatomic group). All specimens were loaded at 45 degrees in a universal testing machine until failure. The fracture resistance data were analyzed using one-way ANOVA and the fracture mode was assessed using the Chi-square test. Results showed that the anatomic group presented statistically significantly higher fracture resistance than the prefabricated group and Control group ($p < 0.05$). The prefabricated group showed no statistically significant difference from the control group regarding fracture resistance. For failure mode, there was no statistically significant difference among all groups. The control and prefabricated groups showed specimens with irreparable fracture mode. Therefore, an anatomically customized post is a reliable fabrication technique to restore flared root canal of ETT for better adaptation and improved fracture resistance.

Keywords: *anatomically customized post, prefabricated fiber post, fracture resistance, fracture mode*

1. Introduction

The primary goal of dentistry has always been to preserve the natural tooth. However, when the tooth is devitalized by caries or trauma, endodontic treatment is needed to preserve the tooth. In the endodontically treated teeth (ETT) with substantial tooth structural loss, post and core are typically required to provide resistance and retention for the definitive restoration. While ETT retains biomechanical properties comparable to vital teeth in terms of modulus of elasticity and hardness (Cheron et al., 2011; Randow & Glantz, 1986; Sedgley & Messer, 1992). A variety of factors, including the remaining tooth structure, restorative materials, and restoration technique are essential for the success and longevity of ETT restoration. Likewise, several studies have found that the prosthetic aspects are the most common cause of ETT failure (Olcay et al., 2018; Phang et al., 2020).

Numerous post materials and fabrication techniques have been proposed to replace missing tooth structures, including metal alloy cast posts and fiber-reinforced posts (McLaren et al., 2009; Ozyurek et al., 2020). In the past, a metal cast post was introduced to restore ETT with extensive tooth structure loss. Since the intimate adaptation of the metal cast post to the residual root conformity promotes ETT fracture resistance. Due to the high fracture resistance of metal alloy cast posts, they have become a standard procedure for restoration. However, studies showed that metal cast post had many concerns including the stiffness of the cast metal alloy post, stress distribution, irreparable fracture, and unpleasant esthetic appearance (F et al., 2014; Sorensen & Martinoff, 1984).

With the previously mentioned concerns of metal cast post and the increasing esthetic demands, fiber-reinforced resin composite (FRC) post has been developed as an alternative treatment. FRC post presents several advantages, including pleasing color, ease of manipulation, reduced chair time, and cost-effectiveness. FRC post has a similar modulus of elasticity to dentin that offers a more even distribution of stress on the remaining radicular dentin when compared with a stiffer material such as metal cast post

(Abduljawad et al., 2016; D'Arcangelo et al., 2007; McLaren et al., 2009). Fiber posts also produced convincing outcomes in previous clinical trial studies (da Costa et al., 2011; Gomes et al., 2016). Contrary to metal cast posts, prefabricated fiber posts typically do not conform well to the post space, particularly in cases of wide and significant flared root canals. Mismatch of post and post space results in a higher chance of errors and failures in cement layers of ETT restoration. (Rocha et al., 2017; Tay & Pashley, 2007). From numerous fiber posts available today, D.T. Light-post (RTD Dental, Saint-Egrève, France) is a widely accepted system. A study about fatigue resistance in various post systems has shown that D.T. Light-post presented a high level of fatigue resistance and success outcome (Grandini et al., 2005).

Multiple fabrication techniques have been proposed to improve the fiber post's adaptation to the post space in ETT with flared root canal for higher retention and uniform cement layer. To reproduce the anatomy of the post space, indirect anatomical fiber post using an impression of the root canal and anatomically customized post adapting the fiber post with resin composite were among the techniques attempted (Falcao Spina et al., 2017; Gomes et al., 2014; Rocha et al., 2017; Silva et al., 2011). Relining fiber post with resin composite can achieve adaptation of fiber post to post space with less chair time and processes compared to conventional techniques. The technique exhibited high fracture resistance compared to other techniques such as accessory fiber post, filling post space with resin cement, and reinforcement of flared root canal with flowable resin composite (Clavijo et al., 2009; Sary et al., 2019; Silva et al., 2011). Despite the diversity of proposed fabrication techniques, there is no consensus concerning which option is the appropriate approach. Therefore, this study was designed to analyze the fracture resistance and fracture mode of mandibular premolars in vitro using D.T. Light-Post with conventional and customized fabrication techniques.

2. Objectives

1. To compare the fracture resistance of ETT restored using fiber post with and without resin composite adaptation
2. To analyze the effect of adapting resin composite to fiber post on fracture mode of ETT

3. Materials and Methods

This study was approved by the ethical committee of the Faculty of Dentistry, Chulalongkorn University, Thailand.

3.1 Inclusion criteria

Human mandibular single-root premolars extracted less than 6 months were used in this study. The teeth were according to inclusion criteria, including teeth without cracks, caries, and restorations. Root canal condition was assessed with periapical film to exclude curved and open apex root canal. After measuring using a digital caliper (Mitutoyo Corporation, Kanagawa, Japan), teeth with a buccolingual root dimension of 7.0 ± 1.0 mm and length from the buccal cementoenamel junction (CEJ) to the apex of 14.0 ± 1.0 mm were chosen. The number of samples was calculated using the G*Power program and data from a previous study (Sary et al., 2019), resulting in a suggested total sample size of at least 24. Thus, a total of 24 teeth were selected. Following that, the teeth were cleaned with an ultrasonic scaler to remove calculus and soft tissue. The teeth were then stored in distilled water for storage.

3.2 Specimen preparation

The crown of the tooth was sectioned perpendicular to the tooth axis 2 mm above buccal CEJ. For the endodontic treatment procedure, ProTaper Next rotary system (Dentsply Sirona, North Carolina, USA) was used. Root canal preparation was performed at a working length of 1 mm from the apical foramen using 21 mm M-Wire NiTi rotary files (Dentsply Sirona, North Carolina, USA) with X-Smart endodontic rotary motor (Dentsply Sirona, North Carolina, USA). The root canals were irrigated with 2.5% sodium hypochlorite (NaOCl) during each instrumentation. 17% ethylenediaminetetraacetic acid (EDTA) solution was applied for 1 minute after root canal instrumentation was completed. Canals were flushed with 2.5% sodium hydroxide and normal saline solution to eliminate any residual EDTA and dried with paper points. Gutta-percha

(Dentsply Maillefer, Ballaigues, Switzerland) and AH Plus Jet non-eugenol sealer (Dentsply Maillefer, Ballaigues, Switzerland) were used to obturate the root canals with the lateral condensation technique. Following that, teeth were stored in distilled water for 24 hours at 37°C.

For post space preparation, gutta-percha was removed using a Gates-Glidden drill (Dentsply Maillefer, Ballaigues, Switzerland), leaving 5 mm for apical seal. With the aid of a digital caliper and periapical films, flared root canal with a standardized radicular dentin wall of 2 mm at cervical was achieved using high-speed no.8850 taper diamond bur (Komet, South Carolina, USA) as shown in Figure 1. Size #1 D.T. Light-Post (Quartz Fiber, Double-tapered, Ø=1.5 mm at cervical, 0.9 mm at apical) was used in this study. Post space was prepared in accordance with the manufacturer's specifications at 5 mm from the root apex. The roots' outer surface was coated with a thin coating of polyvinyl siloxane 2 mm below the buccal CEJ to simulate the periodontal ligament. The roots were embedded perpendicular to the horizontal axis in acrylic resin using a polyvinyl chloride (PVC) ring. After that, all specimens were immersed in water to avoid overheating due to polymerization. Specimens were kept for 24 hours before restoration.

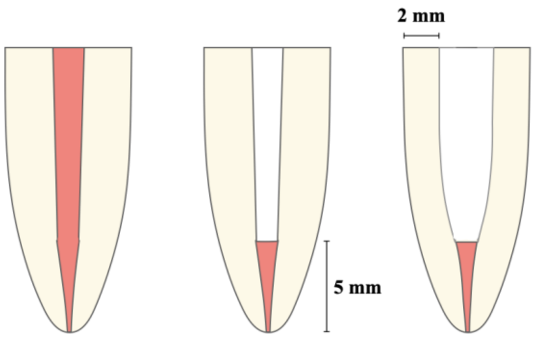

Figure 1 Illustrating procedures of gutta-percha removal and post space preparation

3.3 Restoration

The specimens were categorized into 3 groups of 8 samples in each group. experimental groups were restored according to their restorative approaches.

Control group: specimens were restored without fiber posts. Built-it FR fiber reinforced core material (Kerr, California, USA) was used to fill the post space.

Prefabricated group: specimens were restored using size #1 prefabricated D.T. Light-Post.

Anatomic group: specimens were restored using size #1 prefabricated D.T. Light-Post relined with Filtek Z350XT resin composite (3M ESPE, Minnesota, United States).

For the adhesive procedure, dentin was etched with 37% phosphoric acid for 15 seconds and then rinsed abundantly. To eliminate moisture, teeth were gently air blown and paper points were applied. The Optibond Solo Plus adhesive (Kerr, California, USA) was applied to post space and post surface for 15 seconds according to the manufacturer. The excess adhesive was removed using a dry applicator brush. Following that, the tooth was light-cured for 20 seconds. The NX3 Nexus Third Generation dual-cure adhesive resin cement (Kerr, California, USA) was used for cementation in the prefabricated group and anatomic group. Cotton pellets were used to remove excess cement and the specimens were light-cured for a minimum of 20 seconds. Following post-cementation, a 3.5 mm standardized core was built with Built-it FR fiber reinforced core material (Kerr, California, USA). The specimens were kept in distilled water for 7 days at 37 °C prior to fracture testing.

For the anatomic group, KY gel water-based lubricant (Reckitt, Berkshire, England) was used to lubricate the post space. The adhesive was applied to the post surface, Filtek Z350XT resin composite was relined onto the fiber post and placed into the post space. After that, the post was light-cured for 20 seconds within the post space. The post was then withdrawn from the canal for an additional 20 seconds of light-curing to complete the polymerization process. Then, the post was cleaned with water and alcohol. Following that, the post relined with resin composite was cemented using the same protocol as the prefabricated group.

3.4 Fracture resistance test

Lloyd LR 10K universal testing machine (Lloyd Instruments Ltd, West Sussex, UK) was used to test fracture resistance in this study. The specimen was mounted at a 45° angle to the root's axis. Stainless steel testing rod with a round tip of 2.0 mm in diameter at a crosshead speed of 0.5 mm/minute was applied at the linguo-occlusal surface of the core until fracture as shown in Figure 2.

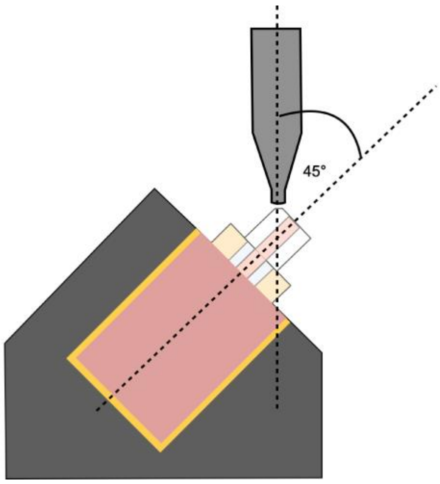

Figure 2 Illustration of the fracture resistance test set up of each sample at 45° off-axis until fracture

3.5 Fracture mode

All specimens were evaluated to identify the type and position of the fracture of ETT. The tooth fractures in the cervical third were classified as reparable. Fractures in the middle and apical third of the ETT were classified as irreparable.

3.6 Statistical analysis

Statistical analysis was performed by SPSS 20.0 software (SPSS Inc, Illinois, USA). Data distribution was assessed using a normality test. One-Way ANOVA was used to analyze fracture resistance in each sample group. A Chi-square test was used to analyze fracture mode.

4. Results and Discussion

4.1 Results

Fracture resistance data presented normal distribution and was recorded in Newtons (N). The mean fracture resistance and standard deviation of each experimental group were shown in Table 1. The fracture resistance of the anatomic group was statistically significantly higher than other groups ($p < 0.05$). The Control group presented the lowest fracture resistance. However, the Prefabricated group showed no statistically significant difference from the control group ($p > 0.05$).

Table 1 Mean and standard deviation of fracture resistance (N) in each group

Study groups	**N**	**Mean(N) / SD**	**Min, Max**
Control	8	584.5 ± 24.8^{1}	555.9, 618.4
Prefabricated	8	615.4 ± 32.8^{1}	575.3, 663.6
Anatomic	8	675.9 ± 47.3^{2}	625.4, 747.7

The same superscript number indicated no statistically significant difference, analyzed by One-Way ANOVA and Tukey HSD post-hoc test ($p > 0.05$).

The fracture mode in each study group was shown in Table 2. Of all the fractures found, 87.5% of the fractures showed to be reparable. One sample (12.5%) in the prefabricated group was reported with irreparable fracture mode. While two samples (25%) in the Control group exhibited irreparable fracture mode. The Chi-square test showed no statistically significant difference in failure mode in all groups (p = 0.319).

Table 2 Number and percentage of failure modes in each study group

Study groups	**Number (Percentage within the group)**	
	Reparable	**Irreparable**
Control	6 (75)	2 (25)
Prefabricated	7 (87.5)	1 (12.5)
Anatomic	8 (100)	0 (0)

Pearson Chi-Square test showed no statistically significant difference in failure modes (p = 0.319).

4.2 Discussion

While endodontic treatment is needed to preserve the devitalized tooth. Prosthetic restoration is the key factor for long-term successful treatment outcomes in ETT restoration, especially in flared root canals (Olcay et al., 2018; Phang et al., 2020) due to various difficulties found in ETT restoration, including the decreased remaining dentin, technique sensitive procedures, and the mismatch between the post space and the diameter of prefabricated fiber post (Barcellos et al., 2013; McLaren et al., 2009; Sary et al., 2019). In this study, different fabrication techniques have been utilized to discover an appropriate solution to the mentioned concerns. From the results of this research, there was a statistically significant higher fracture resistance found in the anatomic group. Therefore, the assumption that adapting resin composite to prefabricated fiber post would provide a beneficial effect was demonstrated.

Regarding fracture resistance, the lowest fracture resistance was found in the control group at 584.5±24.8 N. While the highest fracture resistance was 675.9 ± 47.3 N in the anatomic group. The statistically significant increase in mean fracture resistance observed in the anatomic group could be attributed to the close and even contact between the anatomically customized post and the post space, contributing to improved frictional retention that could help provide stability of restoration under occlusal loading. Increased frictional retention and stability of the post-restoration, together with the similar modulus of elasticity of the materials used in the restoration, resulted in a more uniform stress distribution throughout the post and remaining dentin complex. Also, the consistent contact of the post to the post space showed to result in a greater sustained seating pressure throughout cementation. This seating pressure was reported to create higher-quality adhesive interfaces and less risk of defects in the cement layer compared to using prefabricated fiber posts (Chieffi et al., 2007). All the mentioned advantages and higher fracture resistance in the anatomically customized post could mean less chance of failure of ETT restoration under occlusal loading.

Likewise, numerous research supported that anatomically customized posts have a positive direct influence on ETT restoration, regarding fracture resistance, bond strength, and stress distribution pattern (Anchieta et al., 2012; D'Arcangelo et al., 2007; Faria-e-Silva et al., 2009; Sary et al., 2019; Silva et al., 2011; Xiong et al., 2015). Furthermore, case report studies showed successful outcomes of this fabrication technique in a three-year follow-up period (da Costa et al., 2011; Gomes et al., 2016). On the other hand, a study observed no statistically significant difference in fracture resistance among restoration with different post-adaptation to post space (Buttel et al., 2009). Nonetheless, in the mentioned research, the gap between post diameter and post space was different from the current study.

In the prefabricated group, a statistically significant lower fracture resistance was found as there was a great mismatch between the size of the post and the post space. Contrary to the anatomic group, prefabricated posts in flared root canals presented a thick and uneven cement layer. This inconsistent cement layer increased the probability of errors in both adhesive and cement. These defects could further complicate restoration and lead to failure of the restoration. A previous study showed that there was a larger area of air bubbles in the cement layer when restoring ETT with prefabricated fiber post with a thick layer of resin cement compared to customized fiber post with resin composite (Rocha et al., 2017). This statement also corroborated with other studies indicating that one of the most prevalent reasons for ETT restoration failures using prefabricated fiber posts was an adhesive failure (Olcay et al., 2018; Phang et al., 2020).

Regarding failure mode, two specimens from the control group and one specimen from the prefabricated group were irreparable as the fracture exceed the cervical third of the root. While all the samples in the anatomic group resulted in reparable failure mode. However, there was no statistically significant difference in failure mode among all groups. This might be explained by the previously mentioned advantages of the anatomically customized post. Remaining radicular dentin was another important factor involving the fracture resistance and failure mode as reported in previous studies (Sary et al., 2019; von Stein-Lausnitz et al., 2019). In the present study, the indifferent failure mode found across all groups could be attributed to the 2 mm of remaining radicular dentin at a cervical area in this study, which is aligned with a previous study stating that 2 mm of remaining dentin resulted in no significantly different regarding failure mode of ETT in various restoration techniques (Barcellos et al., 2013). Nevertheless, Past research has shown the fiber post's superior stress distribution pattern and reparable failure mode compared to stiffer materials (Mezzomo et al., 2011; Negreiros et al., 2017; Verissimo et al., 2014). In the present study, fiber post was not received surface treatment as there was still controversy about the beneficial effect (Imai et al., 2021).

The remaining radicular dentin was another essential factor in ETT restoration. A study presented that different radicular dentin thickness would affect the fracture resistance of ETT restoration as the higher fracture resistance was found in the non-flared root (Sary et al., 2019). While some studies showed no difference in fracture resistance of ETT restoring with fiber post regarding different radicular dentin thickness (Barcellos et al., 2013; Silva et al., 2011). In the current study, 2 mm of remaining radicular dentin was performed to minimize the contributing factor involving the outcome of the fabrication techniques.

This current research was conducted in vitro and did not take place in an intraoral environment. The temperature and humidity levels were not representative of a real clinical setting. The load was applied in only one direction and angle. Further study may include the addition of more samples, the use of alternative fabrication procedures, and artificial saliva bath, and fatigue resistance testing.

5. Conclusion

Within the limitation of this study, the results suggested that fiber post relined with resin composite demonstrated significantly higher fracture resistance than prefabricated post and without a post. While using only prefabricated fiber post did not present significant benefit on fracture resistance and failure mode compared to restoring without a post. Therefore, it is advised that anatomically customized posts be used to restore the flared root canal of the ETT for enhanced adaptation and fracture resistance.

6. Acknowledgements

No conflict of interest

7. References

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