การเปรียบเทียบความต้านทานต่อการแตกหักของฟันรักษารากที่มีขนาดคลองรากฟันกว้างมาก (ผนังคลองรากฟันบาง) เมื่อใช้เดือยไฟเบอร์จำนวนต่างๆ กัน

COMPARISON OF FRACTURE RESISTANCE OF ENDODONTICALLY TREATED TEETH WITH FLARED ROOT CANAL, RESTORED WITH DIFFERENT NUMBER OF FIBER POSTS

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บทคัดย่อ

ฟันที่ผ่านการรักษารากฟันที่มีคลองรากที่ผายออกมาก ผนังคลองรากฟันบาง เป็นฟันที่มีความเสี่ยงต่อการแตกหักสูงกว่าฟันที่ผ่านการรักษารากฟันทั่วไป มีผู้เสนอวิธีการบูรณะด้วยการก่อแกนด้วยเรซินคอมพอสิตทั้งหมด การใช้เส้นใยแก้วสำเร็จรูปร่วมกับเรซินคอมพอสิต หรือการใช้เดือยฟันไฟเบอร์ร่วมกับการก่อแกนด้วยเรซินคอมพอสิต มาใช้เพื่อเสริมความแข็งแรงของผนังเนื้อฟัน งานวิจัยนี้มีวัตถุประสงค์เพื่อเปรียบเทียบความต้านทานต่อการแตกหักของฟันลักษณะดังกล่าวโดยใช้เรซินคอมพอสิตยึดเดือยฟันไฟเบอร์พร้อมกับก่อแกนฟันเป็นวัสดุเดียวกัน และใส่เดือยไฟเบอร์เสริมในส่วนคลองรากที่ผายออกเป็นจำนวนต่างๆ กัน

แบ่งฟันกรามน้อยล่างซี่ที่หนึ่งที่ผ่านการรักษารากแล้วออกเป็น 3 กลุ่ม กลุ่มละ 5 ซี่ โดยกลุ่มที่ 1 เป็นกลุ่มควบคุมบูรณะด้วยเรซินคอมพอสิตก่อแกนฟัน (Multicore Flow) กลุ่มที่ 2 บูรณะด้วยเดือยฟันไฟเบอร์ 3 จำนวน 1 อัน ร่วมกับการก่อแกนฟันด้วยเรซินคอมพอสิต (FRC Postec Plus No.3, Multicore Flow) และกลุ่มที่ 3 บูรณะด้วยเดือยฟัน ไฟเบอร์เบอร์ 3 จำนวน 1 อัน เบอร์ 0 จำนวน 2 อัน ร่วมกับการก่อแกนฟันด้วยเรซินคอมพอสิต (FRC Postec Plus No.3 & No.0 , Multicore Flow) แล้วทำครอบฟันโลหะทั้ง 3 กลุ่ม จากนั้นทำการทดสอบโดยใช้เครื่องทดสอบอเนกประสงค์ (Universal testing machine: static, LLOYD, Model LR10K) ใส่แรงกดทำมุม 135 องศา กับแนวแกนฟันจนกระทั่งฟันแตก โดยใช้ความเร็วหัวกด เท่ากับ 1 มิลลิเมตร/นาที

ผลการวิจัยพบว่า ค่าเฉลี่ยของแรงที่ทำให้เกิดการแตกในกลุ่มที่ 1 มีค่า 361.80 $\pm$ 93.16 นิวตัน กลุ่มที่ 2 มีค่า 559.46 $\pm$ 155.12 นิวตัน และกลุ่มที่ 3 มีค่า 468.48 $\pm$ 155.17 นิวตัน จากผลการวิเคราะห์ข้อมูลด้วยสถิติวิเคราะห์ความแปรปรวนทางเดียว (One-way ANOVA) พบว่าทั้ง 3 กลุ่มไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติ ($P>0.05$)

การบูรณะฟันที่ผ่านการรักษารากฟันที่มีคลองรากฟันกว้าง ผนังคลองรากฟันบาง สามารถทำได้ด้วยการก่อแกนฟันด้วยเรซินคอมพอสิตเท่านั้น หรือจะใส่เดือยฟันไฟเบอร์ จำนวน 1 หรือ 3 อัน ร่วมกับการก่อแกนด้วยเรซินคอมพอสิต ซึ่งไม่ว่าจะบูรณะด้วยวิธีใด ต่างก็ไม่ได้ให้ความแตกต่างของความต้านทานต่อการแตกหักของฟันลักษณะดังกล่าว

คำสำคัญ: เดือยฟันไฟเบอร์ เรซินคอมพอสิต ความต้านทานต่อการแตกหัก ฟันที่ผ่านการรักษารากฟันที่มีคลองรากฟันกว้าง

Abstract

Endodontically treated tooth with flared root canal poses the greater risk of fracture than the tooth undergone regular endodontic treatment. In order to increase success rate of restoration, several researchers proposed different solutions; building up the whole tooth structure with resin composite core material, resin composite core in combination with preformed glass fibers, or resin composite core in combination with a fiber post to strengthen the tooth structure. However, the solution with the single fiber post in flared root canal resulted in excessive resin cement in the flared root canal that may weaken the tooth structure. Objective: The purpose of this study was to compare the fracture resistance of endodontically treated teeth with flared root canals restored with different number of fiber post.

Method: Fifteen mandibular first premolar teeth were endodontically treated and divided into 3 groups of 5. Group 1 was the control, restored with a resin composite core material (Multicore Flow), Group 2 was restored with a single fiber post and resin composite core (FRC Postec Plus No.3, Multicore Flow), and Group 3 was restored with 3 fiber posts and resin composite core (1 FRC Postec Plus No.3 and 2 fiber posts No.0, Multicore Flow). Samples from all groups were then restored with metal crowns. They were tested at 135 degree angulation in respect to the longitudinal axis of the teeth using a Universal testing machine (LLOYD, Model LR10K) in compressive mode at a crosshead speed of 1 mm/min.

Result: The average fracture resistances were as follows: Group 1: 361.80 $\pm$ 93.16 N, Group 2: 559.46 $\pm$ 155.12 N, Group 3: 468.48 $\pm$ 155.17 N. Data were analyzed using One-way ANOVA, showing no statistical difference between groups ($P > 0.05$).

Conclusion: Endodontically treated teeth can be restored with either resin composite core alone or resin composite core combined with 1 or 3 fiber posts. These three methods gave no significant difference in fracture resistance of the teeth.

Keywords: Fiber Post, Resin Composite, Fracture Resistance, Endodontically Treated Tooth with Flared Root Canal

Introduction

Restoring endodontically treated teeth, particularly when the tooth structure and the root are weakened, remains a challenge [1-5]. The characteristics of the interface between restorative materials and dental structure [6], given the rigidity of the restorative materials, strongly influence the mechanical behavior of endodontically treated teeth [1,6-8].

Cast posts and core were regarded as the treatment of choice for endodontically treated teeth, without considering the quantity and quality of the remaining tooth tissue (9). Although they offer a good fit to the root canal, these posts present only frictional retention in said canal, which represents a danger for the root and may eventually lead to catastrophic root fracture caused by an heightened stiffness in homogeneity between metal and dentine [1,6-10].

For this reason, prefabricated glass fiber posts have been used as a substitute for custom metallic posts in the last decade [2-5,10]. Glass fiber posts have a modulus of elasticity that is closer to that of dentin [1,11], and when bonded with dentin provide adequate stress distribution on the tooth and may decrease the incidence of catastrophic root fractures [1,6,7,10].

The quantity of coronal and root dentin that remains after root canal treatment and post space preparation plays an important role in the resulting longevity of the tooth and restoration [2-5,7,10]. Roots can become weakened if flared, as a result of recurrent caries into the root dentin around the post, over-preparation and instrumentation of the root canal [1,2-5]. Flared root canals have thin dentin walls that are too weak to withstand normal masticatory forces and end up being susceptible to fractures [2-5]. The morphology of flared canals also results in very wide, tapered and non retentive posts. In these situations, if a prefabricated post is used the excess space within the root canal will be filled up with a bulk of luting cement. This results in a potentially weak area in the restoration, which may end-up compromising the long-term prognosis [2-5]. Filling the radicular space with restorative materials such as a glass-ionomer cement [11], composite resins [1-5,11], or accessory glass fiber posts [6,7] therefore has been suggested as a solution to reduce the incidence of failure.

Objectives

The aim of this study is to investigate and compare the fracture resistance of endodontically treated teeth with flared root canals restored with different number of fiber post. The stated hypothesis is that the number of post influences the fracture resistance of endodontically treated tooth.

Methods

Human mandibular single-root premolars (extracted for orthodontic reasons) were collected and kept in 0.2% phosphate buffered saline mixed with Sodium Azide. Fifteen teeth were carefully selected by measuring bucco-lingual, mesio-distal width, and root length to recruit the teeth with similar

dimension, allowing maximum deviation of 1 millimeter. The teeth with craze line, cervical caries and cervical abrasion were discarded. Calculus and all deposits were removed with an ultrasonic scaler. The coronal portion of each tooth was cut 5 mm above the cemento-enamel junction, to simulate 3 mm biologic width and 2 mm ferrule height. 1 mm width of chamfer finish line was then prepared at the cemento-enamel junction.

All teeth were mounted parallel to their longitudinal axis in clear epoxy resin to form specimen blocks. All specimens were endodontically treated using K file (Mani Inc., Tochigi Ken, Japan) with master apical file (MAF) no.35 and using stepback technique. The coronal portion was flared with K file until no.80. The root canals were filled with guttapercha and eugenol free root canal sealer, and stored in a container at room temperature with 100% relative humidity for 24 hours. Then the guttapercha was removed using gate glidden drills no.3, 10 mm from the orifice, 4 mm of guttapercha was left for apical seal. All samples were prepared for post space using FRC Postec Plus reamer size 3 that had the same diameter as glass fiber post no.3 (FRC Postec plus, IvoclarVivadent, Liechtenstein). The over-preparation of root canal at middle third and coronal third was flared by milling machine and 2 degree tapered-diamond burs NTI (SCHICK DentalgerateS3Master, Germany, figure 1). The circumferential ferrule was maintained 2 mm in height and thickness. Dimension of the post space are shown in figure 2.



Figure 1: Milling machine (SCHICK Dentalgerate S3 Master, Germany)

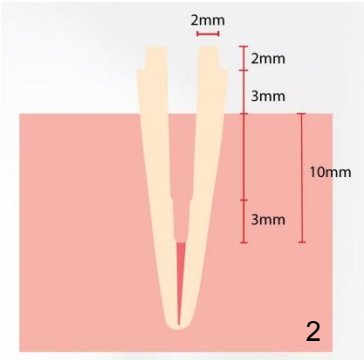


Figure 2: Dimension of the post space of all specimens prepared by milling machine.

The specimens were randomly assigned into 3 experimental groups (n=5) which were restored with different protocols as shown in Table 1 and figure 3.

Table 1: Three experimental groups and their restorative protocol

Group 1	Excite DSC, Multicore Flow
Group 2	Excite DSC, Monobond S, 1 glass fiber post (FRC Postec Plus no.3)
Group 3	Excite DSC, Monobond S, 1 glass fiber post (FRC Postec Plus no.3) and 2 glass fiber posts (FRC Postec Plus no.0)

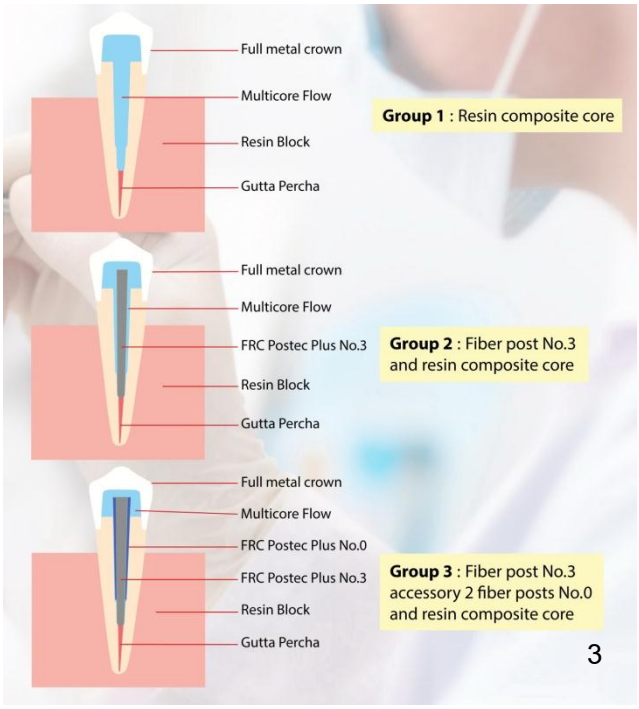
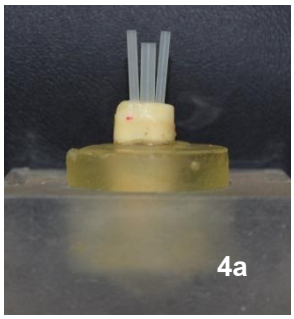


Figure 3: restorative protocols for 3 experimental groups

The root dentin of each specimen was prepared with 37% phosphoric acid then an adhesive system (Excite DSC) was applied according to the manufacturer instruction. For group 1, Multicore flow was injected in the prepared post space to form the composite core. For group 2, the fiber post was applied with Monobond S, then a fiber post no.3 was tried in the canal, luted and fixed with Multicore flow. For group 3, a fiber post no.3 and 2 fiber posts no.0 were tried in (Figure 4a) and fixed with Multicore flow simultaneously. Multicore flow was also used to form 3 mm composite core above the ferrule as shown in Figure 4b.



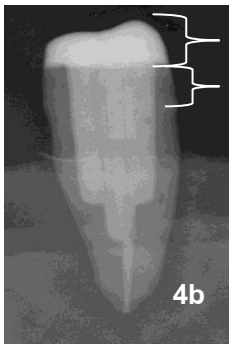


Figure 4a: A specimen in group 3 when trying 3 fiber posts.

Figure 4b: A radiograph of group 3 specimen after 3 fiber posts were fixed and composite core built up.

Specimen preparation for crown and crown fabrication

The teeth were prepared for restoring with full metal crowns. Wax patterns of all lower premolars full metal crowns were fabricated from a silicone mold in order to have a similar crown dimension. Buccal cusp was cut to achieve 2 mm flat area corresponding to the head of load cell. The wax patterns were cast to produce full metal crowns using nickel-chromium alloy (Wiron99® Bego, Germany). Then the crowns were tried in and fixed on all specimens with zinc phosphate cement.

Fracture resistance test

All specimens were statically loaded with 10 kN load cell in the Universal Testing Machine (LLOYD, Model LR10K) using cross head speed of 1 mm/ minute at 135 degree to longitudinal axis of the tooth (figure 5a, 5b). The load was increased until the teeth were fractured and the force required to cause fracture was recorded. The data were analyzed by one-way ANOVA and Scheffe multiple comparison test. The fracture sites were also investigated by visual examination and classified to 3 levels (for each tooth, the length of the root was measured from CEJ to the root apex and divided by 3, this length was used to divide the root into 3 sections); 1. Fracture at the cervical third: site of fracture is within the cervical 1/3 of root length, 2. Fracture at the middle third: site of fracture is within the middle 1/3 of root length, and 3. Fracture at the apical third: site of fracture is within the apical 1/3 of root length.



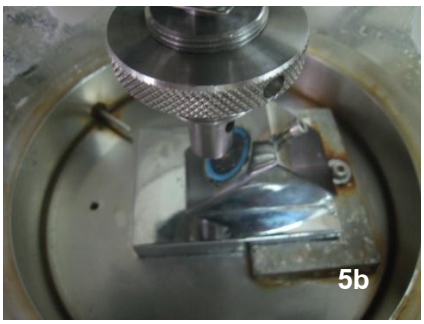


Figure 5a: The specimen restored with full metal crown mounting at 135 degree before testing in the Universal Testing Machine.

Figure 5b: The head of load cell was aligned 135 degree to longitudinal axis of the tooth.

Results

Table 2 shows the results of maximum compressive load (N) of each experimental group. Group 1 has an average maximum compressive load of 361.8 N and most of the specimens fractured at the cervical third area, only one specimen fractured at the junction between middle and cervical third of the root. Group 2 has an average maximum compressive load of 559.46 N, all specimens fractured at the middle third area. All the fiber posts were not fractured in this group, only some crack and craze lines of the post were observed. Group 3 has an average maximum compressive load of 468.48 N, and 4 of the specimens fractured at middle third, only one specimen fractured at apical third of the root. The fiber posts were not fractured except 1 post that was fractured at the apical third of the post.

Results from the statistical analysis showed that group 2 has the strongest fracture resistance to compressive load (559.46 N) and group 1 has the weakest fracture resistance to compressive load (361.80 N). However, an analysis with one-way ANOVA and multiple comparison tests showed no significant difference between three groups ($P > 0.05$).

Table 2: Average maximum compressive load (N) and Standard deviation of each experimental group

Group	Average maximum compressive load (N)	Standard deviation
1	361.80	93.16
2	559.46	155.12
3	468.48	155.57

Table 3: Fracture site of each experimental group

Fracture site	Group 1	Group 2	Group 3
Cervical 1/3 of the root	4	-	-
Junction between cervical 1/3 and middle 1/3 of the root	1	-	-
Middle 1/3 of the root	-	5	4
Apical 1/3 of the root	-	-	1



Figure 6: Fractured specimens from Group 1



Figure 7: Fractured specimens from Group 2



Figure 8: Fractured specimens from Group 3

Conclusions and Discussion

The aim of this laboratory study was to investigate and compare the fracture resistance of endodontically treated teeth with flared root canal, restored using different restorative techniques. The results of the study showed that the group restored with a fiber post and composite core has the strongest fracture resistance to compressive load, while the group restored with composite core alone has the weakest fracture resistance. Interestingly, additional accessory posts did not improve the fracture resistance of flared roots. However, no significant difference between these three groups was found at P = 0.05. Therefore the hypothesis of this study: the number of post influences the fracture resistance, and failure site of flared roots, were rejected.

The majority of endodontic treatments are performed on teeth significantly affected by caries, and therefore already structurally weakened. The teeth are then further weakened by endodontic treatment procedures and the loss of inherent dentinal fluid. As a result, they require special considerations for the final restoration, in order to prolong their longevity [9-12].

The custom cast posts have been widely used for many years, and provide excellent clinical service. However, in recent years, prefabricated non-metallic posts have been introduced that include fiber posts, composite posts and zirconium posts, with evidence of relatively equal performance.

Direct post and core restorations can reduce both cost and time factors for the patient. A further advantage is the lack of necessity to remove additional dentine in order to remove undercuts, which further weakens the tooth. A recent systematic review suggested that the prefabricated post and core resulted in fewer failures than the conventional cast post and core system [13]. Several literature review and clinical studies also support the effectiveness of prefabricated posts [14-16].

Despite a large number of literature, controversy remains in the area of post application. A number of in-vitro studies have compared different types of posts, core materials and luting cements [12,17-22]. It is now accepted that posts may help reinforce the remaining tooth structure [9,17-18]. However, it should be noted that inappropriate post usage and improper post space preparation can significantly weaken the root, and lead to failure of the final restorations.

The decision in regards to the need for a post will depend on the size and position of the tooth in the arch, the amount of coronal tooth structure remaining, the functional requirements of the tooth, as well as the root canal configuration [11,12,17-19]. Posts also provide retention for the core restoration and can contribute to the reinforcement of endodontically treated teeth by supporting the remaining coronal tooth structure [9,10,17-19].

In the evaluation of the relationship between filling techniques, it was observed that endodontically treated teeth with flared roots filled with composite resin and/or accessory glass fiber posts presented a lower incidence

of catastrophic fractures compared with cast posts and core groups. This was probably due to the similarity between the elastic modulus of dentin (15-25 GPa), glass fiber posts (30-40 GPa), and composite resin (20 GPa). The values of the modulus of elasticity resulted in a biomechanical homogeneity unit. Because of the low modulus of elasticity of these materials, these might act as shock absorbers and increase the fracture resistance of the tooth. However, in this study, the endodontically treated teeth with flared root canal restored with resin composite core material alone (group 1) showed cervical third root fracture making them amenable to retreatment, whereas the teeth restored with a single glass fiber post and composite core (Group 2) demonstrated all middle third root fractures and the teeth restored with 3 glass fiber posts and composite core demonstrated middle and apical third root fractures making them non-restorable. Thus the restoration of endodontically treated tooth with flared root canal using resin composite core material alone could be a good policy preventing non-restorable fracture of the tooth.

In general, multi-root teeth have a greater chance of having thin root canal wall which is considered as a danger zone because it leads to greater risk of perforation during root canal preparation procedure as well as greater risk of tooth fracture after restoration [20,22]. In this study single-root premolar teeth were therefore chosen to avoid creating danger zones, which might have affected the fracture resistance results.

Limitations of the present study must be recognized, the results obtained show a rather high standard deviation, explained by the variation in root canal morphologies even though the teeth were carefully selected. Other reasons include the small sample size (n = 5), the age of teeth when extracted, unseen micro-fractures in the tooth structure and technical sensitivities of the sample preparation.

In addition, the fracture resistance value, obtained from a compressive test, may not be a good representative of the real clinical situation compared to the fatigue test. In the oral environment, the adhesive failure normally occurs as a result of cyclic loads associated with time and environmental factors such as temperature, pH, and microorganisms [23-24]. To determine the longevity of restorations, a controlled clinical trial would have been more suitable. However, the number of parameters influencing the interested results can be extremely large and can take an extremely long time and a large patient group for sufficient data to be collected. A solution to this problem could be in vitro investigations using cyclic fatigue loading, which simulates accelerated mechanical deterioration of the restoration [23-24]. Although time consuming, this test would be the most suitable test in order to obtain the most relevant results to the clinical situation.

Given the limitations of this study, one may conclude that using resin composite core alone, glass fiber post associated with composite core, or accessory fiber glass posts, seem to be an effective method to

improve the fracture resistance on flared root canals. Restoration with resin composite core alone however gave a favorable fracture site in this study. In addition, fatigue and clinical studies are necessary to clarify which are the best techniques and materials to recover the resistance to fracture of endodontically compromised teeth with flared root canals.

Acknowledgement

This research was supported by Faculty of Dentistry Grant (2008), Srinakharinwirot University.

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