ความต้านทานการแตกหักของฟันที่ได้รับการรักษาคลองรากที่มีและไม่มีเฟอร์รูลบูรณะด้วยเดือยฟันคอมโพสิตเสริมเส้นใยที่มีความยาวแตกต่างกัน

นายพรพจน์ เจียงกองโค

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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ปีการศึกษา 2554

FRACTURE RESISTANCE OF ENDODONTICALLY TREATED TEETH RESTORED WITH VARIOUS LENGTHS OF FIBER REINFORCED POST; WITH AND WITHOUT FERRULE

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Thesis Title	FRACTURE RESISTANCE OF ENDODONTICALLY TREATED TEETH RESTORED WITH VARIOUS LENGTHS OF FIBER REINFORCED POST; WITH AND WITHOUT FERRULE
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พรพจน์ เจียงกองโค : ความต้านทานการแตกหักของฟันที่ได้รับการรักษาคลองรากฟันที่มีและไม่มีเฟอร์รูลบูรณะด้วยเดือยฟันคอมโพสิตเสริมเส้นใยที่มีความยาวแตกต่างกัน (FRACTURE RESISTANCE OF ENDODONTICALLY TREATED TEETH RESTORED WITH VARIOUS LENGTHS OF FIBER REINFORCED POST; WITH AND WITHOUT FERRULE) อ. ที่ปรึกษาวิทยานิพนธ์หลัก: รศ.ทพ.ดร.แมนสรวง อักษรนุกิจ, 42 หน้า.

บทนำ ฟันที่รับการรักษาคลองรากฟันมักจะมีปริมาณเนื้อฟันบริเวณตัวฟันเหลือน้อย เฟอร์รูลเป็นสิ่งจำเป็นที่จะช่วยทำให้ฟันที่ได้รับการรักษาคลองรากมีความแข็งแรงมากยิ่งขึ้น แต่อย่างไรก็ตามจากการศึกษาพบว่าปริมาณเนื้อฟันที่เหลือเหนือจากขอบเขตการเตรียมฟันไม่ได้ทำให้ความต้านทานการแตกหักเพิ่มมากขึ้น นอกจากนี้การบูรณะฟันที่ได้รับการรักษาคลองรากด้วยเดือยฟันคอมโพสิต ร่วมกับการใส่ครอบฟันโลหะการที่จะมีหรือไม่มีเฟอร์รูลนั้นไม่ได้ทำให้ความต้านทานการแตกหักมีค่าแตกต่างกัน

วัตถุประสงค์ เพื่อศึกษาผลของความยาวเดือยฟันคอมโพสิตเสริมเส้นใยต่อค่าความต้านทานการแตกหักและเพื่อศึกษาผลของเฟอร์รูลและครอบฟันโลหะต่อค่าความต้านทานการแตกหัก

วัสดุและวิธีการ ในกลุ่มที่ทดสอบความยาวของเดือยฟันจะแบ่งเป็นสี่กลุ่มย่อย โดยมีตัวอย่างกลุ่มละ 6 ตัวอย่าง ดังนี้ สัดส่วนระหว่างความยาวของตัวฟันและเดือยฟัน 1:2 1:1 2:1 และกลุ่มฟันธรรมชาติที่มีการกรอแต่ง เป็นกลุ่ม 1 2 3 4 ตามลำดับ สำหรับกลุ่มที่ทดสอบเฟอร์รูลและการครอบฟันด้วยโลหะหรือการบูรณะด้วยคอมโพ-สิตเรซิน จะแบ่งเป็นสามกลุ่มย่อย ดังนี้ กลุ่มครอบฟันโลหะที่มีเฟอร์รูล กลุ่มครอบฟันโลหะที่ไม่มีเฟอร์รูล กลุ่มคอมโพสิตเรซินที่มีเฟอร์รูล และมีการรวมกลุ่ม สัดส่วนระหว่างความยาวของตัวฟันและเดือยฟัน 1:2 และกลุ่มฟันธรรมชาติที่มีการกรอแต่ง เข้ามาเปรียบเทียบด้วย ในกลุ่มทดลอง จะมีการบูรณะด้วยเดือยฟันคอมโพสิตเสริมเส้นใย มีรูปร่างขนาน เส้นผ่านศูนย์กลาง 1.5 มิลลิเมตร ยังมอดูลัส18 จิกะปาสคาล ยึดกับผนังคลองรากด้วยเรซินซีเมนต์พานาเวียเอฟ เนื้อฟันบริเวณคอฟันปรับสภาพด้วย สารบอนดิ้ง เคลียฟิลเอสอีบอนด์ ส่วนตัวฟันบูรณะด้วยคอมโพสิตเรซิน เคลียฟิลโฟโตคอร์ ครอบฟันยึดด้วย เรซินซีเมนต์พานาเวียเอฟ แรงกดชิ้นงานใช้เครื่องอินสตรอน

ผลการศึกษา ค่าความต้านทานการแตกหักในกลุ่มความยาวเดือยฟันมีค่าไม่แตกต่างกันอย่างมีนัยสำคัญทางสถิติ สัดส่วนระหว่างความยาวของตัวฟันและเดือยฟัน 1:2 เมื่อมีการแตกหักพบว่าจะสามารถบูรณะซ่อมแซมได้ นอกจากนี้ยังพบว่า กลุ่มครอบฟันที่มีเฟอร์รูลให้ค่าความต้านทานการแตกหักสูงที่สุดอย่างมีนัยสำคัญทางสถิติ

สรุปผลการศึกษา ความยาวของเดือยฟันไม่มีผลต่อค่าความต้านทานการแตกหัก แต่พบว่าสัดส่วนระหว่างความยาวของตัวฟันและเดือยฟัน 1:2 เมื่อมีการแตกหักพบว่า จะสามารถบูรณะซ่อมแซมได้ นอกจากนี้ยังพบว่า กลุ่มครอบฟันที่มีเฟอร์รูลให้ค่าความต้านทานการแตกหักสูงที่สุด

ภาควิชา ทันตกรรมประดิษฐ์ ลายมือชื่อนิสิต.......................................

สาขาวิชา ทันตกรรมประดิษฐ์ ลายมือชื่อ อ.ที่ปรึกวิทยานิพนธ์หลัก..........................

ปีการศึกษา 2554

5176120732: MAJOR PROSTHODONTICS

KEYWORDS: POST LENGTH/ FRACRURE RESISTANCE/ FIBER REINFORCED COMPOSITE POST/ FERRULE

PORNPOT JIANGKONGKHO: FRACTURE RESISTANCE OF ENDODONTICALLY TREATED TEETH RESTORED WITH VARIOUS LENGTHS OF FIBER REINFORCED POST; WITH AND WITHOUT FERRULE. ADVISOR: ASSOC. PROF. MANSUANG ARKSORNNUKIT, Ph.D., 42 pp.

Introduction: Endodontically treated teeth (ETT) often lack of coronal tooth structure. The ferrule effect has been shown to provide positive reinforcement to ETT by resisting the leverage of occlusal force. However, another study reported that the presence of tooth structure coronal to finishing lines did not enhance fracture resistance. Moreover, the restoration of FRC posts with metal crowns with or without ferrule was not significantly different in fracture resistance. It was also demonstrated that the placement of a metal crown may obscure the effect of different post and core buildup techniques. Conflicting reports about ETT with presence of ferrule, and final restorations were found among the literatures.
Objectives: To clarify the effect of fiber reinforced composite post length on the fracture resistance of ETT restored without crown and to investigate the effect of ferrule and the full coverage metal crown on the fracture resistance of ETT. **Methods:** Four groups based on different post length with n=6 in each group; crown height(C)/post length(P) ratio 1:2, C/P 1:1, C/P 2:1, and prepared extracted teeth (PET) were evaluated. Three groups based on ferrule and full coverage metal crown with n=6 in each group; metal crown with ferrule (MC/F), metal crown without ferrule (MC/NF), composite resin coverage with ferrule (CR/F) in combination with previous C/P 1:2, and PET groups were also compared. This study used experimental fiber reinforced composite posts containing glass fibers with a parallel configuration, a diameter of 1.5 mm, and modulus of elasticity of 18 GPa luted with resin cement (Panavia F 2.0). Cervical dentin was conditioned with self-etching bonding agent (Clearlfil SE bond). The core was built-up with composite resin (Clearfil Photocore). The metal crowns were luted with resin cement. An oblique compressive load was applied using the universal testing machine. **Results:** There was no significant difference in fracture resistance among different post length (P>0.05). The crown/post ratio of 1:2 generated more specimens with restorable mode of failure. Additionally, the MC/F group demonstrated the highest fracture resistance compared to the others (P<0.05).
Conclusion: Within the limitation of this study, post lengths did not influence the fracture resistance but demonstrated in the more favorable fracture mode in C/P ratio of 1:2 group. MC/F group presented with the highest fracture resistance compared to the others.

Department: Prosthodontics Student's Signature……………………
Field of Study: Prosthodontics Advisor's Signature……………………
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LIST OF ABBREVIATIONS

ABBREVIATIONS	DESCRIPTIONS
ETT	endodontically treated teeth
FRC	fiber reinforced composite
FPD	fixed partial denture
RPD	removable partial denture
GPa	gigapascal
MPa	megapascal
CEJ	cementoenamel junction
mW/mm^2	milliwatt per square millimeter
N	newtons
PVC	poly vinyl chloride
P	p value
FEA	finite element analysis
%	percent
°C	degree in Celsius
mm	millimeter
s	second

ABBREVIATIONS	DESCRIPTIONS
et al	et alii (and others)
ANOVA	analysis of variance
SD	standard deviation
α	alpha

CHAPTER I

INTRODUCTION

Endodontically treated teeth (ETT) often lack coronal tooth structure as a result of caries, endodontic treatment, tooth fracture, and previous extensive restoration[1]. Post is required to provide adequate retention for the core foundation and the final restoration[2]. Posts can either be custom made or prefabricated[3]. Cast posts have been used to replace the tooth structure removed during endodontic treatment and should be closely adapted to the post space[3]. The closely adaptation between the post and the root dentin provides even stress distribution at the post-dentin-cement interfaces[4]. It is believed that this interfaces facilitates stress distribution along the root dentin during the clinical function[4]. In spite of their popularity, cast posts have some disadvantages which may affect the long term success of the restoration; inhomogeneous stress distribution, biological side effects due to microleakage and corrosion, and the color reflection of the cast posts on all-ceramic restorations[5]. The most common failure of cast post and core is post dislodgement, followed by the root fracture due to poor stress distribution[6, 7]. Root fracture caused by the mismatch of the modulus of elasticity, with that of the metal post was 10 times greater than that of the dentin[5, 8]. Currently, the fiber reinforced composite (FRC) posts are widely used due to their ease of fabrication, aesthetic properties, and the modulus of elasticity which is close to that of dentin[3]. In addition, the FRC posts can be directly bonded in a single appointment[1]. The similarity in the modulus of elasticity of the FRC posts to that of dentin results in lower stress transmitted from the FRC post to root dentin than the cast post and core or the metal prefabricated post with a resin composite core[2, 5, 7]. The FRC posts have demonstrated their durability and are less likely to cause root fracture as seen in retrospective studies of up to 6 years[9].

Post retention is a major factor affecting the survival of restoration. Post debonding has been reported as the most common complication contributing to the incidence of root fracture[10]. Post length has a significant effect on its retention in the root canal. Increasing the post length apically improves retention; while, the apical region of the post space may provide unpredictable bonding[3, 10-12]. It has been suggested that the longer post results in the higher the fracture resistance[7]. Moreover, adhesive resin cement has been shown to provide increase retention of the FRC posts [13]. The optimal length of the FRC post is still controversial.

A ferrule is defined as “a band or ring of sound dentin encircling the root or crown of the tooth”[14]. The ferrule provides positive reinforcement to ETT by resisting the leverage of occlusal forces, and the wedging effect of tapered posts[15, 16]. Existisng of 2 millimeters of ferrule provided significantly higher fracture resistance of the restorations[17]. However, another study reported the presence of ferrule did not enhance the fracture resistance[18]. Moreover, ETT restoration using FRC posts and metal crown with or without the ferrule did not result in significant differences in the fracture resistance[18]. It has also been demonstrated that the placement of a metal crown may obscure the effect of different post and core built-up techniques[10]. The fracture resistance of ETT restored with different post lengths, presence/absence of a ferrule and presence/absence of metal crown is still inconclusive.

Objectives

To clarify the effect of FRC post length on the fracture resistances of ETT restored without crown and to investigate the effect of ferrule and full metal crown on the fracture resistance of ETT.

Research scope

This in vitro aim to compare the effect of FRC post length on the fracture resistances of ETT restored without crown and to investigate the effect of ferrule and full coverage metal crown on the fracture resistance of ETT. Specimens were prepared in the same manner and tested by universal testing machine until fracture.

Research questions

Are fracture resistances of endodontically treated teeth restored with either in: the different post lengths, final restorations, or ferrule types the same?

Agreement

This was an in vitro experimental study which did not represent intra-oral situation. The entire study was conducted within Chulalongkorn University facilities by one researcher using the same instrument.

Research limitation

1. This study cannot simulate real condition in oral cavity due to laboratory experimental research.

2. Research are affected by confounding factors such as size and morphology of tooth.

Type of research

Laboratory experimental research.

Proposed benefits

1. to understand effect of ferrule to fracture resistance of endodontically treated teeth.

2. to understand effect of final restoration to fracture resistance of endodontically treated teeth and refer its result to clinical use.

3. to understand the appropriate length of post for restoring endodontically treated teeth and applying in clinic.

4. Dentist can choose proper length of post, final restoration, and ferrule type for longevity of restoration.

Hypotheses

The null hypotheses were that there would be no influence of the FRC post length on the fracture resistance of ETT restored without crown and the restoration designs did not affect the fracture resistances of ETT.

CHAPTER II

LITERATURE REVIEW

Endodontically treated teeth

It has been reported that ETT changes in mechanical properties[19], most significantly, a reduction in fracture strength[20]. In some studies, changes in properties such as modulus of elasticity and proportional limit, compressive strength, or brittleness have not been observed for these teeth[21]. Reduction in the strength of ETT is most likely caused by the degradation in structural integrity following the substantial loss of tooth structure, which occurs during endodontic therapy and cavity preparation[22]. The longevity of a restored tooth thus depends on the amount of remaining tooth structure and on the efficiency of the restorative procedure used to replace lost structural integrity[13].

Nowadays, there are several restorative options beside full coverage restorations that could be used for ETT as insertion of a metallic or a FRC post, core built-up, or insertion of an adhesively bonded restoration. All of which have been proven as clinical success. In cases involving with severe damage or complete loss of the coronal structure, a post is usually inserted in the root canal in order to provide sufficient retention to the core structure especially when the restored tooth is an important abutment for a fixed restoration.

Type of post

The prosthetic restoration of ETT frequently requires preprosthetic treatment of remaining ETT structure prior to retaining the permanent restoration. The preprosthetic treatment of an ETT consists of rebuilding ETT structure using a post and core to provide a preparation for retaining a crown[23]. Types of post and cores are categorized in many different ways. Post and cores was classified by material composition[24].

1. Cast post and cores

The cast metal post and core were the traditional standard treatment of restoring ETT, however, this technique requires more time consuming and a more laboratory cost. The laboratory of cast post and cores may result in many errors, for example, the porosities within the casting can cause increasing the risk of post fracture , the difficulty replacement of burnout post or wax into the post holes in models can cause inadequate length of cast posts that compared with preformed system[25]. All of these reasons have made the preformed post systems with directly built cores increased in popularity.

2. Prefabricated Post and Cores

Prefabricated posts are usually made of stainless steel, nickel chromium alloy, or titanium alloy. They are very rigid and strong[24]. The stainless steel post (parapost system) modulus of elasticity is 8 to 9 times that of dentin[26]. They have various size and shape. Passive tapered posts offer the least retention of the prefabricated posts, but allow minimal removal of radicular dentin because their tapered shape resembles the overall canal morphology. If adequate canal length is available, they are a good treatment of choice in thin roots[27]. Additional retention can be gained with a parallel post or by the use of an active post[28].

Many of the prefabricated posts are made of titanium alloys because they concerns about corrosion of posts. Titanium posts have low fracture strength that means they are not strong enough to be used in thin post channels. A radio density of titanium posts similar to gutta-percha and sealer, has made it difficult to detect on radiographs. Removal of titanium posts can be a problem because they sometimes break when force is applied with a post removal instrument. Ultrasonic energy may be necessary to remove titanium posts, which can cause damage to the tooth or surrounding tissues. For these reasons, titanium should be avoided because they offer no real advantages over the stronger metal posts.

2.1 Fiber Posts

The original fiber-based posts consisted of carbon fibers embedded in polymer resin, usually epoxy resin. The modulus of elasticity of fiber post is approximately 1- 2 times to that of dentin, so they are slightly flexible and may allow post flexion to mimic tooth flexion[24]. Under loading, stress distribution to the root dentin is more favorable manner than metal posts, resulting in fewer root fractures. In contrast, the carbon fiber posts are dark and unsuitable for use in all ceramic restorations, but they are relatively easy to remove by touching the middle of the post with an ultrasonic or rotary instrument[29]. Other types of fiber posts also available, including quartz fiber, glass fiber, and silicon fiber posts. They offer the same advantages as the carbon fiber posts, but with better esthetics[24].

2.2 Ceramic and Zirconium posts

The concept of ceramic post and core is the esthetic that they would not change the translucency or color of the ETT. While the esthetics were achieved, the glass ceramic was deficient in strength. Zirconia ceramics have the highest fracture toughness, a high Weibull modulus and considerable flexural strength[30]. Retrieval of ceramic and zirconium posts are very difficult if re-endodontic retreatment is necessary or post removal from fractures. It is impossible to grind away a zirconium post. For these reasons, ceramic and zirconium posts should be avoided[24].

Factors consideration for success of ETT

1. Post selection

The restoration of severely damaged ETT with intra-radicular posts is still a controversial subject in the literature. There are numerous types of post materials available. Metal posts include custom-fabricated cast post cores and prefabricated metal posts. Non-metal posts include custom-fabricated resin composite and ceramic post cores and prefabricated ceramic and fiber-reinforced composite posts. Cast metal post and core has been used for many years. The use of these fiber-reinforced composite posts has advantages, such as more rapid treatment and better biocompatibility, aesthetics, and corrosion resistance[3]. Moreover, it has been reported that fiber-reinforced composite posts decrease the irreparable root fractures, compared with the cast posts[31]. Because the lower modulus of elasticity of a glass fiber post reduced the risk of debonding due to the lower stresses at the post/cement interface[32]. When the post/cement bond failed, root stresses in the glass fiber post were higher than in the metallic cast post restored tooth. However, the glass fiber post restored root would still be less prone to fracture, because the fracture risks of the composite core and the post were higher than those of the root[33].

2. Post space preparation

A post is placed in the root canal of a structurally damaged tooth only when additional retention is needed for a core and coronal restoration. Placement of posts does not usually improve the strength of the remaining tooth structure, excessive post-space preparations might result in reduced strengths and compromised apical endodontic seals and the risk of root perforations in premolar and mandibular incisor teeth in particular[34]. In many instances, posts are not required for the retention of radicular cores in molar teeth. If required, then a short post might be placed in the palatal canal of maxillary molars and in the distal canal of mandibular molars. Maintenance of the obturation seal is critical to resist bacterial microleakage in endodontically treated teeth. To avoid violation of the apical seal, at least 4–5 mm of apical gutta-percha should be retained[35]. A recent study of 126 extracted single-rooted maxillary anterior teeth with intact apices reported that the optimum apical seal after post-space preparation was associated with 6 mm of remaining gutta percha[35]. Ideally, the post core should be placed immediately after obturation to reduce the effects of canal contamination resulting from a leaking interim post and temporary crown.

3. Coronal restoration and ferrule

After endodontic treatment, permanent coronal restorations should replace interim restorations as soon as possible to prevent subsequent tooth fractures[34]. When adequate sound dentin supported enamel is present, then intracoronal bonded resin composite restorations might demonstrate a better clinical performance in preventing tooth fractures in ETT than amalgam restorations[36]. When posterior tooth cusps have been weakened, then cuspal coverage with bonded resin composite, amalgam, cast metal alloy, or high-strength ceramic materials is essential to prevent tooth fractures[37]. Extensive coronal tooth structure loss requires the placement of either directly fabricated core crowns or indirectly fabricated complete crowns that are usually retained with post cores. When full crowns are required, then the incorporation of 1.5–2.0 mm high circumferential coronal ferrules might reduce root fractures[1].

Some ETT will be used as abutments for fixed and removable prostheses that are subjected to heavy horizontal and torqueing forces during function, such as long-span and distal-cantilevered fixed partial dentures (FPD) and distal-extension base removable partial dentures (RPD), which place the teeth at higher risk for fracture[38]. The use of ETT can be confidently advocated for single crowns. However, the use of ETT to support a precision attachment RPD, a distal-extension base RPD, or a posterior cantilevered FPD cannot be considered to be highly predictable[38].

4. Luting cement selection

Zinc phosphate, zinc polycarboxylate, glass-ionomer, and resin cements are the most commonly used as post luting cements. It has been reported that the cement layer provides a buffer zone that contributes to uniform stress distribution between the post and the canal[39]. A thicker or variably thickened layer of cement could transfer stresses to the tooth in a different manner than a uniform thin layer of cement[40]. The inherent weakness and brittleness of the cement affect the fracture resistance of the ETT[41]. The normal occlusal forces create micromovements of a crown and the cemented post[42]. These micromovements are considered to cause disintegration of the brittle cement in the most coronal surface of the post, resulting in concentration of stresses at the apical end of the root and leading to root fracture because of an increased lever arm. Many of the newer resin cements are claimed to bond effectively to dentin and to metal[43]. It has been showed that resin cements give additional resistance to fracture compared to brittle, nonbonding zinc phosphate cement[44]. They also reported that resinous cements are difficult to manipulate.

Although zinc phosphate cement demonstrated push-out strengths comparable with other resin cements for the cementation of titanium or fiber-reinforced composite posts, posts cemented with zinc phosphate cements often failed because of the cement fragility, and low bonding potential to the root dentin and the post surfaces. This explains why roots reinforced with posts that are cemented with dentin adhesives are more fracture resistant than those cemented with zinc phosphate cements.

It can be seen from the discussion on monoblocks that two prerequisites are simultaneously required for a monoblock to function successfully as a mechanically homogenous unit. First, the materials that constitute a monoblock should have the ability to bond strongly and mutually to one another, as well as to the substrate that the monoblock is intended to reinforce. Second, these materials should have a modulus of elasticity that is similar to that of the substrate. The interaction of these two parameters is nicely illustrated in a recent finite element analysis study of different cements in combination with posts used to restore weakened roots[45]. With the increase of the modulus of elasticity of the different cements, the Von Mises stress concentrations in the root dentin decreased from 24.5 to 20.8 MPa. When resin cement (Panavia F2.0), a heavily filled resin cement with an elastic modulus of 18.3 GPa, and a zinc phosphate cement (elastic modulus 9.3–13.4 GPa) were used, materials with a similar modulus of elasticity to that of dentin, the respective Von Mises stress concentrations in the root dentin were lower (20.9 and 20.8 MPa). This is because some of the stresses were redistributed to the cement layer (Von Mises stress concentrations 12.3 and 14.0 MPa). One the contrary, when Superbond C&B cement (elastic modulus 1.8 GPa) and a glass-ionomer cement (elastic modulus 4.0 GPa) were used for cementation, high stress concentrations were found in the root dentin (Von Mises stress concentrations 24.5 and 23.6 MPa, respectively). These stresses were directly transferred to the root dentin, as the stress concentrations within the cement layers were low (Von Mises stress concentrations 2.4 and 4.4 MPa, respectively)[46].

CHAPTER III

MATERIAL AND METHODS

The protocol of this study was approved by the Ethics Committees of Chulalongkorn University (#15/2010).

Part one: the fracture resistance of ETT restored with experimental FRC post and a composite resin with different post lengths

1.Tooth preparation

Twenty four recently extracted mandibular second premolars with similar root sizes, stored in freezer after extraction, were selected after transillumination, visual examination. Teeth with cracks, dental caries, or other visible defect were excluded. Buccolingual and mesiodistal width of the specimen were 7.65$\pm$0.5 mm and 5.15$\pm$0.5 mm, respectively. Teeth were ramdomly devided in 4 groups. The crown height (C)/post length (P) ratio which demonstrated the best result will be used in part 2. The 4 groups were as follows:

1.Group 1:2 (C/P ratio 1:2): Teeth restored with experimental FRC posts,10.0 mm into the root, cemented with adhesive resin cement (Panavia F2.0, Kuraray, Okayama, Japan), core built-up and final restoration using composite resin (Clearfil Photo Core, Kuraray, Okayama, Japan).

2.Group 1:1 (C/P ratio 1:1): Teeth restored with experimental FRC posts, 5.0 mm into the root, cemented with adhesive resin cement, core built-up and final restoration using composite resin as in group 1.

3.Group 2:1 (C/P ratio 2:1): Teeth restored with experimental FRC posts, 2.5 mm into the root, cemented with adhesive resin cement, core built-up and final restoration using composite resin as in group 1.

4.Group PET (prepared extracted tooth/PET) : Tooth was trimmed parallel to the root surfaces using diamond cylinder round end (141 020 Intensive, Grancia, Switzerland). The occlusal surface of the specimen was flat-topped and 45 degree bevel was performed on buccal cusp using the same bur and polishing with superfine diamond bur (288 013 Intensive, Grancia, Switzerland). The gingivo-occlusal dimensions of prepared tooth was 5 mm for all preparation. Group 4 was served as a positive control and shared specimen with group 5 of part 2.

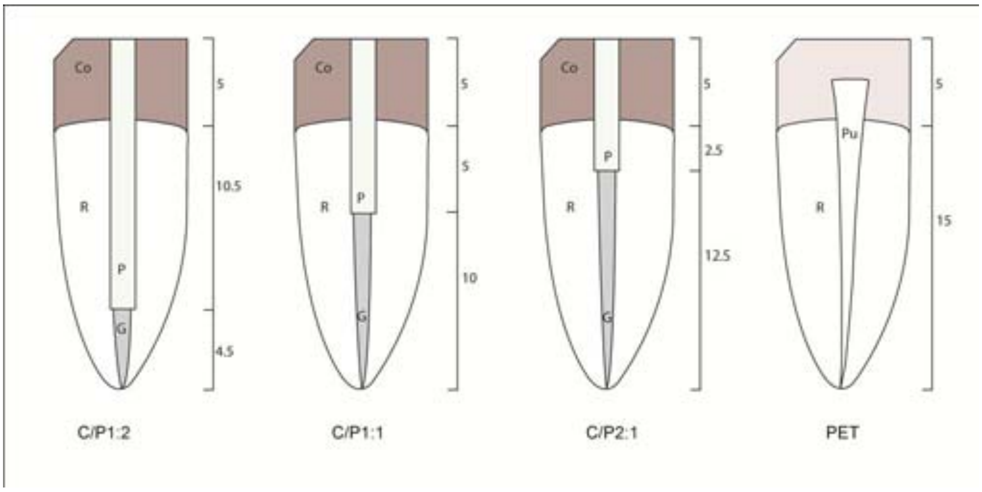


Figure1. Composite resin post core combination, (Co) composite resin, (P) experimental FRC post, (R) root, (G) gutta percha, Pulp (Pu), (dimension in millimeter)

The teeth were decoronated perpendicular to the root axis at cementoenamel junctions (CEJ), using a low-speed cutting machine (Isomet 1000, Buehler, Lake Bluff, IL, USA). Root lengths were measured from the CEJ on the facial surface, and mesiodistal widths were measured between the proximal surfaces at the CEJ. All teeth were within 6 months after extraction.

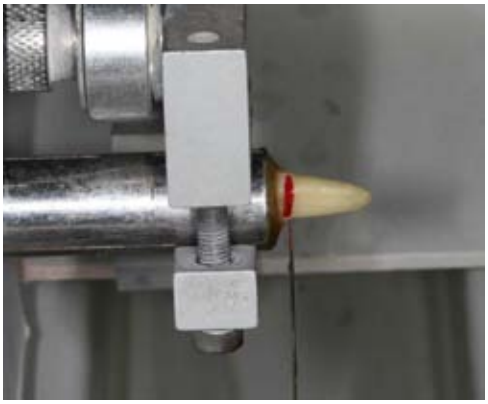


Figure2. Decoronated teeth using Isomet

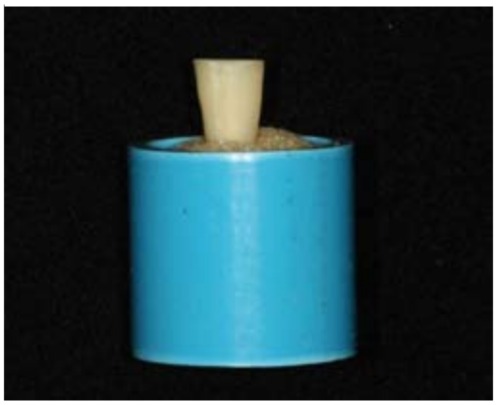


Figure3. Decoronated teeth

2. Endodontic and post space preparation

Endodontic access was prepared in a conventional manner. The instrumentation consisted of enlarging the apical preparation to three file size larger than first file at working length (Dentsply, Baillagues, Switzerland). The working length of each tooth was determined by inserting a No.10 file into the canal until it appeared at the apex, and then subtracting 0.5 mm. Each tooth was instrumented at working length 14.5 mm from CEJ to No. 35 K-file (Dentsply, Ballaigues, Switzerland) and irrigated with 2.5% sodium hypochlorite. The canal was obturated with gutta percha and root canal sealer modified grossman formula (CU Product, Bangkok, Thailand) with lateral condensation technique. The post space was prepared with diameter 1.5 mm to the depth of 10.0, 5.0, 2.5 mm (Whaledent, Cuyahoga Falls, OH, USA) in group 1, 2, 3, respectively.

Figure4. Obturated canal

Figure5. Prepared post space

3. Simulated periodontal ligament

Root of the specimen was dipped into melted wax (Trubyte, York, PA, USA) to a depth of 2 mm below the facial CEJ to produce a 0.5 mm layer which approximately equal to the average thickness of the periodontal ligament. The coated root was mounted in acrylic resin block (Formatray, Kerr, Romulus, MI, USA) reinforced with nylon ring. Each tooth was removed from the resin block when the first sign of polymerization was observed. After that the root was inserted into the polyvinyl siloxane (Reprosil, Caulk, Milford, PA, USA) index which will serve as the aid in realign specimen into the mold. The wax spacer was removed from the root surface and replaced by polyvinyl siloxane (Reprosil, Milford, PA, USA). Excess polyvinyl siloxane was removed with a scalpel blade to provide a flat surface 2 mm below the facial CEJ of each tooth. This was done to approximate alveolar supporting bone in healthy teeth. [5]

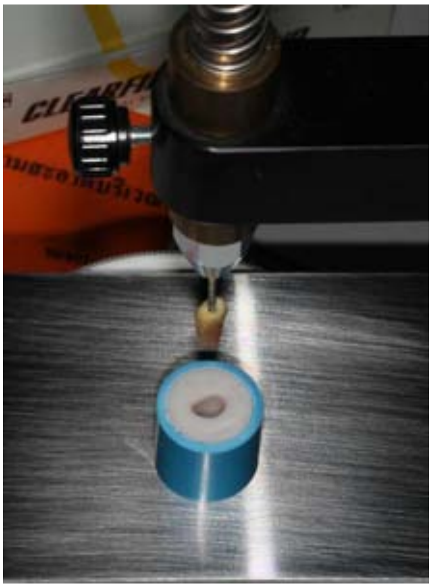


Figure6. Simulated periodontal ligament

4. Restored with post and core

Root canal was irrigated with normal saline and dried with paper point. Then root dentin was primed with ED primer for 30 second and dried with gentle air. The resin cement was mixed following the manufactures's instruction and applied to the post and post space, excess cement was removed. The light-activated polymerization (Elipar Trilight 3M ESPE, St.Paul, MN) with power density 550 mW/cm^2 for 40 second was performed. Cervical dentin was conditioned by Clearfil SE Bond in following sequence, first primer was applied for 20 second and the conditioned surface was dried by gentle air, second bonding was applied for 10 second and dried with gentle air and then light-activated polymerization with power density 550 mW/cm^2 for 20 second. The composite resin was used as the core foundation and light-activated polymerization for 40 second at both facial and lingual surface using core-forming matrix. After polymerization, the gingivo-occlusal dimension of the core foundation was trimmed parallel to the tooth axis to achieve a 5 mm gingivo-occlusal height from the CEJ using diamond cylinder round end bur. The 45° bevel was established at the buccal cusp using the same bur and polished with a superfine diamond bur. The specimens were stored in 37 °C 100% humidity 24 hours prior to the test.

A

B

C

D

Figure7. Cemented experimental FRC post (A), Placed core-forming matrix (B), Core built-up with composite resin (C), Polishing and beveled 45°

5. Fracture resistance test

The universal testing machine (model 8872, Instron, Fareham, UK.) was used to apply a compressive load to tooth with a crosshead speed of 2 mm/min at the angle of 135 degree to the long axis of teeth on buccal cusp position. The failure load was recorded in Newton (N). The failure of specimen was evaluated when the graph plot between force and compressed distance showed an abrupt change in load, indicating a sudden decrease in the specimen's resistance to the compressive loading. Specimens were visually examined under a stereomicroscope 30X (Meiji ML9300, Saitama, Japan) to identify the modes of failure. Modes of failure were classified in 2 groups. Group 1; unrestorable fracture, was defined as fractures located below the PVC ring (below 2 mm of the finishing line). Group 2; restorable fracture, was defined as any fractures located above the PVC ring.

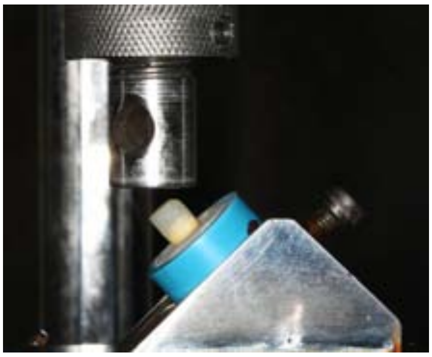


Figure8. A 135 degree of compressive load

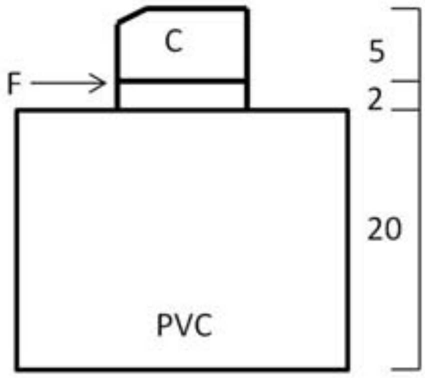


Figure9. The ETT in PVC ring, (C) crown, (F) finishing line, (dimension in millimeter)

6. Statistical analysis

All data were statistically analyzed with one way analysis of variance (ANOVA) to compare the mean loads of the group, and multiple comparison was performed to identify the significant different pairs at $p<0.05$.

Part two: fracture resistance of ETT restored with experimental FRC post of the optimal length from part 1 and a composite resin with and without ferrule with and without metal crown. They were;

1.Tooth preparation

Eighteen recently extracted mandibular second premolars with similar root sizes, stored in freezer after extraction, were selected after transillumination, visual examination. Teeth with cracks, dental caries, or other visible defect were excluded. Buccolingual and mesiodistal width of the specimen were 7.65$\pm$0.5 mm and 5.15$\pm$0.5 mm, respectively. Teeth were ramdomly devided in 5 group including C/P 1:2 and NT groups. They were;

1.Group MC/F (crown with ferrule:MC/F): Teeth restored with experimental FRC posts, cemented with adhesive resin cement, core built up using composite resin, and final restoration with metal crown and 2 mm ferrule.

2.Group MC/NF (crown without ferrule:MC/NF): Teeth restored with experimental FRC posts, cemented with adhesive resin cement, core built-up using resin composite, and final restoration with metal crown.

3.Group CR/F (composite with ferrule:CR/F): Teeth restored with experimental FRC posts, cemented with adhesive resin cement, core built-up and final restoration with 2 mm ferrule using composite resin.

4. Group 1:2 (C/P ratio 1:2): Teeth restored with experimental FRC posts, 10.0 mm into the root, cemented with adhesive resin cement, core built-up and final restoration using composite resin.

5.Group PET (prepared extracted tooth:PET) : Tooth was trimmed parallel to the root surfaces using diamond cylinder round end. The occlusal surface of the specimen was flat-topped and 45 degree bevel was performed on buccal cusp using the same bur and polishing with superfine diamond bur. The gingivo-occlusal dimentions of prepared tooth was 5 mm. Group 5 was served as a positive control.

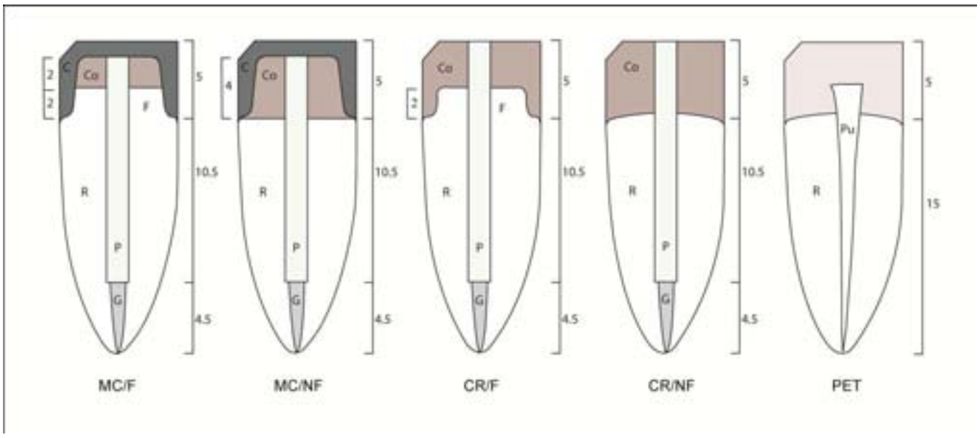


Figure10. Composite resin post core combination, (Co) composite resin, (P) experimental FRC post, (R) root, (G) gutta percha, (C) metal crown, (F) ferrule, Pulp (Pu), (dimension in millimeter)

The teeth were decoronated perpendicular to the root axis at cementoenamel junctions (CEJ) on buccal surface for MC/NF, and above CEJ 2 mm for MC/F and CR/F, using a low-speed cutting machine. Root lengths were measured from the CEJ on the facial surface, and mesiodistal widths were measured between the proximal surfaces at the CEJ. All teeth were within 6 months after extraction.

2. Endodontic and post space preparation

Endodontic procedure was the same as part one but the post space was prepared with diameter 1.5 mm to the depth of 10.0 mm for all groups.

3. Simulated periodontal ligament

The procedure was the same as part one.

4. Restored with post and core

4.1 Group 1 (crown with ferrule: MC/F):

Root canal was irrigated with normal saline and dried with paper point. Root dentin was primed with ED primer for 30 second and dried with gentle air. The resin cement was mixed following the manufactures's instruction and applied to the post and post space, excess cement was removed. The light-activated polymerization with power density 550 mW/cm^2 for 40 second was performed. Cervical dentin was conditioned by Clearfil SE Bond in following sequence, first primer was applied for 20 second and the conditioned surface was dried with gentle air, second bonding was applied for 10 second and dried with gentle air and then light-activated polymerization with power density 550 mW/cm^2 for 20 second.

The composite resin was used as the core foundation and light-activated polymerization for 40 second at both facial and lingual surface using core-forming matrix. After polymerization, the gingivo-occlusal dimension of the core foundation was trimmed parallel to the tooth axis to achieve a 5 mm gingivo-occlusal height from the CEJ using diamond cylinder round end bur. The 45° bevel was established at the buccal cusp using the same bur and polished with a superfine diamond bur. Each tooth was prepared using of a high-speed handpiece with water coolant. Diamond taper round end was used to prepare the facial and lingual surface with uniform reduction. The 0.8 mm wide chamfer finishing line on facial and lingual surface at the level of CEJ with a 4 mm gingivo-occlusal height was established, leaving 1 mm space for a metal crown using a taper round end diamond bur.

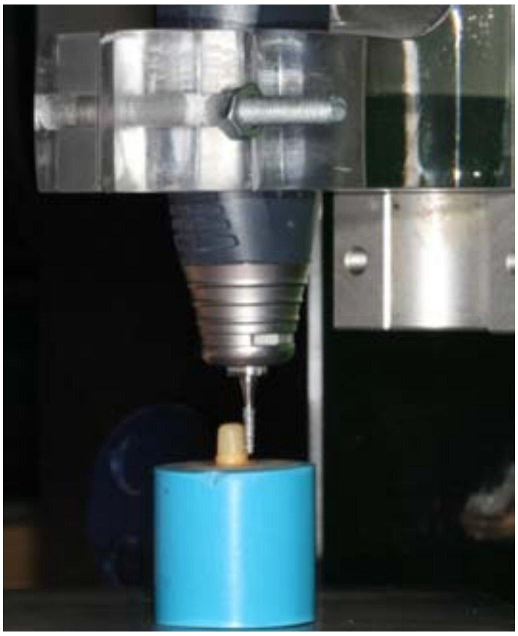
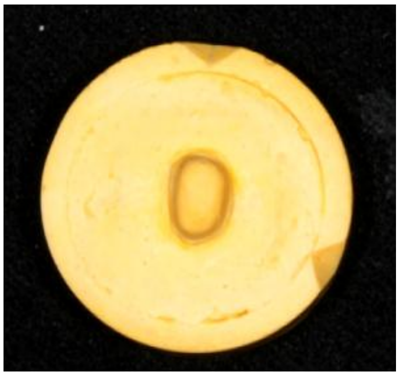


Figure11. Tooth preparation for full metal crown

A first impression was made using polyvinyl siloxane with double mixed single impression technique before tooth preparation and used to fabricate the full crown wax pattern. A second impression was made using polyvinyl siloxane with double mixed single impression technique for die fabrication. The type 4 stone (Velmix die stone, Sybron Kerr, Peterborough, UK) was poured into the second impression, the die was removed and margin of die was remarginated.

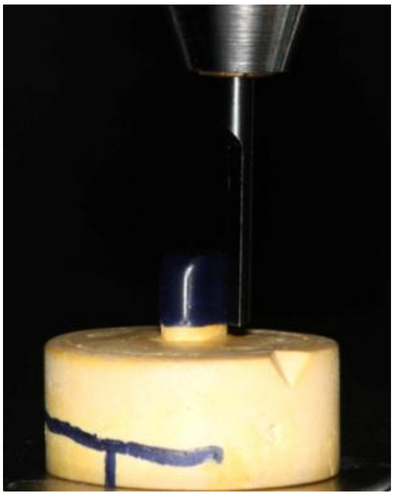
The melted wax (blue inlay, Kerr, Orange, USA) was poured into the before tooth preparation impression, the die was seated, after the wax was cooled, the impression was removed, and the margin was remarginated.

A



B

C



D

Figure12. The melted wax in first impression (A), the die (B), duplicated wax in die (C), finished wax for full metal crown (D)

The wax patterns were sprued, invested, and cast with nikel-chromium alloy (Wiron 99, Bego, Germany). The crowns were tried on the prepared teeth and adaptation of each tooth was checked by silicone test-fit (Fit checker, GC, Tokyo, Japan). The prepared teeth were conditioned with ED primer for 30 second then cemented to the prepared teeth with adhesive resin cement according to the manufacture's instruction. The specimens were stored in 37 °C 100% humidity 24 hours prior to the test.

4.2 Group 2 (crown without ferrule:MC/NF)

All procedure were the same as MC/F.

4.3 Group 3 (composite with ferrule:CR/F)

Each tooth was prepared using of a high-speed handpiece with water coolant. Diamond taper round end bur was used to prepare the facial and lingual surface with uniform reduction. The 0.8 mm wide chamfer finishing line on facial and lingual surface at the level of CEJ with a 2 mm gingivo-occlusal height was established. All procedure were the same as MC/F except step 6-11 were excluded.

4.4 Group 4 (C/P 1:2)

All procedure were the same as C/P1:2 of part 1.

5. Fracture resistance test

The procedure was the same as part one.

6. Data collection and analysis

All data were statistically analyzed with one way analysis of variance (ANOVA) to compare the mean loads of the group, and multiple comparison was performed to detect significant pairs at $p<0.05$.

CHAPTER IV

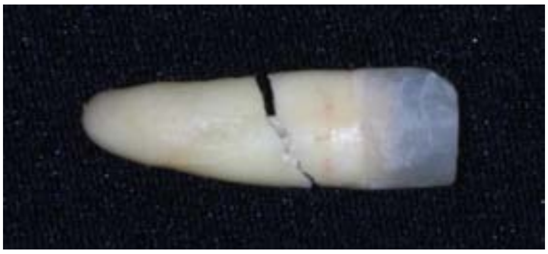
RESULTS

The fracture loads of different post lengths are shown in Figure 5. The loads ranged from 1347.75 N (C/P 1:2) to 1588.87 N (PET), however the 1-way ANOVA suggested no statistically significant difference among groups (P>0.05). Failure modes of C/P 1:2 group was split evenly between restorable fractures and unrestorable fractures (3/3), while those of the others were all unrestorable fractures type (0/6).

The fracture loads of different ferrule and full coverage metal crown are shown in Figure 6. The fracture loads ranged from 1347.75 N (C/P1:2) to 2543.01 N (MC/F). The 1-way ANOVA suggested significant differences among groups and the Tukey HSD indicated that the fracture load of the MC/F was statistically higher than those of the other groups. Failure modes are summarized in Table 1. The failure modes of CR/F group were 4 restorable fractures and 2 unrestorable fractures, followed by C/P1:2 and MC/NF groups at 3 restorable fractures and 3 unrestorable fractures. The MC/F group showed unrestorable fractures of all specimens.

Table1. Mode of failures in all test groups.

	C/P 1:2	C/P 1:1	C/P 2:1	MC/F	MC/NF	CR/F	PET
Restorable fracture	3	0	0	0	3	4	0
Unrestorable fracture	3	6	6	6	3	2	6



A

B

C

D

Figure 13. Unrestorable fracture (A, B), restorable fracture (C, D).

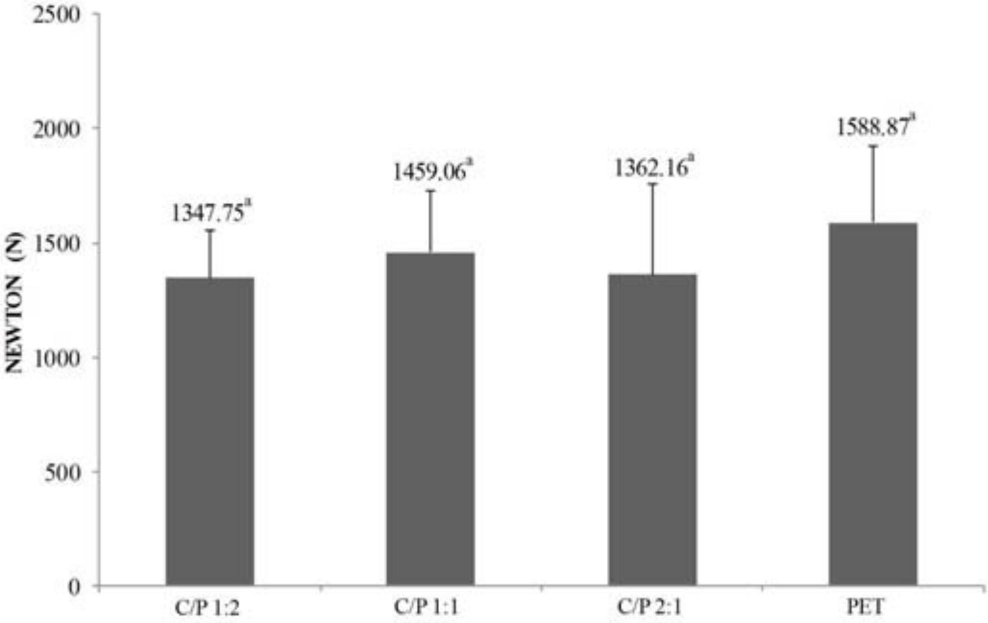


Figure14. Mean and standard deviation of fracture resistance of different post length groups. Group with same superscript letters were not significantly different at p>0.05.

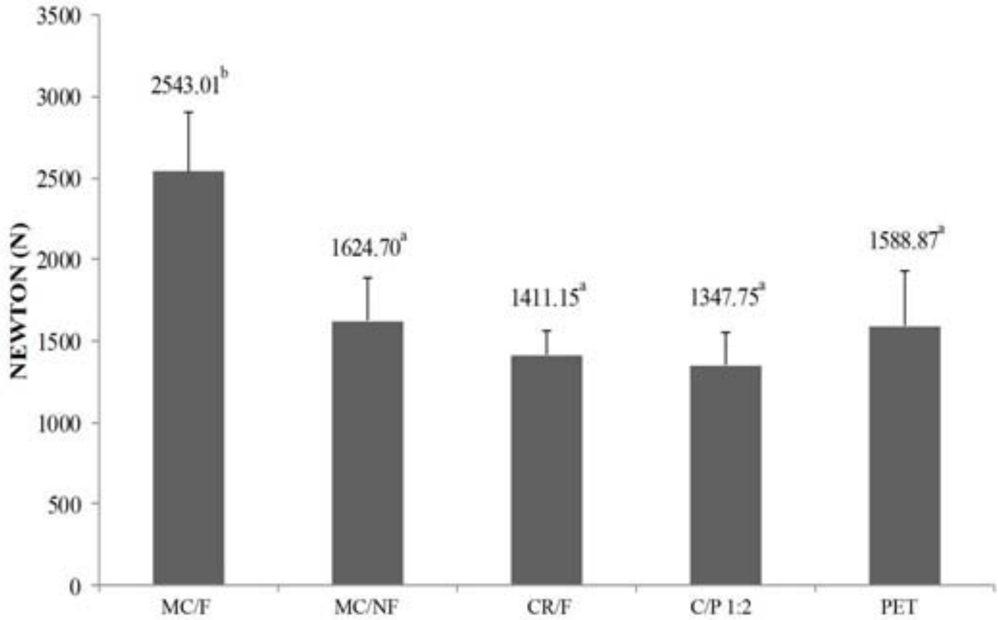


Figure15. Mean and standard deviation of fracture resistance of different the restoration design groups. Group with same superscript letters were not significantly different at p>0.05.

CHAPTER V

DISCUSSION

In the present study, it was found that using different lengths of experimental FRC posts did not affect the fracture resistance of composite resin restored ETT. Therefore; the null hypothesis that there would be no influence on the fracture resistance of ETT restored with different post length of experimental FRC post without crown was accepted.

It has previously been reported that different lengths of cast posts or prefabricated metal posts had the effect on the fracture resistance[12]. When cast posts were used, extension of post into the root canal was suggested to be at least equal to the crown length[16]. It was found that increasing post lengths may reduce the root dentin wall thus weaken the strength of the root[47]. Contrarily, the present study showed differences in the length of FRC posts did not influence the fracture resistance. This may be attributed to the modulus of elasticity of the FRC posts, composite resin core foundation material, which are close to that of dentin. This intended to stimulate the monobloc configuration. The result of this present study corresponded with the finite element analysis (FEA) study which showed the maximum von Mises stress of 11 GPa. The modulus of elasticity of the FRC posts with different lengths were equivalent and located only in the cervical area[48].

The fracture resistance values of the C/P 1:1 group were slightly higher than the C/P 2:1 and C/P 1:2 groups respectively. However, when considering mode of failure of the C/P1:2 group, the fracture modes were 50% restorable root fractures, whereas the other groups had 100% unrestorable root fractures. This is likely due to the ability of the FRC posts to absorb, rather than transfer stress to the root dentin[2]. The longer posts in the C/P 1:2 group, with a larger bonding area of FRC post to the root, may absorb some stress and better distribute the transferred stress throughout the whole tooth structure resulting in a restorable mode of failure[7]. In contrast, the use of shorter posts in the C/P 1:1 and C/P 2:1 groups may have resulted in lower stress absorption within the post compared to the C/P 1:2 group, resulting in a 100% unrestorable mode of failures. The result from the FEA of the shorter posts suggested that stress concentration shifted from the root/cement interface to the apical portion of the post[49], causing a fracture at the end of the post. The influence of the reduced post length on failure mode was in agreement with the study of Giovani and Vanson, who found a close association between the short post and the risk of root fracture[7].

The use of longer posts demonstrated a higher percentage of the restorable mode of failure compared to shorter posts (Table1), which was desirable in clinical situation. However, the longer posts require more dentin removal for the post space preparation. It should be emphasized that in some cases such as small or curved roots, removal of adequate dentin for longer posts may lead to root weakening or stripped perforation at the apical region; therefore the shorter posts may be considered as an alternative.

In considering the restorative materials used in this study, Clearfil SE Bond and Clearfil Photocore was selected due to the high shear bond strength between the cervical dentin and the composite resin core (28.9 MPa)[50]. The Panavia F 2.0 was used as a luting agent between the root dentin and the FRC post because it demonstrated high shear bond strength between the root dentin and the FRC posts and possessed a similar modulus of elasticity (18 GPa) to dentin[46].

The investigation on the effect of ferrule and full coverage metal crown on the fracture resistance of ETT, 1-way ANOVA suggested significant among groups, therefore, the null hypothesis that the restoration design had no effect on the fracture resistances of ETT was rejected.

The results showed that the MC/F group had a significantly higher fracture resistance compared to the other groups. Comparing the MC/F and MC/NF groups, the MC/F group showed a significantly higher fracture resistance. The high fracture resistance might be attributed to the effect of the ferrule[1]. However, the ferrule is not the only important factor in the fracture resistance. The final restoration design is also a crucial factor for fracture resistance of ETT[15]. Metal crowns demonstrated good distribution of forces from the core to the root and provided a bracing effect to the tooth with the presence of the ferrule[1]. The result of the present study supported the bracing effect of the crown placement on improving fracture resistance. The final restoration of ETT with a metal crown without the ferrule resulted in an insignificant difference in fracture resistance compared to ETT restored with composite resin without crown. This result indicated that neither metal crown nor ferrule itself could increase the fracture resistance. The result also supported that the combination of the ferrule preparation and the crown placement should be employed to achieve high strength of the whole restoration complex.

The MC/NF, CR/F, and C/P 1:2 groups generated insignificant differences of failure load compared to the each other, but were significantly lower in failure load compared with the MC/F group. The lower strength of the final restoration with the composite resin in the absence of the ferrule in MC/NF group presented in the same core fractures as in CR/F, C/P 1:2 groups. Notably, the fracture resistances of the CR/F and C/P 1:2 groups were over 1300 N which is 4 times greater than the normal bite force[51]. However, dynamic loading, temperature, and the effects of the oral environment were not performed in this study. Restoration of ETT with the experimental FRC posts in combination with the composite resin may be considered as the intermediate restoration.

Interestingly, no statistically significant differences were detected between the PET and the ETT restored with the FRC post combination with the composite resin core groups. The present study used the combinations of experimental FRC post and the composite resin core bonded to the root dentin with resin cement (Panavia F). Each material has the modulus of elasticity close to that of dentin (18 GPa). The close match of the modulus of elasticity may provide better stress distribution and stress absorption rather than transferring the stress to the root dentin[8]. With the closeness of fracture resistance between the experimental FRC post restored ETT and PET, it may suggest that the FRC post with modulus of elasticity equal to dentin in combination with the composite resin neither reinforced nor weakened the root.

CHAPTER VI

CONCLUSIONS

Within the limitations of this study, it could be concluded that:

1. There was no significant difference in fracture resistance among different post length groups ($P>0.05$).
2. The final restoration of a metal crown with the presence of a ferrule resulted in a significantly higher fracture resistance than the others ($P<0.05$).

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APPENDIX

Raw data of all groups

	C/P 1:2	C/P 1:1	C/P 2:1	MC/F	MC/NF	CR/F	PET
	1325.57	1652.49	1263.5	2026.6	1998.59	1451.47	1516.7
	967.2	1854.67	883.64	2676.45	1802.48	1527.51	2236.43
	1570.94	1124.85	1064.32	2674.34	1476.92	1148.89	1375.2
	1423.59	1473.35	1500.61	2173.46	1378.81	1445.65	1374.93
	1424.55	1407.42	2023.74	2950.59	1342.2	1344.23	1657.19
	1374.66	1241.56	1437.14	2756.61	1749.2	1549.17	1372.77
mean	1347.75	1459.06	1362.16	2543.01	1624.70	1411.15	1588.87
SD	203.71	266.76	397.47	360.57	264.20	147.42	336.85

Normality test for post length groups

One-Sample Kolmogorov-Smirnov Test

Length			newton
C/P1:2	N		6.000
	Normal Parameters[a]	Mean	1347.752
		Std. Deviation	203.715
	Most Extreme Differences	Absolute	0.290
		Positive	0.186
		Negative	-0.290
	Kolmogorov-Smirnov Z		0.710
	Asymp. Sig. (2-tailed)		0.694
C/P1:1	N		6.000
	Normal Parameters[a]	Mean	1459.057
		Std. Deviation	266.757
	Most Extreme Differences	Absolute	0.145
		Positive	0.145
		Negative	-0.105
	Kolmogorov-Smirnov Z		0.356

	Asymp. Sig. (2-tailed)		1.000
C/P2:1	N		6.000
	Normal Parameters[a]	Mean	1362.158
		Std. Deviation	397.468
	Most Extreme Differences	Absolute	0.197
		Positive	0.197
		Negative	-0.119
	Kolmogorov-Smirnov Z		0.483
	Asymp. Sig. (2-tailed)		0.974
NT	N		6.000
	Normal Parameters[a]	Mean	1588.870
		Std. Deviation	336.848
	Most Extreme Differences	Absolute	0.261
		Positive	0.253
		Negative	-0.261
	Kolmogorov-Smirnov Z		.638
	Asymp. Sig. (2-tailed)		.810

a. Test distribution is Normal.

Descriptives for post length groups

Newton

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
C/P1:2	6	1347.752	203.715	83.166	1133.966	1561.537	967.200	1570.940
C/P1:1	6	1459.057	266.757	108.903	1179.113	1739.001	1124.850	1854.670
C/P2:1	6	1362.158	397.468	162.265	945.042	1779.275	883.640	2023.740
NT	6	1588.870	336.848	137.518	1235.369	1942.371	1372.770	2236.430
Total	24	1439.459	305.250	62.309	1310.563	1568.355	883.640	2236.430

Test of Homogeneity of Variances for post length groups

Newton

Levene Statistic	df1	df2	Sig.
.733	3	20	.545

ANOVA for post length groups

Newton

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	222560.061	3	74186.687	.773	.523
Within Groups	1920530.868	20	96026.543		
Total	2143090.929	23			

Normality test for crown and ferrule groups

One-Sample Kolmogorov-Smirnov Test

Group			Newton
MC/F	N		6.000
	Normal Parameters[a]	Mean	2543.008
		Std. Deviation	360.568
	Most Extreme Differences	Absolute	0.309
		Positive	0.181
		Negative	-0.309
	Kolmogorov-Smirnov Z		0.756
	Asymp. Sig. (2-tailed)		0.616
MC/NF	N		6.000
	Normal Parameters[a]	Mean	1624.700
		Std. Deviation	264.199
	Most Extreme Differences	Absolute	0.212

		Positive	0.212
		Negative	-0.181
	Kolmogorov-Smirnov Z		0.519
	Asymp. Sig. (2-tailed)		0.950
CR/F	N		6.000
	Normal Parameters[a]	Mean	1411.153
		Std. Deviation	147.420
	Most Extreme Differences	Absolute	0.259
		Positive	0.175
		Negative	-0.259
	Kolmogorov-Smirnov Z		0.635
	Asymp. Sig. (2-tailed)		0.815
C/P1:2	N		6.000
	Normal Parameters[a]	Mean	1347.752
		Std. Deviation	203.715
	Most Extreme Differences	Absolute	0.290
		Positive	0.186
		Negative	-0.290
	Kolmogorov-Smirnov Z		0.710
	Asymp. Sig. (2-tailed)		0.694
NT	N		6.000
	Normal Parameters[a]	Mean	1588.870
		Std. Deviation	336.848
	Most Extreme Differences	Absolute	0.261
		Positive	0.253
		Negative	-0.261
	Kolmogorov-Smirnov Z		0.638
	Asymp. Sig. (2-tailed)		0.810

a. Test distribution is Normal.

Descriptives for crown and ferrule groups

Newton

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
MC/F	6	2543.008	360.568	147.201	2164.615	2921.401	2026.600	2950.590
MC/NF	6	1624.700	264.199	107.859	1347.440	1901.960	1342.200	1998.590
CR/F	6	1411.153	147.420	60.184	1256.445	1565.861	1148.890	1549.170
C/P1:2	6	1347.752	203.715	83.166	1133.966	1561.537	967.200	1570.940
NT	6	1588.870	336.848	137.518	1235.369	1942.371	1372.770	2236.430
Total	30	1703.097	508.528	92.844	1513.209	1892.984	967.200	2950.590

Test of Homogeneity of Variances for crown and ferrule groups

Newton

Levene Statistic	df1	df2	Sig.
1.669	4	25	.189

ANOVA for crown and ferrule groups

Newton

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	5616878.133	4	1404219.533	18.648	.000
Within Groups	1882549.819	25	75301.993		
Total	7499427.951	29			

Multiple comparison

Tukey HSD

group	N	Subset for alpha = 0.05	
		1	2
C/P1:2	6	1347.752	
CR/F	6	1411.153	
NT	6	1588.870	
MC/NF	6	1624.700	
MC/F	6		2543.008
Sig.		0.425	1.000

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