ผลของอัตราส่วนความยาวแกนฟันต่อความยาวเดือยฟันคอมโพสิตเสริมเส้นใย

และชนิดซีเมนต์ยึดเดือยฟันที่แตกต่างกัน ต่อความต้านทานความล้มเหลว

ในฟันที่ได้รับการรักษาคลองรากฟัน

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EFFECT OF DIFFERENT CORE TO FIBER POST LENGTH RATIOS AND LUTING CEMENT TYPES ON FAILURE RESISTANCE OF ENDODONTICALLY TREATED TEETH

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A Thesis Submitted in Partial Fulfillment of the Requirements
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Department of Prosthodontics
Faculty of Dentistry
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ยศณรงค์ อิ่มหนำ : ผลของอัตราส่วนความยาวแกนฟันต่อความยาวเดือยฟันคอมโพสิตเสริมเส้นใยและชนิดซีเมนต์ยึดเดือยฟันที่แตกต่างกัน ต่อความต้านทานความล้มเหลว ในฟันที่ได้รับการรักษาคลองรากฟัน. (EFFECT OF DIFFERENT CORE TO FIBER POST LENGTH RATIOS AND LUTING CEMENT TYPES ON FAILURE RESISTANCE OF ENDODONTICALLY TREATED TEETH) อ. ที่ปรึกษาวิทยานิพนธ์หลัก : ผศ.ทพญ.ดร.ปรารมภ์ ซาลิมี, 51 หน้า.

การวิจัยนี้มีวัตถุประสงค์ เพื่อศึกษาผลของอัตราส่วนความยาวแกนฟันต่อความยาวเดือยฟันชนิดคอมโพสิตเสริมเส้นใยและชนิดเรซินซีเมนต์ที่ใช้ยึดเดือยฟันที่แตกต่างกัน ต่อความต้านทานความล้มเหลวในการบูรณะฟันที่ได้รับการรักษาคลองรากฟัน โดยนำฟันกรามน้อยซี่ที่หนึ่งล่างจำนวน 48 ซี่ แบ่งเป็น 6 กลุ่มอย่างสุ่ม กลุ่มละ 8 ซี่ ตามอัตราส่วนความยาวแกนฟันต่อความยาวเดือยฟันที่แตกต่างกันสามอัตราส่วน (2:3 1:1 และ 3:2) และซีเมนต์ที่ใช้ยึดเดือยฟันสองชนิดคือ พานาเวียเอฟสอง และรีไลเอ็กซ์ยูนิเซม โดยนำฟันมาตัดส่วนตัวฟันออกและทำการรักษาคลองรากฟันทุกซี่ด้วยวิธี สเต็ปแบ็ค สำหรับกลุ่ม 1 2 และ 3 ทำการบูรณะเดือยฟันคอมโพสิตเสริมเส้นใยดีทีไลท์โพสท์เบอร์ 1 ด้วยอัตราส่วนความยาวแกนฟันต่อความยาวเดือยฟันที่ต่างกันคือ 2:3 (6 มม.ต่อ 9 มม.) 1:1 (7.5 มม.ต่อ 7.5 มม.) และ 3:2 (9 มม.ต่อ 6 มม.) ยึดเดือยฟันด้วยพานาเวียเอฟสอง ส่วนกลุ่มที่ 4 5 และ 6 ทำการบูรณะด้วยอัตราส่วนเช่นเดียวกับกลุ่มที่ 1 2 และ 3 แต่ยึดเดือยฟันด้วยรีไลเอ็กซ์ยูนิเซม ทำการบูรณะส่วนแกนฟันด้วยเรซินคอมโพสิต และทำการบูรณะครอบฟันโลหะชนิดนิเกิล-โครเมียม โดยยึดครอบฟันด้วยพานาเวียเอฟสอง นำฟันลงบล็อกยึดฟันที่ทำจากอะคริลิกเรซินและสร้างเอ็นยึดปริทันต์จำลอง นำไปทดสอบการต้านทานความล้มเหลวด้วยเครื่องทดสอบสากลโดยหัวกดทำมุม 45 องศากับแนวแกนฟันด้วยความเร็วหัวกด 1 มม.ต่อนาที บันทึกแรงที่ทำให้เกิดความล้มเหลว ผลการทดสอบพบว่าค่าเฉลี่ยการต้านทานความล้มเหลวในกลุ่มที่ 1 2 3 4 5 และ 6 เท่ากับ 454.3 ±22.4 นิวตัน 423.1 ±27.9 นิวตัน 295.7 ±24.8 นิวตัน 556.2 ±16.9 นิวตัน 541.1 ±20.2 นิวตัน และ 413.0±13.4 นิวตัน ตามลำดับ ผลการทดสอบทางสถิติโดยการวิเคราะห์ความแปรปรวนแบบทางเดียว พบว่าในกลุ่มที่ยึดเดือยฟันด้วยพานาเวียเอฟสอง กลุ่มที่ 1 และกลุ่มที่ 2 มีค่าแตกต่างจากกลุ่มที่ 3 อย่างมีนัยสำคัญทางสถิติ ($p<0.05$) และในกลุ่มที่ยึดเดือยฟันด้วยรีไลเอ็กซ์ยูนิเซม กลุ่มที่ 4 และกลุ่มที่ 5 มีค่าแตกต่างกันอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) เมื่อเปรียบเทียบระหว่างชนิดซีเมนต์ในแต่ละอัตราส่วนด้วยสถิติทดสอบที (t-test) พบว่ากลุ่มที่ยึดเดือยฟันด้วยรีไลเอ็กซ์ยูนิเซมมีค่าการต้านทานความล้มเหลวสูงกว่ายึดเดือยฟันด้วยพานาเวียเอฟสองในแต่ละอัตรา ส่วนอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) งานวิจัยนี้สรุปได้ว่าการบูรณะด้วยอัตราส่วนความยาวแกนฟันต่อความยาวเดือยฟัน 2:3 และ 1:1 จะให้ค่าการต้านทานความล้มเหลวสูงกว่าการบูรณะด้วยอัตราส่วน 3:2 และการยึดเดือยฟันด้วยรีไลเอ็กซ์ยูนิเซมให้ค่าการต้านทานความล้มเหลวสูงกว่าการยึดเดือยฟันด้วยพานาเวียเอฟสองในแต่ละอัตราส่วนอย่างมีนัยสำคัญทางสถิติ

ภาควิชา ทันตกรรมประดิษฐ์	ลายมือชื่อนิสิต..
สาขาวิชา ทันตกรรมประดิษฐ์	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก................................
ปีการศึกษา ..2553.........................	

5176128832: MAJOR PROSTHODONTICS

KEYWORDS: FIBER REINFORCED COMPOSITE POST (FRC POST) / FAILURE RESISTANCE / CORE : POST LENGTH RATIO

YOSNARONG IMNAM: EFFECT OF DIFFERENT CORE TO FIBER POST LENGTH RATIOS AND LUTING CEMENT TYPES ON FAILURE RESISTANCE OF ENDODONTICALLY TREATED TEETH.

ADVISOR: ASST. PROF. PRAROM SALIMEE, Ph.D., 51 pp.

The objective of this study was to evaluate the effect of different core to fiber post length ratios on failure resistance of endodontically treated teeth. Forty-eight mandibular first premolar were randomly divided into six groups (n=8 for each group) which were restored with three different core length to fiber post length (2:3, 1:1 and 3:2) and two different post luting cement; Panavia F 2.0 (Kuraray) and RelyX Unicem (3M ESPE). All teeth were removed the crown and endodontically treated with step-back technique. The group 1, 2 and 3 were restored with different three core to fiber post length ratios; 2:3 (6mm:9mm), 1:1 (7.5mm:7.5mm) and 3:2 (9mm:6mm) respectively. The specimens were cemented fiber post (DT light post No.1, Bisco) with Panavia F 2.0. The cores were built up with resin composite (Tetric ceram, Ivoclar) and full metal crowns (Ni-Cr) were fabricated and cemented on all specimens with Panavia 2.0. For group 4, 5 and 6, specimens were prepared the same as the group 1, 2 and 3 respectively but using RelyX Unicem for luting fiber posts. All teeth were embedded in acrylic resin blocks with periodontal ligament simulation. Failure resistances were determined using universal testing machine at 45 degrees angle to tooth long axis with cross head speed 1.0 mm/min until failure occurred. The result found that the failure resistance of group 1, 2, 3, 4, 5 and 6 were 454.3 ±22.4 N, 423.1 ±27.9 N, 295.7 ±24.8 N, 556.2 ±16.9 N, 541.1 ±20.2 N and 413.0±13.4 N, respectively. The data were analyzed with one way ANOVA showed that in groups using Panavia F 2.0, group 1 and group 2 were significantly higher than group 3 ($p<0.05$). In groups using RelyX Unicem, group 4 and group 5 were significantly higher than group 6 ($p<0.05$). The *t*-test showed that the groups using RelyX Unicem were significantly higher failure resistance than the groups using Panavia F 2.0 in each ratio ($p<0.05$). Within the limitations of this study, teeth restored with core:post ratio at 2:3 and 1:1 indicated significantly higher failure resistance than restored with ratio 3:2. RelyX Unicem used for luting fiber post exhibited significantly higher failure resistance than Panavia F 2.0 in each ratio.

Department: Prosthodontics	Student's Signature…………………………
Field of Study: Prosthodontics	Advisor's Signature………………………..
Academic Year: 2010	

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CONTENTS

Pages

LIST OF TABLES

Tables **Pages**

LIST OF FIGURES

Figures **Pages**

CHAPTER I

INTRODUCTION

Endodontically treated teeth with extensive loss of coronal tooth structure caused by dental caries, fracture and trauma are commonly restored with a post and core with crown to retain the restoration (1-3). The amount of remaining tooth structure is an importance factor which affects the survival rate of restored endodontically treated teeth. The less remaining tooth structure increase the risk of failure. In addition, the loss of water content in dentin and loss of collagen fiber after treatment can reduce tooth resilience that lead to high risk for root fracture (4, 5).

Fiber reinforced composite posts (FRC) have become more and more popular to restore endodontically treated teeth because of their favorable mechanical and esthetic properties. In contrast to metal posts, the elastic modulus of FRC posts is closed to that of dentin and resulting in good stresses transmitted to the root and reduced the incident of root fractures. In addition, the FRC posts result in more esthetics in anterior restorations compared to the dark shade of metal post (2, 6-8). Previous studies suggested that the success rate of teeth restored with posts related to many factors such as post length, post diameter, post design, post material, core material, ferrule effect and luting cement (2, 3). The post length is one of the important factor that relates to fracture resistance and retention of post which affect the success rate of endodontically treated teeth (9-11). Some cases of teeth such as the extensive root caries that need crown lengthening or teeth with periodontal condition with bone resorption or gingival recession result in increased clinical crown length and reduced root length these make the short length of post in bone and makes it questionable for dentist to restore these teeth with FRC posts which bond to root is still unclear.

Many studies showed that the increasing in fracture resistance in restored teeth was associated with increasing post length in root. Giovani et al. (12) investigated the fracture resistance in teeth restored with FRC posts with different post length. The results showed that the 10 mm FRC posts had significantly higher fracture resistance when compared with 6 mm posts. Similar result was found by McLaren et al. (13) that the teeth restored with 10 mm FRC posts had significantly higher fracture resistance when compared with 5 mm posts. The results also consistent with the study of Cecchin et al. (14) who found that the teeth restored with FRC posts at 12 mm and 8 mm had significantly higher fracture resistance compared with the teeth restored with post at 4 mm, while no significant difference was found between the 12 mm and 8 mm groups. Hsu et al. (15) evaluated the effect of post length on the stress distribution of maxillary central incisors with the three dimensional finite element analysis. The results showed that the longer fiber posts had better stress distribution than the shorter fiber posts. Adanir and Belli (16) investigated the effect of different length of fiber post and different types of luting cement on fracture resistance. Three different post lengths; shorter than clinical crown length, equal to clinical crown length and longer than clinical crown length were cemented with two different luting cement; Super-Bond C&B and Panavia F. The results showed that the teeth restored with post length shorter than clinical crown length had significantly less fracture resistance than the others and there was no significant difference on fracture resistance between different luting cement types. However, the specimens in this study were not restored with crown which may not reproduce the real clinical conditions. The crown restoration may affect the fracture resistance. The specimens in this study only simulated the different post length in the same length of root. The condition of the teeth with crown lengthening or periodontal teeth which had different of the loss of bone support lead to different post length clinically. Reinhardt et al. (17) reported that the loss of bone support resulting in increasing stress concentration and leaded to high potential of root fracture (17). Recently, the new group of resin cements, self-adhesive cements, such as RelyX Unicem has been introduced for luting fiber posts. Previous studies reported that RelyX Unicem obtained higher bond strength than Panavia F 2.0 (18-20). Using RelyX Unicem for luting post may affect to fracture resistance of restored teeth.

The purpose of this study was to evaluate the effect of three different core length to fiber post length at 2:3, 1:1 and 3:2 with two different post luting cement (Panavia F 2.0 and RelyX Unicem) on failure resistance of endodontically treated teeth with simulated metal crown.

The purposes of this study

1. To investigate and compare failure resistance of restoring technique of endodontically treated teeth with fiber post which have different core length to post length ratios using Panavia F 2.0 for luting posts.
2. To investigate and compare failure resistance of restoring technique of endodontically treated teeth with fiber post which have different core length to post length ratios using RelyX Unicem for luting posts.
3. To investigate and compare failure resistance of restoring technique of endodontically treated teeth with fiber post which have different post luting cement in each core length to post length ratios.

Hypotheses

<u>Hypothesis 1</u>

Null hypothesis: There is no significant difference of failure resistance between the endodontically treated teeth restored with fiber post which have different core length to post length ratios using Panavia F 2.0 for luting posts.

Alternative hypothesis: There is significant difference of failure resistance between the endodontically treated teeth restored with fiber post which have different core length to post length ratios using Panavia F 2.0 for luting posts.

<u>Hypothesis 2</u>

Null hypothesis: There is no significant difference of failure resistance between the endodontically treated teeth restored with fiber post which have different core length to post length ratios using RelyX Unicem for luting posts.

Alternative hypothesis: There is significant difference of failure resistance between the endodontically treated teeth restored with fiber post which have different core length to post length ratios using RelyX Unicem for luting posts.

Hypothesis 3

Null hypothesis: There is no significant difference of failure resistance between the endodontically treated teeth restored with fiber post which have different post luting cement in each core length to post length ratio.

Alternative hypothesis: There is significant difference of failure resistance between the endodontically treated teeth restored with fiber post which have different post luting cement in each core length to post length ratio.

Keywords

- Fiber reinforced composite post (FRC post)
- Failure resistance
- Core : post length ratio

Proposed benefits

1. To investigate and compare failure resistance of restoring technique of endodontically treated teeth which have different core length to fiber post length ratios and different post luting cements.
2. To select and apply the appropriate fiber post technique restoration for endodontically treated teeth for clinically condition.
3. To gain the knowledge for further study in restoration of endodontically treated teeth.

Type of research

Laboratory experimental research

CHAPTER II

LITERATURE REVIEW

Fiber reinforced composite post

Fiber reinforced composite post gained popularity in the 1990s for endodontically treated teeth restoration (2). The main advantage of FRC post was the modulus of elasticity more closely to dentin (21). The FRC posts were combined with root dentin by luting cement which can form a structurally and mechanically homogeneous complex that can distribute the applied forces along the post and root to reduce stress concentration resulting in increasing fracture resistance (22). In clinical studies, Monticelli et al. (23) reported that the failures of the endodontically treated teeth restoration with FRC posts were very low. The study of Isidor et al. (24) showed that teeth restored with carbon fiber posts, the first of FRC post, had higher fracture resistance when compared to the teeth restored with titanium posts or metal posts. The carbon fiber posts were dark shade, which was an esthetic problem when using in anterior zone (2). This was the same problem of dark shade of metal posts. The other types of FRC post have been developed to improve the esthetics. The glass and quartz fibers have been introduced with translucent fiber posts (25). Sirimai et al. (26) reported that when considering the failure modes of FRC post restoration were more favorable when compared with the failure mode of metal post restoration. Moreover, FRC posts are relatively easy to remove with an ultrasonic or rotary instrument when compared to metal posts (27).

The success rate of teeth restored with FRC posts related to many factors such as post length, post diameter, post design, ferrule effect, core material, and luting cement (2, 3).

Post length

The post length is the importance factor which influences stress distribution in the root and affects the fracture resistance of the teeth (28). An increase in the success rate of endodontically treated teeth restoration with metal posts has been recommended when the length of the post is equal to or greater than the crown length (29, 30). A higher failure rate is seen when the post length is too short (31). Similar to the restorations with FRC post, many studies showed that teeth restored with longer FRC post in root had significantly higher fracture resistance compared with shorter FRC post (12-14, 32). Hsu et al. (15) evaluated the effect of post length on the stress distribution of maxillary central incisors with the three dimensions finite element analysis. The results showed that the longer FRC posts had better stress distribution than the shorter posts. Scotti et al. (33) reported that the fatigue résistance of teeth restored with the crown length to FRC post length ratio at 1:1 was not different when compared to the crown length to post length ratio at 2:3 and 1:2. Adanir and Belli (16) investigated the effect of different length of FRC post on fracture resistance. The teeth were restored with three different FRC post lengths; shorter than clinical crown length, equal clinical crown length and longer than clinical crown length. The results showed that the teeth restored with post length shorter than clinical crown length had significantly less fracture resistance than the others. Moreover, Reinhardt et al. (17) had advised that not only the greatest length of post but also the quantity of bone support surrounding the root increases the fracture resistance, the finite element analysis showed that when the bone support of roots decreased resulting in increasing stress concentration and leaded to high potential of root fracture (17).

Post diameter

Post diameter is the factor that influences the fracture resistance of endodontically treated tooth. Post diameter relates to the remaining dentin (34, 35). Robbin (36) recommended that the diameter should be “as small as possible” to increase the fracture resistance by minimizing loss of tooth structure. The previous studies found that the greater the amount of remaining dentin of the post channel was the better fracture resistance (34, 35, 37). Stern and Hirshfeld (38) suggested that the optimal diameter of the metal post should be one third the diameter of the root. The study of Lassila et al. (38) showed that in the same post space, large FRC posts had more favorable of the fracture resistance than small posts.

Post design

The posts are classified according to shape such as parallel, tapered, or parallel-tapered combination and surface configuration such as active or passive. Parallel metal posts are more retentive than tapered posts (39, 40) and this also is reported to be true for FRC posts (41). The tapered or tapered-end posts results in an extensive and higher incidence of root fracture more than parallel posts since tapered posts have a wedging effect (42). Sorensen and Martinoff (9) reported a higher success rate with parallel posts than tapered posts. Qualtrough et al. (41) reported that the teeth restored with parallel FRC post had more retention than tapered posts. Shah et al.(43) evaluated the retentive strength of active and passive FRC posts. The results showed that the post-tooth retentive strengths for active posts were significantly higher than the passive posts.

Ferrule effect

The ferrule effect is an important factor to long-term success of post restoration (44). A ferrule is defined as a vertical band of tooth structure at the gingival aspect of a crown preparation. It provides mainly resistance form and some retention to prevent fracture of the root and dislodgement of the post (44-47). Sorensen and Engelman (44) reported that ferrule with 1 mm of vertical height has been shown to double the resistance to fracture compared with teeth restored without a ferrule. Libman and Nicholls (48) stated that an adequate ferrule should be 1.5 to 2 mm. The study of Akkayan and Gulmez (49) showed that the teeth which 2 mm ferrule restored with FRC posts had more fracture resistance than the teeth with 1.0 to 1.5 mm ferrule. This result was consistent with the study of Ng et al. (50) which showed that the fracture resistance of the teeth with 2 mm ferrule restored with fiber post was significantly higher than the teeth with no ferrule. On the other hand, a study by al-Hazaimeh and Gutteridge (51) reported no difference in fracture resistance with or without a 2 mm ferrule using prefabricated posts and resin cement but the fracture patterns of the teeth with a ferrule were more favorable compared to the teeth without a ferrule. The result of this study is the same with study of Saupe et al. (52) who showed that the fracture resistance of compromised endodontically treated teeth restored with FRC post which have ferrule and no ferrule were not significantly different.

Core material

Core material is a factor affected the ability to distribute stress of post (53). Yaman and Thorsteinsson (54) reported that stiffer core material increases the cervical stress concentration resulting in decreasing failure resistance of the restoration. The choices of core material which build-up after cementation of the post are glass-ionomer materials, amalgam and composite resin. The glass-ionomer materials, including resin-modified glass ionomer, lack adequate strength for core buildup materials (55, 56) and should not be used in teeth with extensive loss of tooth structure. The strength of glass-ionomer material is reported to be lower compared to amalgam and resin composites (57, 58). Amalgam has been used as a core buildup material since it has good physical and mechanical properties (58, 59). However, amalgam has some disadvantages which the crown preparation must be delayed to permit the material time to set. It can cause esthetic problems with ceramic crowns and sometimes makes the gingiva look dark and does not bond to dentin or adhesive resin. For these reasons, amalgam is no longer widely used (60).

Currently, resin composites is the most popular core material and has some characteristics of an ideal buildup material. It can be bonded to many of the current posts and to the remaining tooth structure to increase retention (61). It has high tensile strength and the tooth can be prepared for a crown immediately after polymerization. The study of Pilo et al. (62) showed that resin composites cores have no difference on fracture resistance compared with amalgam and cast post and cores. Moreover, resin composite cores had more favorable fracture patterns than the other cores. The resin composite is tooth colored and can be used under translucent restorations without affecting the esthetic result. On the negative side, composite shrinks during polymerization, causing gap formation in the areas in which adhesion is weakest. It absorbs water after polymerization causing it to swell (58, 59, 63). Bonding ability of resin composite to dentin depends on moisture control. If the dentin surface is contaminated with blood or saliva during bonding procedures, the bonding ability is greatly reduced (64).

Post retention in the root

Post retention refers to the ability of a post to resist vertical dislodging forces. Retention is influenced by the post length, the post diameter and the post design, the luting cement used (39). Moreover, in order to improve the bond strength between the fiber post and the resin cement, many chemical and mechanical surface treatment procedures have been investigated to enhance the roughening fiber post surface for increasing the surface area and enhancing the mechanical interlocking (65-68).

For chemical surface treatment procedures, chemical solutions such as silane coupling agents, hydrofluoric acid (HF), hydrogen peroxide (H_2O_2) and potassium permanganate have been investigated in attempt to improve the bond strength between the FRC posts and the resin cement (69-71). Silane coupling agents are generally used to increase the surface wettability and provide a chemical bond between inorganic substrates such as glass or quartz fibers of the post and the polymer of resin cement (72). Previous studies reported that silanization significantly improved bond strength between FRC post and resin cement (65, 66, 72). However, bond strengths to FRC posts is still relatively low that the clinical relevance of the differences have been considered of minor importance (72). The study of Vano et al. (69) found that when hydrofluoric acid was used for conditioning FRC posts, despite this treatment can improves in bond strength but the extremely corrosive effect of the acid on the glass phase cause micro-cracks to longitudinal fractures of the FRC posts. Many studies showed that post surface treatment with hydrogen peroxide and potassium permanganate significantly increases the bond strength between FRC posts and resin composites. Hydrogen peroxide and potassium permanganate results in removing a surface layer of epoxy resin to exposed quartz fibers for silanization (65, 67, 69). Yenisey and Kulunk (73) studied the surface treatment of glass and quartz fiber post using chemical solvents. The result suggested that the surface treatment with 10% hydrogen peroxide for 20 minutes significantly increased the bond strength of the FRC post.

For mechanical surface treatment procedures such as airborne-particle abrasion with aluminum oxide or silica were evaluated the bond strength between FRC posts and resin cement. The previous studies reported that the airborne-particle abrasion with aluminum oxide had more effective in increasing the bond strength than chemical techniques such as etching with hydrofluoric acid or silanization (66, 68, 71). The sandblasting with alumina particles resulted in increased surface roughness and surface area. Air abrasion with silica coated aluminium oxide particles (CoJet) creates a silica layer on the post surface about 15 microns. This treatment showed higher bond strength between FRC post and resin cement when compared with phosphoric acid or hydrofluoric acid etching (74, 75). Although the airborne-particle abrasion can improves bond strengths but this treatment was considered too aggressive for FRC posts with the risk of significantly modifying their shape and fit within the root canals (75). Application time, alumina particle size and pressure may have influenced the airborne-particle abrasions. Asmussen et al. (76) found that FRC posts were airborne-particle abraded with 50 microns alumina particles at 2.5-bar pressure for 5 sec and a distance of 30mm. This regimen did not aggressive to changes of the shape of the FRC post.

Luting cement

Luting cement is an importance factor that relate to retention between post and root canal dentin which affect success rate of post restoration. Zinc phosphate, zinc polycarboxylate, glass-ionomer, and resin cements are commonly used for post luting. It has been reported that the cement layer provides a buffer zone that contributes to uniform stress distribution between the post and the root canal (77). A thickness layer of cement and bonding ability relate to stress distribution between the post and the root canal (78). The weakness bonding ability and brittleness of the cement affect high fracture resistance of the endodontically treated tooth (79). Mendoza et al. (80) suggested that resin cement was significantly increased the resistant to fracture than conventional cement. The resin cement is more popular for luting FRC posts since increasing retention (81, 82), improving fracture resistance (80) and less leakage of the restored teeth than other cements (83).

Resin cement was classified by polymerization process into self-cure, light-cure, and dual-cure. Ferrari et al. suggested that self-cure or dual-cure cements should be used because of limited light penetration into the root, even with translucent posts (84). Moreover, self-cured and dual-cured composites produce lower shrinkage stresses compared with light-cured that more stress relief from polymerization process (85).

Resin cement was classified by adhesive systems into total-etch , self-etch and self-adhesive resin cements (86). Total-etch or etch and rinse adhesive systems such as Variolink II, Calibra and Super bond and self-etch adhesives or self etching primers such as Panavia 21, Panavia F 2.0 and Multilink are widely used for luting FRC posts. Recently, the new group of resin cements, self-adhesive cements, has been introduced for luting FRC posts such as RelyX Unicem. Goracci et al.(87) evaluated the bond strengths of total-etch, self-etch and self-adhesive resin cements (Variolink II, Panavia 21and RelyX Unicem) to glass fiber posts. The result showed that Variolink II were significantly higher bond strengths than Panavia and RelyX Unicem. Transmission electron microscopy analysis revealed that Panavia 21 and RelyX Unicem did not effectively remove the thick smear layer created on root dentin during post space preparation. Similar to the study of Valandro et al. (88) concluded that more reliable bond strengths of the total-etch adhesive systems than self-etch adhesives systems. Adanir and Belli (16) investigated the fracture resistance of the teeth using Super-Bond C&B and Panavia F for posts luting. The results showed that there were no significant difference on fracture resistance between using Super-Bond C&B and Panavia F. On the other hand, Mannocci et al.(89) found that self-etch adhesive cements resulted in a higher push-out bond strength than the total-etch adhesive cements (89). Because the advantage of self-etch adhesive cements is good moisture control than total-etch adhesive cements (90). However, total-etch and self-etch have some disadvantages that are more “technique sensitive” than most of the other luting cements. These require many steps such as preparing dentin surface. It may has problem of contamination of the dentin or post (2).

Self-adhesive cements were introduced in 2002 as a new group of resin cements. These materials were designed with the purpose of overcoming some limits of both conventional resin cements. Self-adhesive cements do not require any pretreatment of the tooth substrate. The simple used, a single clinical step, reduce the mistakes by technique sensitivity (20). Self-adhesive cements are still relatively new and detailed information or clinical data of effectiveness are limited. RelyX Unicem is the most investigated self-adhesive cement. Features of RelyX Unicem are explained by the manufacturer (3M ESPE product). The adhesion mechanism is claimed to rely on micromechanical retention and chemical interaction between monomer acidic groups and hydroxyapatite. Goracci et al.(87) investigated the push-out bond strength of Variolink, Panavia and RelyX Unicem.

The result found that no significant difference between RelyX Unicem and Panavia F but the both cements had significantly lower bond strengths compared to Variolink. Different results were reported by Bitter et al. (18) that the push-out bond strength of RelyX Unicem was significantly higher than that of Panavia F and Variolink. Moreover, the bond strength of RelyX Unicem was significantly higher after thermo-cycling. The authors explain that the self-adhesive cements are moisture tolerance may its favorable adhesion in the root canals (18).

CHAPTER III

MATERIAL AND METHODS

Materials used in this study

1. Quartz fiber reinforced post (DT light post, Bisco Inc, France)
2. Panavia F2.0 (Kuraray medical, Japan)
3. RelyX Unicem (3M ESPE, Germany)
4. Resin composite (Tetric N Ceram, Ivoclar Vivadent, USA)
5. 37% Phosphoric acid (Total Etch, Ivoclar Vivadent, USA)
6. Bonding agent (Tetric N Bond, Ivoclar Vivadent, USA)
7. Silane coupling agent (mixture of Clearfil SE bond primer and porcelain bond activator, Kuraray medical, Japan)
8. Self cured acrylic resin (Formatray, Kerr, USA)
9. Additional polyvinyl siloxane impression materials putty and light body type (Reprosil, Dentsply, USA)
10. Pink baseplate wax (Modelling wax, Dentsply, USA)
11. PVC mold 22 mm in diameter
12. Stone type IV (Velmix die stone, Sybron Kerr, UK)
13. Blue inlay wax (blue inlay casting wax, Kerr, USA)
14. Fit checker (Fit checker, GC Corporation, Japan)
15. Base metal alloy (4all, Ivoclar Vivadent Williams #0123, USA)
16. Root canal sealer (CU Product, Chulalongkorn University, Thailand)
17. Gutta percha point (Coltene Whaledent, USA)
18. 2.5% Sodium hypochlorite (CU Product, Chulalongkorn University, Thailand)
19. Temporary filling (Fermin, Detax, Germany)

Instruments used in this study

1. Low speed cutting machine (Isomet 1000, Buehler, USA)

2. High speed airoter 330,000 rpm (high speed airotor, 798 W&H, Australia)
3. Light curing unit (Translux EC, Kulzer, Germany).
4. Diamond burs (ISO 314197, Intensiv, Switzerland)
5. Digital calipers (Best Co., Japan)
6. Dental surveyor (Hanau surveyor, Hanau, Germany)
7. K-file (K-Reamer, Dentsply , USA)

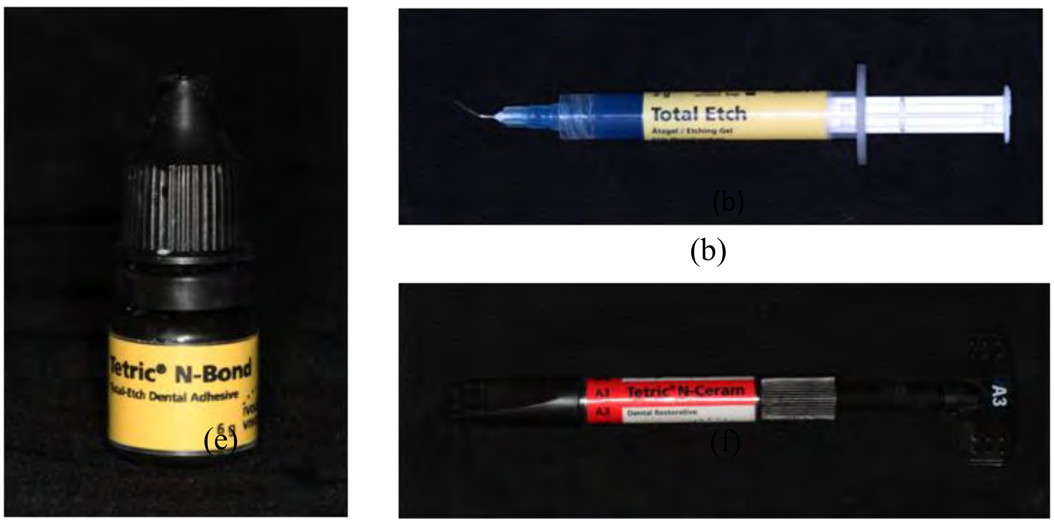
Figure 1 Quartz fiber reinforced post (DT light post).

(a)

(b)

Figure 2 Resin cement: Panavia F2.0 (a) RelyX Unicem (b).

Figure 3 Silane coupling agent.



(b)

(a) (c)

Figure 4 Core build up materials : Bonding agent (a)

37% Phosphoric acid (b) Resin composite (c).

Tooth preparation

Forty-eight extracted human mandibular first premolar from patients received orthodontic treatment with criteria of straight root canal, non-carious and non-restorations were used in this study. The root lengths at the cemento-enamel junction (CEJ) of all selected teeth were 14.0±0.5 mm. The teeth were scaled to remove calculus and organic debris. All teeth were stored in 0.9% normal saline solution.

The teeth were randomly divided into six groups of 8 which were restored with three different core length to fiber post length at 2:3, 1:1 and 3:2 and two different post luting cement (Panavia F 2.0 and RelyX Unicem) (Table I and Figure 5).

Table I Six groups of testing with three different core to fiber post length ratios and two different post luting cements

Group	Root length (mm)	Core length (mm)	Post length (mm)	Core : Post ratio	Cement type
1	14	6	9	2:3	Panavia F 2.0
2	12.5	7.5	7.5	1:1	Panavia F 2.0
3	11	9	6	3:2	Panavia F 2.0
4	14	6	9	2:3	RelyX Unicem
5	12.5	7.5	7.5	1:1	RelyX Unicem
6	11	9	6	3:2	RelyX Unicem

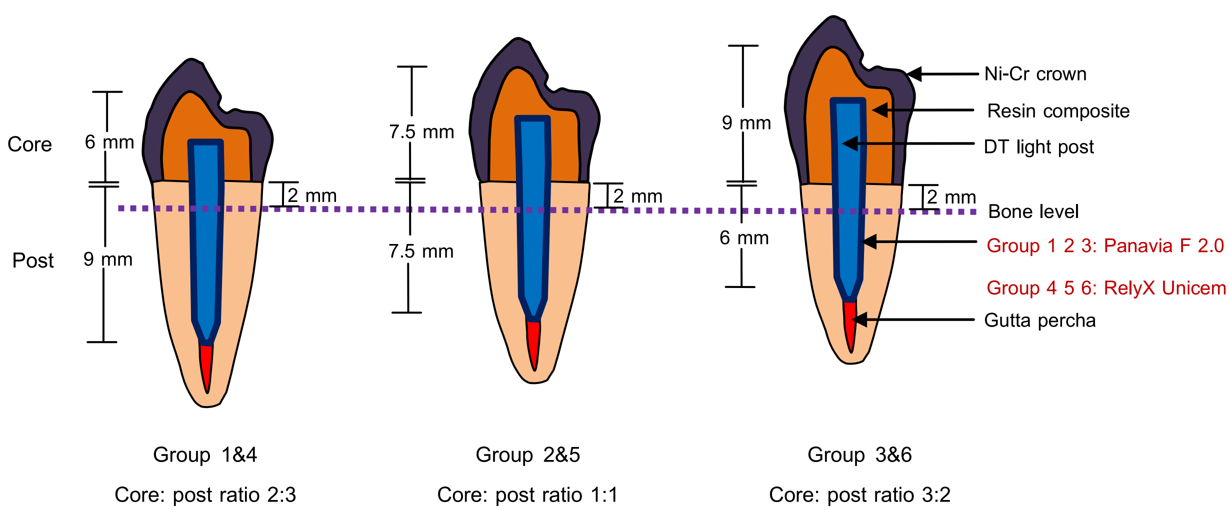


Figure 5 Diagram of six groups of testing with three different core to fiber post length ratios and two different post luting cement.

The crowns were removed with a low speed cutting machine with three different root lengths ; group 1&4 at 14 mm root length, group 2&5 at 12.5 mm root length and group 3&6 at 11.0 mm root length. Mesiodistal and buccolingual dimensions and root lengths of all teeth were measured with digital calipers to ensure the nearly similar size and shape of root in each group. The data are showed in Table II.

Table II Mean dimensions and standard deviation (mm) of mandibular first premolar roots in each group

Group	Root length (mm)	Mesio-distal width (mm)	Bulcco-ligual width (mm)
1	14.13 (0.05)	5.26 (0.24)	7.67 (0.19)
2	12.59 (0.04)	5.05 (0.14)	7.06 (0.20)
3	11.13 (0.07)	4.95 (0.21)	7.02 (0.21)
4	14.08 (0.06)	5.08 (0.18)	7.47 (0.23)
5	12.55 (0.06)	5.06 (0.19)	7.26 (0.15)
6	11.11 (0.04)	4.94 (0.13)	7.17 (0.15)

Canal preparation

Each tooth was endodontically treated by using a conventional step-back technique. Canals were cleaned and shaped by using K-file size of 35 and 5.25% sodium hypochlorite irrigation at working length of 1 mm from the apex. The prepared teeth were dried with paper-points and obturated with gutta-percha and root canal sealer by using a lateral condensation technique. The access was filled with temporary filling. All specimens were stored in distilled water at 37 °C for 72 hours.

Post core and crown restoration

For group 1, the post spaces were prepared to 9.0 mm in length for DT light post No.1 using a drill recommended by manufacturer. The posts were applied with silane coupling agent for 5 sec to treat the post surface. The posts were cemented into the root canal with Panavia F 2.0 by the mixed ED primer was applied to the post space with microbrush for 30 seconds, gently air dried, then excess primer was removed using paper points. Panavia F 2.0 paste A and paste B were mixed and applied to the posts. The posts were inserted to the post spaces and seated by the finger pressure. Excess cement was removed and light polymerization was performed for 40 seconds with the halogen light. The cores were fabricated by conditioning the teeth with 37% phosphoric acid gel. Then, the bonding agent was applied and light polymerization was performed for 20 seconds. To obtain the simulate core dimension, the acetate molds were made in a vacuum plasticizer for 6.0 mm core height. The acetate mold was filled with the resin composite and positioned on the coronal portion of the teeth. The excess resin composite was removed and the cores were light polymerized for 40 seconds. After polymerization, the specimens were prepared with circumferential shoulder margin (0.5 mm) with no ferrule by using a diamond rotary cutting instrument prepared for full metal crown. The total core length from the buccal CEJ was 6.0 mm. Impressions for crown were made with vinyl polysiloxane impression material and poured with type IV dental stone. The crown patterns were made with casting wax by using silicone index which duplicated the standard anatomical form of crown with the crown height of 8.0 mm. The notch was located at the center of occlusal surface 3.0 mm from buccal cusp tip with 1 mm width and 0.5 mm depth for the load application. The casting wax was cast in Ni-Cr alloy. The metal crowns were cemented with Panavia F 2.0. After finishing the procedures, the core:post ratio of this group was 2:3

For group 2, to obtain the core:post ratio at 1:1, the post spaces were prepared to 7.5 mm in length and the 7.5 mm core length was fabricated. The other procedures were the same as in group 1. For group 3, to obtain the core:post ratio at 3:2, the post spaces were prepared to 6.0 mm in length and the 9.0 mm core length was fabricated. The other procedures were the same as in group 1. For groups 4, 5 and 6, the specimens were prepared as same as groups 1, 2 and 3 respectively but luting post with RelyX Unicem by triturated the capsule then the cement was applied directly to the post space through a disposable application tip attached to the capsule. The posts were seated by finger pressure. The excess cement was removed and the cement was allowed to autopolymerize for 5 minutes (Figure 6).

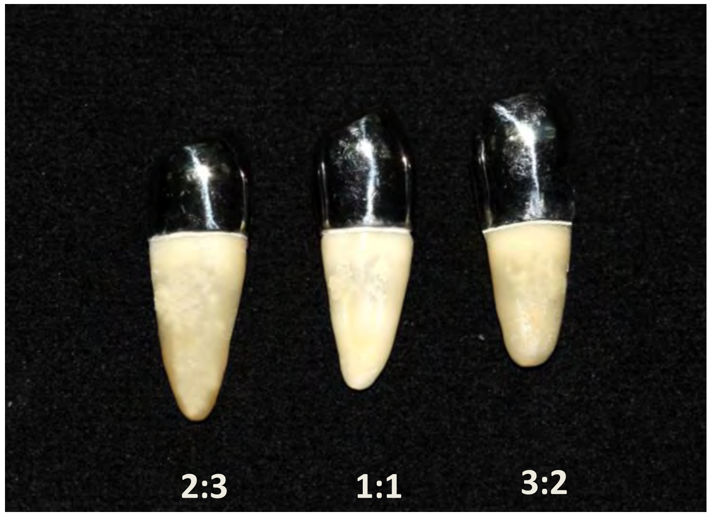


Figure 6 Specimens with three different core to fiber post length ratios.

Block preparation and periodontal ligament simulation

To simulate the periodontal ligament (PDL), the roots of all specimens were immersed into melted wax to a depth 2 mm below the buccal CEJ to produce 0.2 mm layer for PDL space. The teeth were embedded in a PVC pipe ring (22 mm radius, 20mm height) by using self cure acrylic resin at a distance of 2 mm from the buccal CEJ to simulate biological width (7). Specimens were aligned with a dental surveyor to ensure that the long axis of the specimen was parallel to the axial surface of the resin block. Then, the tooth were removed from the block when the first sign for heat of polymerization were observed. After polymerization was complete, the tooth was replaced in the block and a silicone index of the crown to the block was prepared by the putty type of polyvinyl siloxane impression material to ensure accurate repositioning. The wax spacer was removed from the root surface. The light body type of polyvinyl siloxane impression material was injected into the block. Then the tooth was reinserted into the block with the silicone index to ensure the correct position. The impression material was allowed to set. The excess silicone material was removed. In this procedure the thin layer of silicone material was simulated as PDL. All specimens were stored in distilled water at 37 °C for 24 hours (Figure 7).

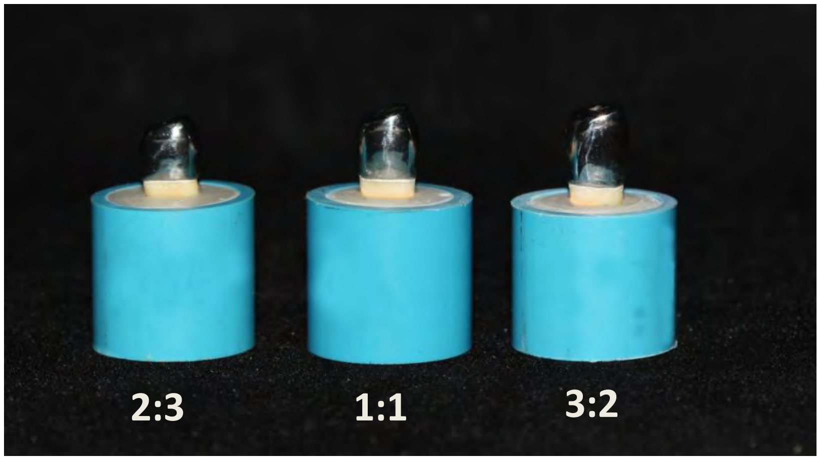


Figure 7 Specimens for failure resistance test.

Failure resistance test

The specimens were subjected to compressive test in a universal testing machine (Instron testing machine model 5566, Instron Co., USA) by locating the position in mounting device so that the load could be applied at an angle of 45 degrees to the long axis of the teeth (Figure 8&9). The load was applied to the specimen with 1 mm/min crosshead speed until failure occurred. Failure resistances (N) were recorded.

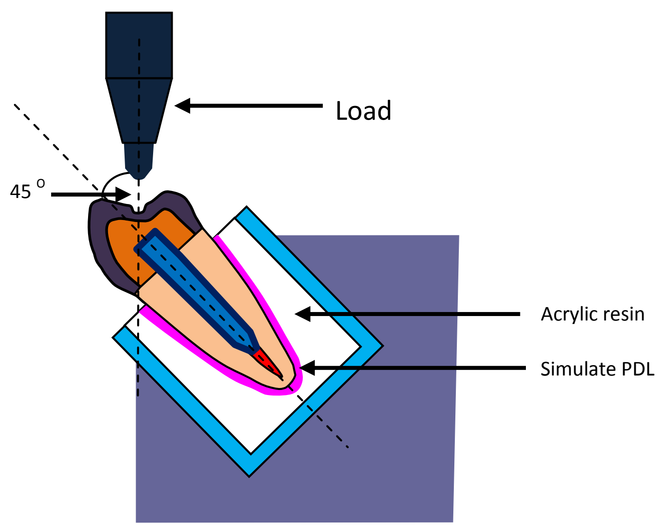


Figure 8 Schematic diagram of compressive test with universal testing machine.

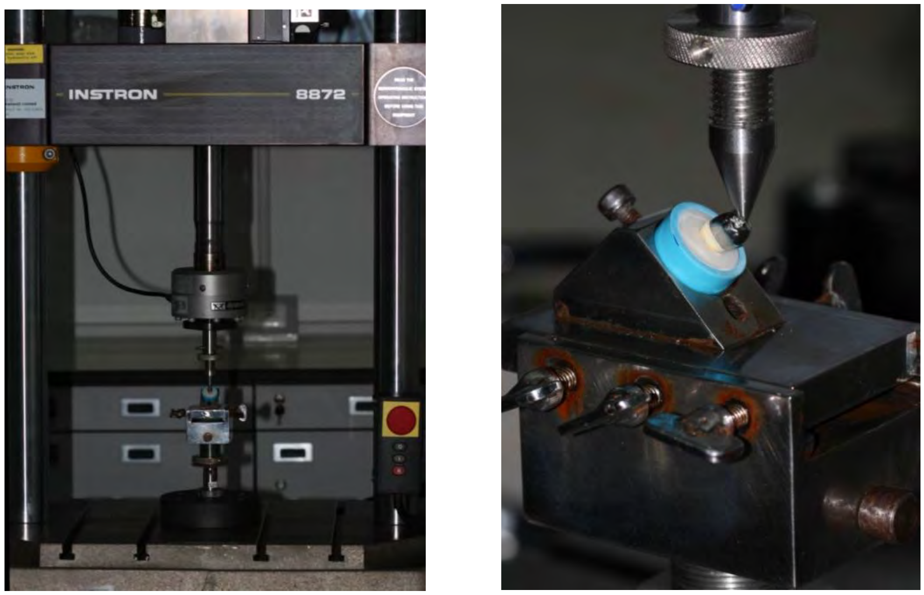


Figure 9 Compressive test with universal testing machine.

Statistics analysis

The data of each group were calculated for mean and standard deviation. The one-Sample Kolmogorov-Smirnov was performed to assess the normal distribution of the data. The one-way ANOVA followed by Tukey HSD test (α=0.05) was analyzed to determine the significant differences between groups using the same luting cement but different core: post ratios. The *t*-test (α=0.05) was analyzed the data to determine significant differences between the types of luting cement in each ratio. All statistics were performed with SPSS version 16.0 for windows (SPSS Inc, USA).

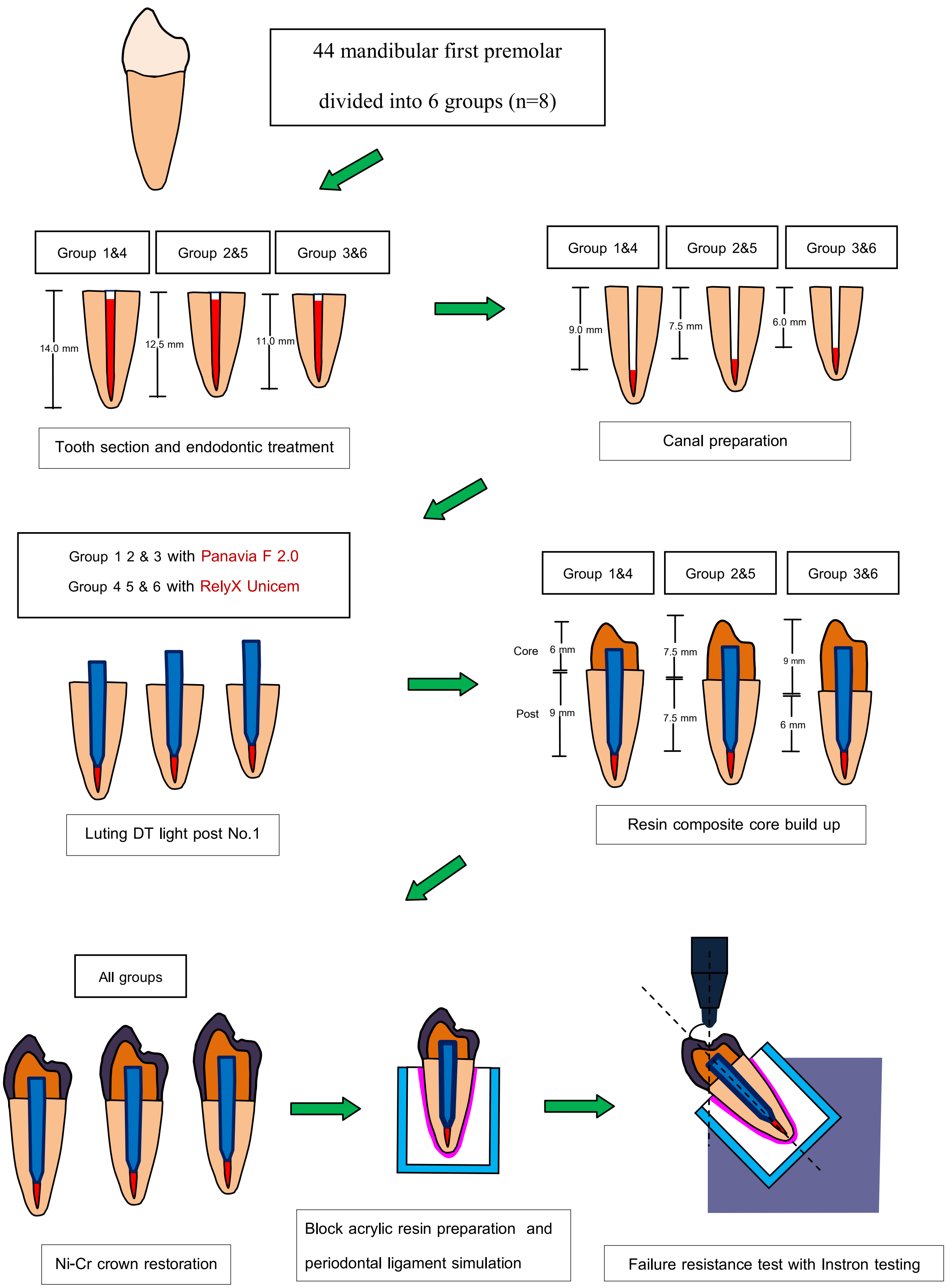


Figure 10 Flow chat of this research methodology.

CHAPTER IV

RESULTS

The mean failure resistance and standard deviation (N) are shown in Table II. In groups using Panavia F 2.0, there was no significant difference of failure resistance between group 1 (453.6 ±23.3 N) and group 2 (424.2 ±28.2 N) but these two groups were significantly higher than group 3 (295.7 ±24.8 N) (Figure 11). In groups using RelyX Unicem, group 4 (555.9 ±16.9 N) was not significantly different in failure resistance to group 5 (541.4 ±20.4 N) but these two groups were significantly higher than group 6 (413.8±11.9 N) (Figure 12). The *t*-test showed that the groups using RelyX Unicem were significantly higher in failure resistance than the groups using Panavia F 2.0 in each ratio (Figure 13).

Table III Mean failure resistance and standard deviation (N) of all groups

Group	Core : Post ratio	Cement types	Failure resistance and standard deviation (N)
1	2:3	Panavia F 2.0	454.3 ±22.4
2	1:1	Panavia F 2.0	423.1 ±27.9
3	3:2	Panavia F 2.0	295.7 ±24.8
4	2:3	RelyX Unicem	556.2 ±16.9
5	1:1	RelyX Unicem	541.1 ±20.2
6	3:2	RelyX Unicem	413.0 ±13.4

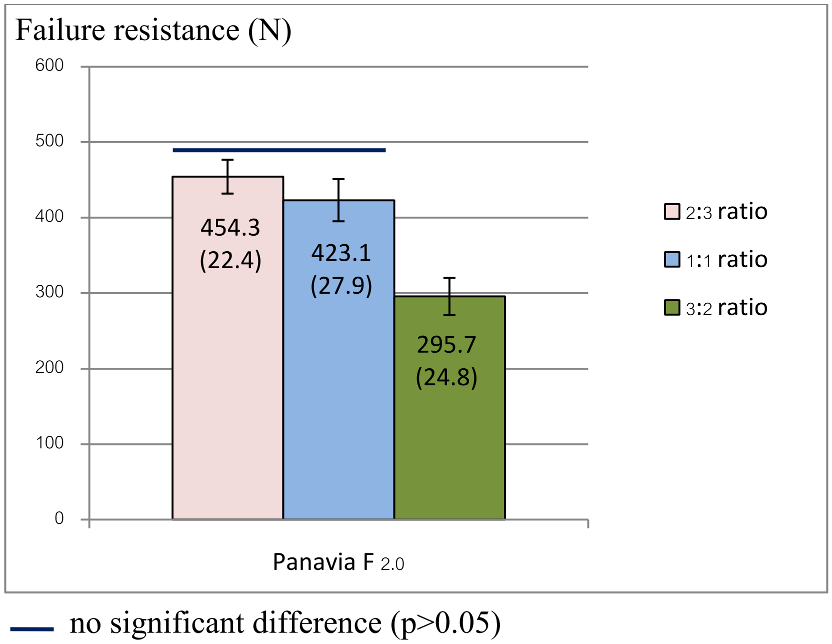


Figure 11 Comparison of the failure resistance in different core:post ratios of the groups using Panavia F 2.0**.**

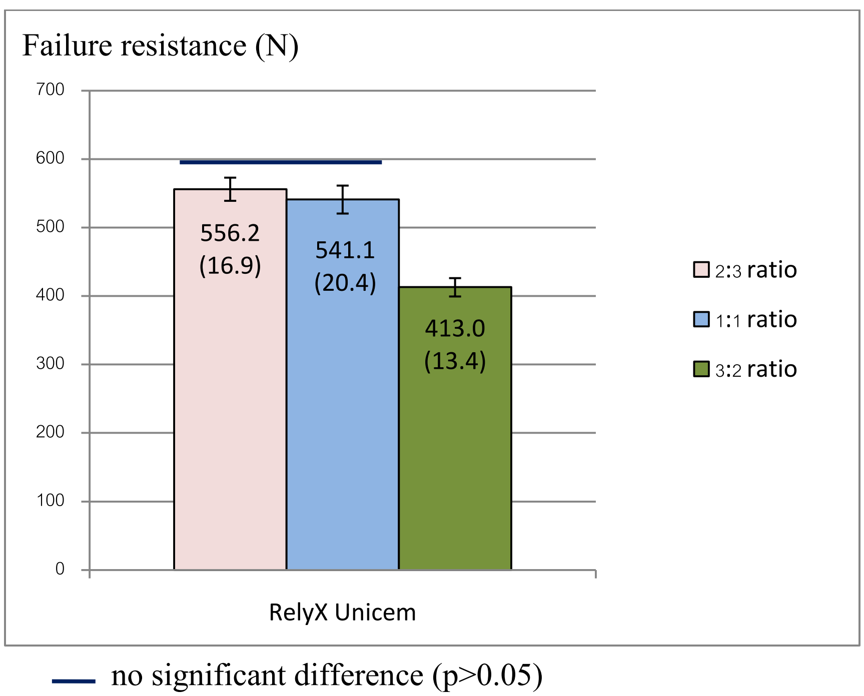
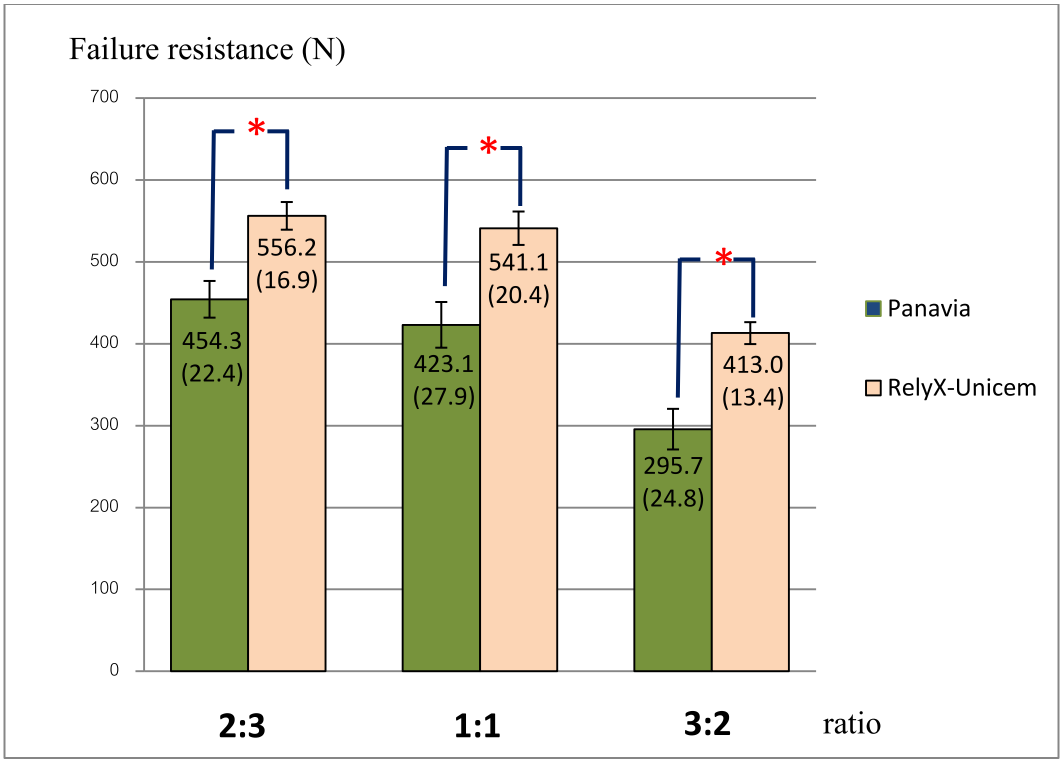


Figure 12 Comparison of the failure resistance in different core:post ratios of the groups using RelyX Unicem.



* significant difference (p<0.05)

Figure 13 Comparison of the failure resistance between Panavia F 2.0 and RelyX Unicem in each ratio.

The failure mode of the specimens in this study was classified into two patterns. Pattern 1: Horizontal post fracture was the debonding of the root-core/crown interface started from the lingual crown margin along to the post, then propagated horizontally to cause the post fracture and then deviated to the root apically and obliquely to the buccal side. Pattern 2: Post debonding was the debonding of the root-core/crown interface started at the lingual crown margin along to the facial part of post, then the fracture propagated apically along the post root interface and deviated obliquely to the buccal side (Figure 14). The distributions of different modes of failure of all groups are showed in Table IV. The position of failure of in all groups occurred around the cervical one third of root length.

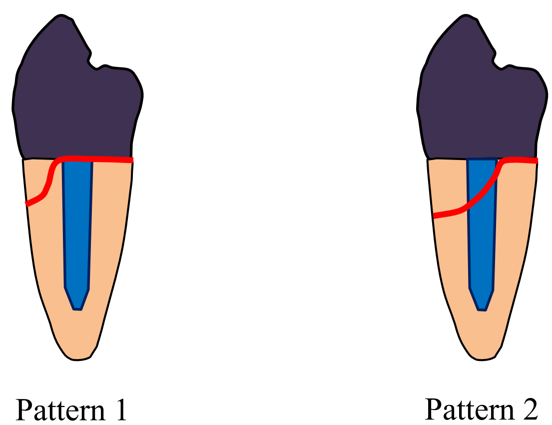


Figure 14 Schematic diagram of pattern 1 and pattern 2 failure mode.

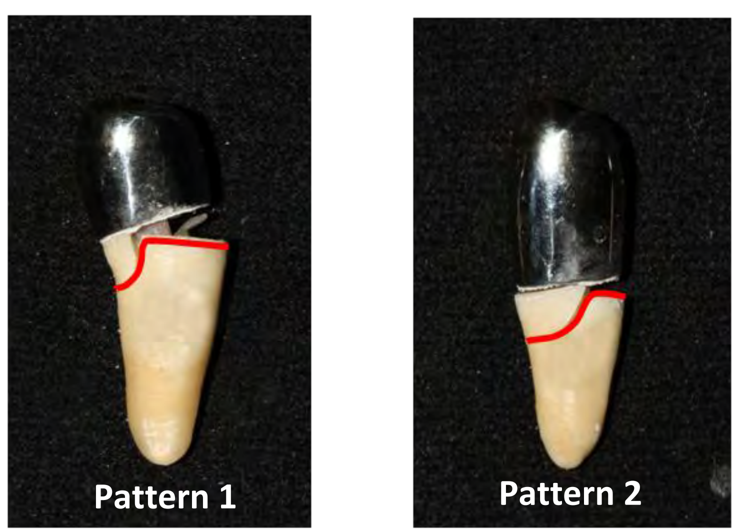
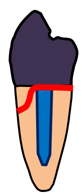
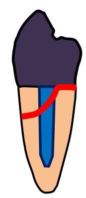


Figure 15 Pattern 1 and pattern 2 failure mode.

Table IV Distribution of different modes of failure of all groups

	Mode of failure		
Group	 Pattern 1	 Pattern 2	**Total**
1	8	0	8
2	8	0	8
3	8	0	8
4	7	1	8
5	6	2	8
6	4	4	8

CHAPTER V

DISCUSSION

The aim of this study was to evaluate the effect of different core length to fiber post length and using different luting cement types on failure resistance. All specimens were restored with metal crown to reproduce the clinical condition that may affect the failure resistance. Previous studies found that the endodontically treated teeth restored with the crown had higher long term survival rate those without the crown restored (91, 92).

The results of this study agreed with the previous studies that the increasing post length in root was associated with the increasing fracture resistance (12-14, 32) because it results in better stress distribution (15, 31). Naumann et al. (93) investigated the effect of alveolar bone loss on the fracture resistance of endodontically treated teeth restored with fiber posts and found that the teeth with increasing loss of alveolar bone had significantly reduced fracture resistance. This finding is consistent with Reinhardt et al. (17) who studied with finite element analysis and found that the mechanical stress increased when the bone support was reduced. Moreover, Meng et al. (94) also found that the teeth which performed crown lengthening before restoring with glass fiber posts lead to decrease in the fracture resistance because of the increasing clinical crown to root ratio and the reducing dentin volume of the taper roots. These findings are similar to our result in groups 3 and 6 which restored with shortest posts in bone at 3:2 ratio were significantly the lowest in the failure resistance. The explanation may be that in these groups were simulated with short root conditions which were similar to the teeth with heavy loss of alveolar bone and the teeth with crown lengthening which have long clinical crown length and short root length, thus the restoration of post length in bone support were limited. In addition, the endodontic filling materials in an apex of root must be 3 - 4 mm to maintain apical sealing which avoids leakage and contamination of root canal in accordance with the endodontic principles (95) that limit increasing post length. Therefore, in these conditions, the post length in bone were shortest. The short post length in bone support increased stress concentration with high potential to root fracture (15, 31).

Our findings showed that the teeth restored with core:post ratio at 2:3 were not significantly different when compared to the teeth restored with core:post ratio at 1:1. This result is similar to the result of Adanir and Belli (16) who found that the teeth restored with FRC post length equal to clinical crown length (9 mm) was not significant different fracture resistance compared to the post longer than clinical crown (12 mm). Similarly, the result of Cecchin et al. (14) found no significant difference of fracture resistance between the teeth restored with fiber posts at 12 mm and 8 mm. It can be indicated that using longer posts are not necessary when core is shorter than root but the ratio of 1:1 post length to core length is required.

In this study, the group with highest loss of bone support showed the lowest failure resistance. The level of bone affect the failure resistance. It can be explained mechanically with the lever and moment principle where bone level simulate as fulcrum. The different core:post lengths affect the moment. From figure 16, the different of bone levels affect the distance from fulcrum to applied load. In high bone level condition, the distance is shorter than moderate and low bone level condition, respectively (L1<L3<L5). From the moment principle, with similarly resistant force of root (F), the applied load of high bone level should be more than moderate and low bone level condition, respectively (F1>F2 >F3). However, the bone support simulation in this study might not simulate the real clinical condition of bone loss. In clinical condition, the teeth which has different bone level, the occluded position is the same. In this study, the level of bone was the same but higher occluded position was simulated. Further studies should consider this limitation.

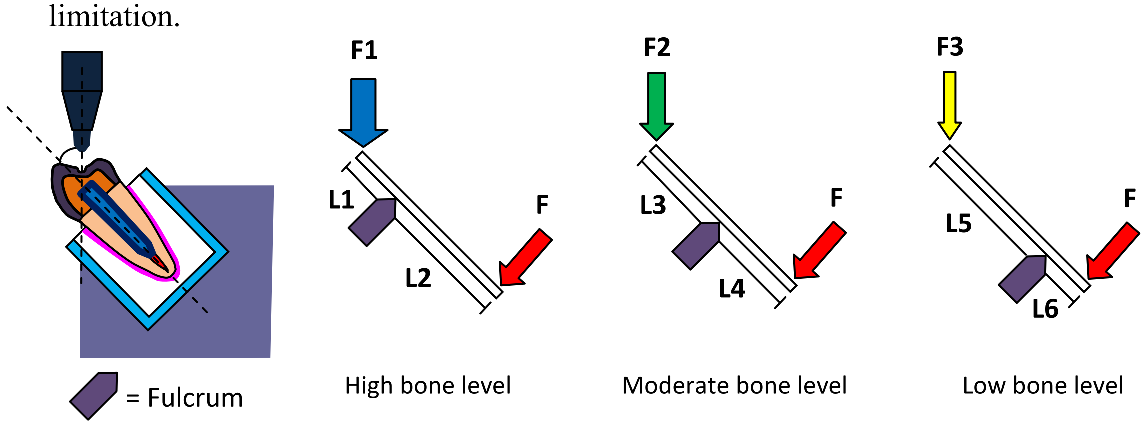


Figure 16 Diagram of lever and moment of different bone levels.

In this study Panavia F 2.0 and RelyX Unicem were selected to investigate. Panavia F 2.0 represents self-etch adhesives which are widely used for luting FRC posts while RelyX Unicem represents self-adhesive resin cement. The results of this study indicated that the groups using RelyX Unicem for luting fiber posts were significantly higher in failure resistance than the groups using Panavia F 2.0 in each post:core ratio. The reason might be that RelyX Unicem obtained higher bond strength than Panavia F 2.0. It was claimed to have high bond strength because of water forming during the neutralization reaction contribute to the cement's initial hydrophilicity. This helps to improve the adaptation and moisture tolerance to the tooth structure by reused the water in the reaction between acidic functional groups and hydroxyapatite to create chemical bond (18, 20). This may relate to the better bonding ability of cement which joins the dentin/resin/post into a single unit, known as a "mono block", which can distribute stresses in an uniform pattern resulting in reinforce and increase fracture resistance of the teeth restored with posts (22). Therefore, teeth restored by posts using cement with higher bonding ability can increase failure resistance. Moreover, the physical properties of cement may affect the failure resistance. Kumbuloglu et al. (96) tested the physical properties of resin cements and reported that RelyX Unicem had higher compressive strength than Panavia F which might increase the failure resistance of the restored teeth.

The bonding ability between fiber post and root canal dentin is affected by the fiber post surface treatment. Previous studies showed that many chemical and mechanical surface treatment procedures improved bond strength between the fiber post and the resin cement (65-68). In this study, silane coupling agent was used for post surface treatment due to the recommendation from manufacturer. Silane coupling agents are generally used to increase the surface wettability and provide a chemical bond between inorganic substrates such as glass or quartz fibers of the post and the polymer of resin cement (65, 72). On the other hand, Wrbas et al.(97) reported that silanization had no significant effect on bond strength of fiber posts. Moreover, bond strength to fiber posts is still relatively low that the clinical relevance of the differences have been considered of minor importance (66, 72). Balbosh and Kern (68) reported that the airborne-particle abrasion with aluminum oxide had more effective in increasing the bond strength than chemical techniques such as etching with hydrofluoric acid or silanization. Further studies should investigate with the airborne-particle abrasion with aluminum oxide surface treatment that may affect the failure resistance.

The failure mode of the specimens in this study was classified into two patterns. The pattern 1, which was horizontal fracture, occurred mainly in group 1-5. It can be explained that the stress concentrated at the root-core/crown interface which had differences in elastic modulus of material resulting in debonding of the interface. Then the stress was distributed along the crown margin and resulting in horizontal post fracture since the post did not have enough strength to resist the stress. The pattern 2 which debonding of post occurred was found in group 4, 5 and 6. The fracture started from the debonding of the root-core/crown interface along to the post, then the stress deviated along the post-root interface resulting in debonding of post and then the fracture deviated obliquely to the buccal side. It seems that pattern 2 was found only in groups luting post with RelyX Unicem.

Previous studies classified the failure mode by different area of fracture: cervical, middle and apical third of root (12, 14). The fractures of all specimens of this study occurred at cervical one third of root. This is similar to the result of Giovani et al. (12) who found that when the teeth restored with FRC post, the main fracture were at the cervical third of root. Moreover, this finding is consistent with Cecchin et al. (14) who found that the fractures of root were predominant at cervical third.

The preparation for crown in this study had no ferrule in order to present the severe condition of short root where it is difficult to obtain ferrule. The preparation for metal crown in this study was shoulder margin (0.5 mm) which was automatically obtained after cutting flat plane of the cross sectional root. Additional preparation was not performed to avoid error from cutting preparation step. All specimens were simulated periodontal ligament with 0.2 mm layer of polyvinyl siloxane that was closed to the clinical conditions. The previous study found that simulated periodontal ligaments significantly affected the results of fracture testing (98). The acrylic resin was used to simulate alveolar bone in this study because the elastic modulus of acrylic resin close to that of alveolar bone (99). In this study, the DT light posts were used. These quartz fiber posts are widely used since it has many advantages. It's modulus of elasticity close to root dentin. The tooth color shade is good esthetics in anterior restorations (48). The DT light post had significantly higher flexural strength than other glass fiber posts (100).

It has been reported that the normal biting force of adults ranges between 222-445 N in the premolar area, and during clenching the occlusal force has been reported to be as high as 520-800 N (101, 102). In the present study, the failure resistances in all groups were found between 295.7–556.2 N, therefore, it may provide sufficient failure resistance for normal occlusal function and should carefully consider in patient with high clenching occlusal force such as bruxism patient.

The load using in this study was static load that may not simulate clinical conditions since in clinical conditions, the load is dynamic and varies by frequency, force, and direction, which is difficult to simulate in laboratory studies. Further studies should investigate in dynamic load condition and evaluate these conditions in clinical practice.

CHAPTER VI

CONCLUSIONS

Within the limitations of this study, the following can be concluded:

1. Teeth restored with core:post ratio at 2:3 and 1:1 indicated significantly higher failure resistance than those restored with ratio 3:2 when using Panavia F 2.0 for luting posts.

2. Teeth restored with core:post ratio at 2:3 and 1:1 indicated significantly higher failure resistance than those restored with ratio 3:2 when using RelyX Unicem for luting posts.

3. RelyX Unicem used for luting fiber post exhibited significantly higher failure resistance than Panavia F 2.0 in each ratio.

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APPENDIX

APPENDIX

Contents **Pages**

Descriptives

	group			Statistic	Std. Error
force	ratio 2:3 Panavia	Mean		454.3112	7.92186
		95% Confidence Interval for Mean	Lower Bound	435.5790	
			Upper Bound	473.0435	
		5% Trimmed Mean		454.1992	
		Median		451.7500	
		Variance		502.047	
		Std. Deviation		22.406	
		Minimum		429.88	
		Maximum		480.76	
		Range		50.88	
		Interquartile Range		46.28	
		Skewness		.100	.752
		Kurtosis		-2.323	1.481
	ratio 1:1 Panavia	Mean		423.0912	9.87280
		95% Confidence Interval for Mean	Lower Bound	399.7458	
			Upper Bound	446.4367	
		5% Trimmed Mean		421.9075	
		Median		426.0600	
		Variance		779.777	
		Std. Deviation		27.924	
		Minimum		390.03	
		Maximum		477.46	
		Range		87.43	
		Interquartile Range		36.99	
		Skewness		.846	.752
		Kurtosis		1.161	1.481

group			Statistic	Std. Error
ratio 3:2 Panavia	Mean		295.7150	8.76650
	95% Confidence Interval for Mean	Lower Bound	274.9855	
		Upper Bound	316.4445	
	5% Trimmed Mean		296.2922	
	Median		302.9150	
	Variance		614.812	
	Std. Deviation		24.795	
	Minimum		258.18	
	Maximum		322.86	
	Range		64.68	
	Interquartile Range		48.01	
	Skewness		-.907	.752
	Kurtosis		-.577	1.481
ratio 2:3 RelyX Unicem	Mean		556.1550	5.98532
	95% Confidence Interval for Mean	Lower Bound	542.0020	
		Upper Bound	570.3080	
	5% Trimmed Mean		555.8472	
	Median		556.8250	
	Variance		286.592	
	Std. Deviation		16.929	
	Minimum		534.13	
	Maximum		583.72	
	Range		49.59	
	Interquartile Range		29.64	
	Skewness		.231	.752
	Kurtosis		-.717	1.481

group			Statistic	Std. Error
ratio 1:1 RelyX Unicem	Mean		541.1138	7.15004
	95% Confidence Interval for Mean	Lower Bound	524.2066	
		Upper Bound	558.0209	
	5% Trimmed Mean		541.5881	
	Median		543.6800	
	Variance		408.985	
	Std. Deviation		20.223	
	Minimum		511.81	
	Maximum		561.88	
	Range		50.07	
	Interquartile Range		41.36	
	Skewness		-.445	.752
	Kurtosis		-1.512	1.481
ratio 3:2 RelyX Unicem	Mean		412.9550	4.74832
	95% Confidence Interval for Mean	Lower Bound	401.7270	
		Upper Bound	424.1830	
	5% Trimmed Mean		413.2028	
	Median		414.4550	
	Variance		180.372	
	Std. Deviation		13.430	
	Minimum		390.51	
	Maximum		430.94	
	Range		40.43	
	Interquartile Range		21.32	
	Skewness		-.407	.752
	Kurtosis		-.636	1.481

Tests of Normality

	group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
force	ratio 2:3 Panavia	.225	8	.200*	.839	8	.074
	ratio 1:1 Panavia	.216	8	.200*	.911	8	.361
	ratio 3:2 Panavia	.237	8	.200*	.849	8	.092
	ratio 2:3 RelyX Unicem	.119	8	.200*	.972	8	.910
	ratio 1:1 RelyX Unicem	.185	8	.200*	.884	8	.208
	ratio 3:2 RelyX Unicem	.145	8	.200*	.972	8	.910

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

One-way ANOVA for differences in failure resistance force between groups using Panavia F 2.

Test of Homogeneity of Variances

force

Levene Statistic	df1	df2	Sig.
.015	2	21	.985

ANOVA

force	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	112939.115	2	56469.557	89.321	.000
Within Groups	13276.452	21	632.212		
Total	126215.567	23			

Post Hoc test

Multiple Comparisons

force

Tukey HSD

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
ratio 2:3 Panavia	ratio 1:1 Panavia	31.22000	12.57191	.054	-.4684	62.9084
	ratio 3:2 Panavia	158.59625*	12.57191	.000	126.9079	190.2846
ratio 1:1 Panavia	ratio 2:3 Panavia	-31.22000	12.57191	.054	-62.9084	.4684
	ratio 3:2 Panavia	127.37625*	12.57191	.000	95.6879	159.0646
ratio 3:2 Panavia	ratio 2:3 Panavia	-158.59625*	12.57191	.000	-190.2846	-126.9079
	ratio 1:1 Panavia	-127.37625*	12.57191	.000	-159.0646	-95.6879

*. The mean difference is significant at the 0.05 level.

Homogeneous

force

Tukey HSD

group	N	Subset for alpha = 0.05 1	Subset for alpha = 0.05 2
ratio 3:2 Panavia	8	295.7150	
ratio 1:1 Panavia	8		423.0913
ratio 2:3 Panavia	8		454.3112
Sig.		1.000	.054

Means for groups in homogeneous subsets are displayed.

One-way ANOVA for differences in failure resistance force between groups using RelyX Unicem

Test of Homogeneity of Variances

force

Levene Statistic	df1	df2	Sig.
1.108	2	21	.349

ANOVA

force	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	99085.718	2	49542.859	169.677	.000
Within Groups	6131.645	21	291.983		
Total	105217.363	23			

Multiple Comparisons

force

Tukey HSD

					95% Confidence Interval	
(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
ratio 2:3 RelyX Unicem	ratio 1:1 RelyX Unicem	15.04125	8.54376	.207	-6.4939	36.5764
	ratio 3:2 RelyX Unicem	143.20000*	8.54376	.000	121.6649	164.7351
ratio 1:1 RelyX Unicem	ratio 2:3 RelyX Unicem	-15.04125	8.54376	.207	-36.5764	6.4939
	ratio 3:2 RelyX Unicem	128.15875*	8.54376	.000	106.6236	149.6939
ratio 3:2 RelyX Unicem	ratio 2:3 RelyX Unicem	-143.20000*	8.54376	.000	-164.7351	-121.6649
	ratio 1:1 RelyX Unicem	-128.15875*	8.54376	.000	-149.6939	-106.6236

*. The mean difference is significant at the 0.05 level.

force

Tukey HSD

group	N	Subset for alpha = 0.05	
		1	2
ratio 3:2 RelyX Unicem	8	412.9550	
ratio 1:1 RelyX Unicem	8		541.1138
ratio 2:3 RelyX Unicem	8		556.1550
Sig.		1.000	.207

Means for groups in homogeneous subsets are displayed.

T-test for differences between the types of luting cement at 2:3 ratio

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
force	ratio 2:3 Panavia	8	4.5431E2	22.40640	7.92186
	ratio 2:3 RelyX Unicem	8	5.5616E2	16.92904	5.98532

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
force	Equal variances assumed	2.942	.108	-10.257	14	.000	-101.84375	9.92874	-123.13878	-80.54872
	Equal variances not assumed			-10.257	13.028	.000	-101.84375	9.92874	-123.28886	-80.39864

T-test for differences between the types of luting cement at 1:1 ratio

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
force	ratio 1:1 Panavia	8	423.0913	27.92449	9.87280
	ratio 1:1 RelyX Unicem	8	541.1138	20.22337	7.15004

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
force	Equal variances assumed	.210	.654	-9.682	14	.000	-118.02250	12.18997	-144.16738	-91.87762
	Equal variances not assumed			-9.682	12.759	.000	-118.02250	12.18997	-144.40804	-91.63696

T-test for differences between the types of luting cement at 3:2 ratio

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
force	ratio 3:2 Panavia	8	295.7150	24.79540	8.76650
	ratio 3:2 RelyX Unicem	8	412.9550	13.43027	4.74832

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
force	Equal variances assumed	2.253	.156	-11.759	14	.000	-117.24000	9.96985	-138.62321	-95.85679
	Equal variances not assumed			-11.759	10.782	.000	-117.24000	9.96985	-139.23781	-95.24219

BIOGRAPHY

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