ผลของวัสดุสร้างแกนฟันชนิดต่าง ๆ ที่มีต่อความต้านทานการแตก ในฟันที่ได้รับการรักษาคลองรากฟันและบูรณะด้วยเดือยคอมโพสิตเสริมเส้นใย

นางสาวประภาพร ปณิธิวัฒน์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรวิทยาศาสตรมหาบัณฑิต
สาขาวิชาทันตกรรมประดิษฐ์ ภาควิชาทันตกรรมประดิษฐ์
คณะทันตแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2553

EFFECT OF VARIOUS CORE BUILD-UP MATERIALS ON FRACTURE RESISTANCE IN ENDODONTICALLY TREATED TEETH WITH FIBER REINFORCED COMPOSITE POST

Miss Prapaporn Panitiwat

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Prosthodontics
Department of Prosthodontics
Faculty of Dentistry
Chulalongkorn University
Academic Year 2010

Thesis Title EFFECT OF VARIOUS CORE BUILD-UP MATERIALS ON FRACTURE RESISTANCE IN ENDODONTICALLY TREATED TEETH WITH FIBER REINFORCED COMPOSITE POST

By Miss Prapaporn Panitiwat

Field of Study Prosthodontics

Thesis Advisor Assistant Professor Prarom Salimee, Ph.D.

Accepted by the Faculty of Dentistry, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

W. Tasachan .... Dean of the Faculty of Dentistry
(Associate Professor Wacharaporn Tasachan)

THESIS COMMITTEE

.... Chairman
(Associate Professor Mansuang Arksornnukit, Ph.D.)

.... Thesis Advisor
(Assistant Professor Prarom Salimee, Ph.D.)

Niyom Thamrongananskul .... Examiner
(Assistant Professor Niyom Thamrongananskul, Ph.D.)

Rochanakit .... External Examiner
(Associate Professor Rumpai Rochanakit)

ประภาพร ปณิธิวัฒน์: ผลของวัสดุสร้างแกนฟันชนิดต่าง ๆ ที่มีต่อความต้านทานการแตกในฟันที่ได้รับการรักษาคลองรากฟันและบูรณะด้วยเดือยคอมโพสิตเสริมเส้นใย. (EFFECT OF VARIOUS CORE BUILD-UP MATERIALS ON FRACTURE RESISTANCE IN ENDODONTICALLY TREATED TEETH WITH FIBER REINFORCED COMPOSITE POST) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ.ทพญ.ดร.ปรารมภ์ ซาลิมี, 51หน้า.

ความต้านทานการแตกในฟันที่ได้รับการรักษาคลองรากฟัน อาจแตกต่างกันขึ้นกับชนิดของวัสดุสร้างแกนฟันที่ใช้ การศึกษาในครั้งนี้มีวัตถุประสงค์เพื่อประเมินความต้านทานการแตกในฟันที่ได้รับการรักษาคลองรากฟันและบูรณะด้วยเดือยคอมโพสิตเสริมเส้นใยโดยใช้วัสดุสร้างแกนฟันชนิดเรซินคอมโพสิตที่แตกต่างกัน 4 ชนิด คือ Tetric N-Ceram, Clearfil Photo Core, MultiCore Flow, LuxaCore Z-Dual Automix กลุ่มตัวอย่างคัดเลือกจากฟันกรามน้อยล่างซี่ที่หนึ่งจำนวน 32 ซี่ ทำการกรอตัดฟันที่ตำแหน่งเหนือรอยต่อระหว่างเคลือบฟันและเคลือบรากฟัน 1 มิลลิเมตรและรักษาคลองรากฟัน ทำการเตรียมคลองรากฟันและยึดเดือยดีทีไลท์ขนาดเบอร์ 1 ด้วยเรซินซีเมนต์ จากนั้นแบ่งกลุ่มตัวอย่างออกเป็น 4 กลุ่มกลุ่มละ 8 ซี่ ทำการสร้างแกนฟันตามวัสดุ 4 ชนิดดังที่กล่าวมาข้างต้นโดยใช้สารยึดติดกับเนื้อฟันตามที่บริษัทผู้ผลิตแนะนำ ทำการกรอแต่งให้ได้ความสูงด้านใกล้ใบหน้า 6 มิลลิเมตร ความสูงด้านใกล้ลิ้น 3 มิลลิเมตร ขอบของครอบฟันมีลักษณะเป็นแชมเฟอร์กว้าง 0.5 มิลลิเมตรเพื่อทำให้เกิดเฟอร์รูล 1 มิลลิเมตร นำฟันมายึดในบล็อกอะคริลิกที่ทำการจำลองเอ็นยึดปริทันต์รอบรากฟัน บูรณะด้วยครอบโลหะผสมประเภทนิเกิล-โครเมียมและยึดกับส่วนแกนฟันด้วยเรซินซีเมนต์ ทดสอบความต้านทานการแตกด้วยเครื่องทดสอบสากล โดยนำชิ้นตัวอย่างยึดเข้ากับแป้นรองซึ่งทำมุม 135 องศากับแนวแกนฟันโดยใช้ความเร็วหัวกด 1 มิลลิเมตรต่อนาทีจนเกิดการแตกเกิดขึ้น บันทึกค่าแรงสูงสุดของชิ้นตัวอย่างแต่ละชิ้น

ผลการศึกษาพบว่า ค่าความต้านทานการแตกมีค่าสูงที่สุดในกลุ่ม Clearfil Photo Core (709.01 ± 207.22 นิวตัน) รองลงมาคือกลุ่ม MultiCore Flow (584.15 ± 166.91 นิวตัน) LuxaCore Z-Dual Automix (484.77 ± 88.59 นิวตัน) และTetric N-Ceram (456.10 ± 140.06 นิวตัน) ตามลำดับ ทำการวิเคราะห์ความแปรปรวนแบบทางเดียวและวิเคราะห์หาความแตกต่างระหว่างกลุ่มโดยสถิติบอนเฟอร์โรนีที่ระดับความเชื่อมั่นร้อยละ 95 พบว่า ไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติของความต้านทานการแตกระหว่างกลุ่ม Clearfil Photo Core และ MultiCore Flow ($p>0.05$) ในขณะที่ค่าความต้านทานการแตกในกลุ่ม Clearfil Photo Core มีค่าสูงกว่า LuxaCore Z-Dual Automix และ Tetric N-Ceram อย่างมีนัยสำคัญทางสถิติ ($p<0.05$) ในการศึกษาครั้งนี้พบว่า Clearfil Photo Core มีแนวโน้มช่วยเพิ่มความต้านทานการแตกในฟันที่บูรณะด้วยเดือยคอมโพสิตเสริมเส้นใยมากกว่าคอมโพสิตชนิดอื่น

ภาควิชา ทันตกรรมประดิษฐ์..... ลายมือชื่อนิสิต..........ประภาพร......ปณิธิวัฒน์......................

สาขาวิชา ทันตกรรมประดิษฐ์..... ลายมือชื่ออ.ที่ปรึกษาวิทยานิพนธ์หลัก..........................

ปีการศึกษา ....2553........................

5176116232: MAJOR PROSTHODONTICS

KEYWORDS: CORE BUILD-UP MATERIALS/ ENDODONTICALLY TREATED TEETH/ FIBER REINFORCED COMPOSITE POST (FRC POST)/ FRACTURE RESISTANCE/ MODULUS OF ELASTICITY (E)

PRAPAPORN PANITIWAT: EFFECT OF VARIOUS CORE BUILD-UP MATERIALS ON FRACTURE RESISTANCE IN ENDODONTICALLY TREATED TEETH WITH FIBER REINFORCED COMPOSITE POST. THESIS ADVISOR: ASST. PROF. PRAROM SALIMEE, Ph.D., 51pp.

Fracture resistance in endodontically treated teeth may be different depending on the type of core build-up material used. The purpose of this present study was to evaluate the fracture resistance of endodontically treated teeth restored with fiber reinforced post using 4 resin composites as core build-up materials: Tetric N-Ceram, Clearfil Photo Core, MultiCore Flow, LuxaCore Z-Dual Automix. Thirty-two human lower first premolar teeth were decoronated perpendicular to the root axis at 1 mm above the facial cemento-enamel junction (CEJ) and the roots were endodontically treated. All specimens were prepared and inserted with D.T. Light-post Illusion (size 1) using dual-polymerizing resin cement (Panavia F2.0). Samples were randomly divided into 4 groups of 8 teeth and built up with 4 core materials mentioned above. The resin composite cores were bonded to dentin using a dentin bonding agent according to manufacturers' recommendation. Each specimen was prepared with a 6-mm height at facial, and 3-mm at lingual axial wall. The 0.5-mm chamfer was prepared allowing 1 mm of ferrule. The teeth were embedded in autopolymerizing acrylic resin blocks with periodontal ligament simulation. The Ni-Cr alloy crowns were fabricated and cemented on the specimens with Panavia F2.0. The fracture resistance was determined using a universal testing machine at 135-degree angle to the long axis of each tooth with a crosshead speed of 1 mm/min until failure occurred. The highest fracture load of each specimen was recorded. It was found that the mean fracture loads was highest in Clearfil Photo Core (709.01 ± 207.22 N), followed by MultiCore Flow (584.15 ± 166.91 N), LuxaCore Z-Dual Automix (484.77 ± 88.59 N) and Tetric N-Ceram (456.10 ± 140.06 N), respectively. One-way analysis of variance (ANOVA) and Bonferroni multiple comparisons test showed that the fracture resistance for Clearfil Photo Core was not significantly different from MultiCore Flow ($p>0.05$), but significantly higher than that of LuxaCore Z-Dual Automix and Tetric N-Ceram ($p<0.05$). Among the cores used in this study, Clearfil Photo Core tended to enhance fracture thresholds of teeth restored with fiber post more than other composites.

Department: Prosthodontics
Field of Study: Prosthodontics
Academic Year: 2010

Student's Signature....Prapaporn Panitiwat.
Advisor's Signature..........

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to all those who gave me the possibility to complete this research project. I am indebted to my supervisor, Assistant Professor Dr. Prarom Salimee for her support, guidance, and patience throughout my master's degree thesis.

I would like to thank Dr. Kevin Tompkins and Mr. Barry Arnold for their English editorial assistance and to Dr. Paipan Bidhyanon for her advice and suggestions in the statistical analysis.

I would also like to thank Unity Dental Co., Ltd and their representatives in Thailand for their assistance in acquiring equipment and generous donation of the Ivoclar-Vivadent products used in this study.

Furthermore, I am grateful to thank the staffs at the Research Center, Chulalongkorn University for their help and kind assistance.

I owe my deepest gratitude to my parents whose firm belief in the value of a good education and steadfast support has made this effort possible. This research work is a tribute to my family's constant love and support throughout my accomplishment.

Lastly, thanks are also due to the grant of the Faculty of dentistry, Chulalongkorn University for providing financial support.

CONTENTS

Page

CHAPTER

Page

CHAPTER

LIST OF TABLES

LIST OF FIGURES

Figure **Page**

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
°C	degree Celsius
g	gram
GPa	gigapascal
min	minute
ml	milliliter
mm	millimeter
µm	micrometer
N	Newton
s	second
SD	standard deviation
vol%	volume percentage
wt%	weight percentage

CHAPTER I

INTRODUCTION

A post and core procedure is indicated when there is insufficient tooth structure remaining to retain the definitive restoration of endodontically treated teeth. The need for suitable and reliable coronal restoration is increasing due to patient demands. The use of prefabricated post and direct core build-up has tremendously increased due to its favorable physical properties compared to a cast post and core, simple procedures, and reduced number of clinical visits [1]. Fiber reinforced composite posts have high tensile strength and fatigue resistance. In addition, their modulus of elasticity is similar to that of dentin which can equally distribute stress along the tooth and reduce the risk of root fracture [2]. Root fracture patterns of teeth with reinforced composite posts and core were different from that observed with metal post and core when the failure modes were retrievable [3]. The core build-up procedure combined with a fiber post should ensure support of a definitive restoration by preserving as much as possible of the healthy tooth structure.

A core can be defined as a restoration used to restore the bulk of the coronal portion of the tooth and is also required to achieve retention and resistance form [4]. Core build-up also acts as a semi-permanent restoration for an extended period of time in a complex treatment plan or clinical evaluation of the success of the root canal filling. Furthermore, it must resist multidirectional masticatory forces and withstand a crown preparation and impression procedure [5]. The material must be capable of maintaining occlusal stability and patient comfort. The core build-up is an important component of the overall success of a restoration.

There are many materials which can be used for direct cores, for instance, amalgam, glass ionomers and resin composite [6-7]. Amalgam has an acceptable long term performance because of its high compressive strength, good dimensional stability, good wear resistance and ease of manipulation. However, there has been much controversy regarding its harmful systemic effects and to the environment [4]. Since amalgam does not bond to tooth structure, cavity preparation requires mechanical retentive features resulting in loss of tooth structure. Metal-free restorative systems without these drawbacks are increasingly popular. As a result, the use of amalgam has declined dramatically. Both glass ionomer cements and resin-based composites have been used as alternative core build-up materials. Glass ionomer cements have many favorable characteristics including chemical bonding to dentin or enamel, fluoride release, similar thermal expansion to tooth structure and are esthetic, but their low strength to withstand occlusal loading has limited their use [8-10]. Resin composite is by far the most popular core build-up material due to esthetics, the fabrication in one appointment, adherence to tooth structure via the use of an adhesive system, and similarity to tooth structure in hardness and fracture toughness [11]. According to a Clinical Research Associates Study in 1995, it was reported 47.6 percent of 8,143 general practitioners routinely used resin composite for direct cores and used amalgam 25.2 percent [1]. Therefore, resin composite has been the most popular core material in clinical practice currently, given the ability to perform immediate preparation after curing [12]. Disadvantages include thermal expansion and polymerization contraction causing marginal leakage, secondary caries, and cuspal flexure or fracture. Improvements in resin composites and enamel-dentin bonding systems tend toward more conservative technique minimizing tooth structure loss.

Strength of core materials is one of the most critically desired properties in obtaining a long term successful restoration [13]. Many studies have shown amalgam and composite are the two strongest build-up materials available [6, 9, 14-15]. The compressive strengths of core materials are also important because cores usually replace a large amount of tooth structure. When remaining tooth structure is limited, e.g. the margin of the crown is slightly below the margin of the core, stress is placed on the core material which demands higher strength of the material [16]. Furthermore, the core material should have an elastic modulus similar to that of dentin to withstand the masticatory force and polymerization shrinkages stress [10].

Although the increasing numbers of competitors on the market indicate an ongoing development of resin composites specifically designed for core build-ups, conventional restorative composites have also been employed for this purpose. Burke et al. concluded hybrid composites had the highest fracture resistance and there was no advantage in using specific composite core build-ups [5]. However, studies have shown composite core build-ups have higher bond strengths than hybrid composites [17-18]. The conflicting reports might be a result of different methods and testing conditions. Despite many studies comparing failure loads of simulated cores in various configurations, to date, there is no agreement on which composite core build-up material can optimally restore teeth requiring fiber post and crown restoration.

The purpose of the present study was to evaluate the fracture resistance among restorative resin composite (Tetric N-Ceram) and three core build-up composites (Clearfil Photo Core, MultiCore Flow, LuxaCore Z-Dual Automix) in restoring endodontically treated teeth with a fiber post and full metal crown restoration by means of compressive testing. The null hypothesis was there were would be no statistically significant differences in the fracture load of the restorations among these composites.

CHAPTER II

LITERATURE REVIEW

Core Build-up Materials

A core can be defined as a restoration used to restore the bulk of the coronal portion of the tooth [1] and is also required to achieve a retention and resistance form of definitive restoration. The material must be capable of maintaining occlusal stability and patient comfort. Core build-up also acts as a transitional restoration for an extended period of time in a complex treatment plan or clinical evaluation of the success of the root canal filling. Furthermore, it must resist multidirectional masticatory forces and withstand a crown preparation and impression procedure. Cores can be built up as direct (at the chair-side) or indirect (made in the laboratory) technique [4]. The ability of a post to distribute stress can be affected by the core. The core should be made from materials with adequate modulus and yield strength. The material should complement the mechanical properties of the underlying post and tooth structure.

Properties of the ideal core material are biocompatibility, cariostatic activity, bonding to tooth/ luting agent, adequate compressive strength/ tensile strength/ flexural strength, low thermal diffusivity, similar thermal expansion to tooth structure, compatibility with temporary cements, esthetics or contrasting color to tooth, dimensional stability, ease of manipulation, short setting time, reasonable cost, good shelf life, radiopaque, non-allergenic, and capability of being added to [4]. The three basic direct core build-up materials are amalgam, glass ionomer-based core material, and resin composite. There have been numerous in vitro experiments that have investigated the physical properties of these core materials. Properties that are important predictors of the clinical behavior include compressive, shear and tensile strengths, along with rigidity. Due to the past studies [8-9], amalgam has been reported to perform the excellent properties because of its high compressive strength and rigidity. Conversely, studies have shown that material derived from glass ionomer cement performs poorly as a loadbearing core material and resin composite has a strength intermediate between amalgam and glass ionomer cement and is more flexible than amalgam.

1. Amalgam

Amalgam is the most commonly used material to build up in the posterior teeth. It can also be used as coronal-radicular core without post in endodontically treated teeth. From the earliest use of amalgam, it has been asked whether mercury can produce local or systemic effects in the human. Amalgam has been reported to perform the best because of its high compressive strength, good dimensional stability, good wear resistance and ease of manipulation. Amalgam has less deformity, higher elastic modulus and higher dimension stability, produces smaller gaps, fewer stresses to tooth structure, than resin composite. Furthermore, it is very cost effective and is not overly technique sensitive.

The principal disadvantages of amalgam are that the silver color does not match to tooth structure, however, it is easy to differentiate from tooth structure during tooth preparation. The dark color of amalgam has limited the use in anterior area or all-ceramic restoration [19]. In addition, it is subjected to have corrosion and galvanic action. Amalgam has other unfavorable characteristics including slow setting, not bonding to tooth structure, allergenic, high coefficient of thermal diffusivity. Thermal expansion of amalgam is 2-3 times greater than that of dentin during changed temperatures, resulting in breaking cement and marginal leakage. llanoitiddAy, weak tensile and flexural strengths make it brittle in thin areas. The highest compressive strength develops after trituration of at least 24 hours. Therefore, spherical high-copper alloys have been developed to achieve the strength faster and a core can be prepared after only 10-15 minutes, e.g. Tytin (Kerr, UK) [4].

Combe et al. investigated the mechanical properties of five groups of materials including high copper amalgam (Duralloy), cermet (Ketac silver), visible light-cured resin composite (Prisma APH), and two composites specifically developed for application (Ti-Core, Coradent) at each time up to 3 months. It was found that amalgam revealed low early compressive strength and the maximum value which was higher than other materials being achieved after 24 hours. Both diametral and flexural strengths of amalgam were lower than light-cured resin composite. In term of elastic modulus, amalgam had values similar to those of dentin (20 GPa) and was higher than the others. In addition, there was less difference between materials regarding to flexural modulus [10].

However, amalgam as core build-up material has been recommended for use with serrated prefabricated post to form retention. Furthermore, preparation and impression have to be delayed for 24 hours after placement. The immediate preparation may affect the retention of the material and creates small cracks. Therefore, amalgam is suitable for the case that has enough time before crown preparation.

2. Glass ionomers and hybrid materials

Glass ionomers are composed of powder and liquid or powder mixed with water. The liquid may be water or dilute solution of tartaric acid in water, hence, water plays an important role in the setting of matrix and hydrosalt. Contamination of water during the setting reaction increases surface roughness, alters color, increases radiopaque, decreases the strength, decreases the surface hardness, and produces volumetric changes which may cause all-ceramic crown fracture or tighter fitting metal casting. Water sorption has been shown to progress through this material rapidly in the first 24 hours. Inadequate water or loss of water during setting may cause a crack or a fracture to a surface of completed cement, or lower bond strength to dentin. Glass ionomers used as core build-up materials were very popular in the past [20]. Properties especially noteworthy are chemical bonding to enamel and dentin, an expansion coefficient comparable to that of tooth structure, core placement and preparation in the same visit, providing a potential anticariogenic effect from fluoride release, biocompatibility, esthetics. Therefore, glass ionomers are used in case of a patient with high caries risk factor or high incidence of caries. Nevertheless, the main problems are their inferior strength and fracture resistance resulting in brittle and high abrasive rate. In addition, glass ionomer-based materials are also less fatigue resistance than resin composite. These limit the use in stress-bearing restoration or abundant loss of tooth structure; for example, in anterior teeth with less tooth structure left, teeth being the abutment of partial denture or fixed prosthesis, posterior tooth with loss of many cusps. Examples of conventional glass ionomers are Fuji IX GP, Fuji II (GC, Japan).

Resin-modified glass ionomers (RMGIs), e.g. Vitremer (3M ESPE, USA), Fuji II LC (GC, Japan), have hydroxyethyl methacrylate (HEMA) added. The polymerizations are two mechanisms, an acid-base reaction and light-cured resin polymerization. Because of the resin content, these restorations are more esthetic and have higher compressive strength, tensile strength, flexural strength, fracture toughness, wear resistance, marginal adaptation than glass ionomers, but they have lower microleakage [21].

Metal-modified glass ionomers (MMGIs) have metal powers added to the cement mix. Data from deciduous tooth studies claimed no improved clinical performance [4].

Cermets, e.g. Ketac Silver (3M ESPE, USA), Cermet (Dentsply, USA), Miracle Mix (GC, USA), Hi-Dense XP (Shofu, Japan), have metals sintered to the glass particles. Sintering increases the toughness and fracture resistance to the material. Silver is added to increase the compressive strength, and flexural strength. However, the fracture toughness of this material appears to be no greater than that of conventional glass ionomer. Cermet cannot be considered for large core build-up procedures in posterior teeth [10], and has very low strength when compared to amalgam and resin composite.

There are few scientific reports of cermet, RMGIs, MMGIs claiming the suitability of core [4]. Therefore, glass ionomers, and hybrid ionomers are used for restoration in low-stress-bearing areas. These materials may be considered filler materials used in small undercuts or to repair small defects in prepared teeth.

3. Resin composite

The use of resin composite has been increasingly popular. According to a Clinical Research Associates Study in 1995, it was reported that 47.6 percent of 8,143 general practitioners routinely used resin composite and 25.2 percent used amalgam for direct cores [1]. Resin composite has many practical advantages. It can be translucent and tooth-colored. Furthermore, it can also be selected for contrasting color to facilitate tooth preparation. Reliable bonding strengths are achieved when used with a dentin bonding agent. Core and tooth preparation can be completed immediately within one appointment. In addition, composite has compressive strengths comparable to amalgam, while flexural and tensile strengths are superior. Disadvantages include polymerization contraction stresses on the tooth which can increase the risk of marginal leakage, post-operative sensitivity, secondary caries, cuspal flexures, or fractures. Composite has a high thermal expansion coefficient, resulting in stress at interfacial bonds. Hydroscopic expansion as a result of water absorption may cause polymerization shrinkage and lead to tighter fitting metal casting or fracture of all-ceramic crowns. It cannot be condensed like amalgam resulting in incorporation of voids in the build-up procedure. A syringe technique has been reported to produce a denser core compared with a bulk-insertion technique, and produces less air trap. For convenience, either light-cured or chemical-cured can be selected. Light-cured material may not perform completed polymerization if insufficient light intensity, curing time, or too great thickness is conducted. Polymerization shrinkage and contraction stress of resin composites depend on a variety of factors: unpolymerized resin contents, type of resin monomer, composite system, setting mechanism, and curing mode. The study of Artopoulou et al. claimed that the different diameter of resin composite core build-up did not affect the retention of core to fiber post, since it was dependent upon the bonded interface between the post and the core materials [11].

Resin composites consist of three phases as follows

- Resin matrix

The most common resins consist of polymer matrix: bisphenol A diglycidyl methacrylate (Bis-GMA), diluent monomer: methyl methacrylate (MMA), ethyleneglycol dimethacrylate (EDMA) and triethylene glycol dimethacrylate (TEGDMA), initiators: camphorquinone and tertiary amine, polymerization inhibitor: hydroquinone, butylhydroxytoluene (BHT) and pigments: titanium oxide or aluminum oxide

- Dispersed inorganic filler particles: barium glass, boron glass, lithium aluminium silicate, strontrium glass, yttrium glass, zirconium glass, barium alumina silicate and colloidal silica
- Coupling agent, an organosilane: methyl, vinyl or epoxy silanes

silanes are bifunctional, silicon-organic compounds which have siloxane groups that react with hydroxyl groups on surface of inorganic filler and other groups that polymerize with the organic matrix. This agent forms a good bond between the inorganic and organic phase of composite.

3.1 <u>Classification of resin composite</u> [21]

3.1.1 <u>Classification by the particle size of inorganic filler particle</u>

3.1.1.1 Lutz and Phillips (1983) classified resin composite into 4 types [22]

3.1.1.1.1 Conventional composites: 8-12 microns
3.1.1.1.2 Small particle composites: 1-5 microns
3.1.1.1.3 Hybrid/ blend composites: 0.6-1 microns
3.1.1.1.4 Microfilled composites: 0.04-0.4 microns

3.1.1.2 Williems et al. (1993) classified resin composite into 3 types [23]

3.1.1.2.1 Traditional resin composites: 10-25 microns
3.1.1.2.2 Small particle blend composites

- *Mid-filled small particle blend composites: 48-60 percent of filler*
  - Fine: 5-10 microns
  - Ultrafine: 0.5-4 microns
- *Dense- filled small particle blend composites: 62-75 percent of filler*
  - Fine: 5-10 microns
  - Ultrafine: 1-4 microns

3.1.1.2.3 Microfilled composites: 0.07-0.3 microns

3.1.1.3 Bayne S. (1994) classified resin composite into 5 types [24]

3.1.1.3.1 Macrofiller: 10-100 microns
3.1.1.3.2 Midifiller: 1-10 microns
3.1.1.3.3 Minifiller: 0.1-1 microns
3.1.1.3.4 Microfiller: 0.01-0.1 microns
3.1.1.3.5 Nanofiller: 0.005-0.01 microns

3.1.2 Classification by the type of inorganic filler particle

3.1.2.1 Microfilled resin composites

Filler is spherical colloidal silica particle size 0.04-0.4 microns. Small particle has higher polishability and translucency than large particle, but lower strength and higher wear than traditional composite. These composites are recommended for use in anterior region because of the smoother finish and more natural appearance. Because microfilled composites are less highly filled, they have higher values of polymerization shrinkage, water sorption and thermal expansion than microhybrid composites.

3.1.2.2 Traditional resin composites

Filler may be as a metal-glass fiber, for example, barium glass, boron glass, lithium aluminium silicate, strontrium glass, yttrium glass, zirconium glass, barium alumina silicate. There are many sizes and shapes of fillers. They are quite difficult to polish, but have higher strength and lower wear than microfilled composite. Hence, this can be found in resin composite core build-up material.

3.1.2.3 Hybrid resin composites

It has become common to add some pyrogenic silica to the resin matrix in addition to the macrofillers in order to influence the viscosity and certain other characteristics. The pyrogenic silica is added to help improve the performance and handling of traditional resin composite. Since the average filler size of hybrid resins are more than 1 micron, the surface characteristics are not as smooth as those of microfilled resins. They are considered for posterior restoration.

3.1.2.4 Microhybrid resin composites

Microhybrid composites are a combination of a microfilled and fine-particle composite and are so called because of their small-diameter (0.4-0.6 microns) filler particle. They were introduced as all-purpose “universal” composites offering both esthetics and superior wear resistance for use in anterior and posterior teeth.

3.1.2.5 Nanohybrid resin composites

Nanohybrid resin composite is developed from microhybrid by reducing particle size to 20-75 nanometers offering better characteristics.

3.1.3 Classification by handling characteristics

3.1.3.1 Conventional resin composites

e.g. hybrid, microhybrid, nanohybrid, and microfilled resin composites

3.1.3.2 Flowable resin composites or low viscosity composites (LVC)

A low viscosity material with low elasticity of modulus can be used as a liner to fill irregular internal surfaces and proximal boxes before placing the packable composite. They can also be used to repair margin in non stress areas. These are recommended for cervical areas, pediatric restorations, and other small, low-stress-bearing areas. They exhibit higher polymerization shrinkage and lower wear resistance than microhybrid composite.

3.1.3.3 Packable resin composites

They have been termed an alternative to amalgam. They have higher filler loading with fibers, porous filler particles, irregular filler particles, or viscosity modifiers. Important properties are high depth of cure, low polymerization shrinkage, radiopacity, and low wear rate. Moreover, they have high viscosity and are non-sticky, so they can be packed into the cavity which is similar to amalgam.

3.1.3.4 Laboratory resin composites

Inlays and onlays in posterior restorations, veneers for anterior teeth, and metal-free bridges are prepared indirectly from composite processed in the laboratory using various procedures of light, heat, pressure, and vacuum which increase the degree of polymerization, physical properties, density, and the wear resistance. Laboratory composites can be combined with fiber reinforcement for increasing the strength and rigidity.

4. Resin specifically designed for core build-up

There are many types of resin composite which can be used as core restorations. These include hybrid, microhybrid, nanohybrid, flowable composite, condensable composite, or resin composite specifically designed for core build-up including flowable and hybrid type.

Flowable composite has a lower filler-resin ratio resulting in mechanical properties which are probably unable to resist occlusal load in high stress situations [25]. However, due to low viscosity, it can be used in a syringe delivery system. This allows ease of manipulation, and an easier, less time-consuming step in comparison with free-hand incremental technique. The flowable composites provide a better post-core integration, and an excellent adaptation onto the post with fewer voids [26]. In addition, material with a low modulus of elasticity is claimed to partially absorb functional loadings, reducing stress concentration at the interface with dentin. Furthermore, it provided a valid support to porcelain crowns for at least 2 years of clinical service [27]. The study of Salameh confirmed flowable core build-ups composite had higher bond strengths to fiber posts than non-flowable composites [17]. In contrast, the study of Sadek et al. [18] claimed that flowable composites had lower bond strength than composite core build-ups and hybrid composites. Their high resinous content may cause high contraction during polymerization. Resin composite core should exhibit good adaptation and reliable bond strength to the post surface. A better combination of properties of the filler and consistency in low-viscosity flowable composite possibly improve integration as found in composites specifically designed for core build-up [18].

From the recent study, core composites showed more homogeneous surface structures, had higher wear values than restorative composites, but had lower roughness values, which reduced bacterial adhesion [28]. Resin composite core build-up offers little advantage compared to other composites, but is still a good choice when used with the non-metallic post [5].

Polymer-based core materials have demonstrated improved physical properties in the laboratory and favorable clinical performance. Core materials use reinforcement with some sort of mechanism; for examples, glass fibers or metal fibers added: *Build-It*$^{\circledR}$ *F.R. (fiber reinforced)*, *Composipost* $^{\circledR}$ *System*; transparent fiber reinforced resin added: *Light-Core*$^{\circledR}$; titanium added: *Ti-Core*$^{\circledR}$, *CorePaste*$^{\circledR}$; ceramic added: *Coradent*$^{\circledR}$. Improvements in material and delivery systems have been developed [19].

4.1 Classification of resin specifically designed for core build-up

i. Light-cured resin composite: Clearfil Photo Core (Kuraray), Rebilda LC (Voco), Encore SuperCure (Centrix)

ii. Dual-cured resin composite: LuxaCore Z-Dual Automix (DMG), MultiCore Flow (Ivoclar Vivadent), CompCore AF (Premier), Bis-Core (Bisco), Build-It FR (Pentron), Core Paste XP (Den-Mat)

iii. Self-cured resin composite: Ti-Core (EDS), Core-Flo (Bisco), CorePaste (Den-Mat**)**

It is still unclear which type of resin composite could be the best choice to build-up onto fiber posts, even though there are many literatures that reported about the properties of core build-up composites. The study of Cho et al. compared the diametral and compressive strength of nine core materials. The result claimed that light-cured hybrid resin composite (Progidy) was stronger than autocured titanium containing composite (Ti-core) and the strength of glass-ionomer and polyurethane was significantly lower than that of resin composites or amalgam [8]. Burke et al. concluded that no advantage was apparent when resin specifically designed for core build-up used, and hybrid composite provided the highest fracture resistance of prepared core build-ups [5]. The study of Ahn et al. found that Clearfil Photo Core had the highest fracture resistance and flexural strength when compared to other core materials [29]. In addition, Ahn and Sorensen claimed that Clearfil Photo Core and Luxacore had flexural strengths approaching to amalgam, but its modulus of elasticity was approximately 15% of that of amalgam. Glass ionomer and resin modified glass ionomer have the lowest strength. From this previous study, it can be concluded that moderate amounts of coronal tooth structure are needed to replace with a prefabricated post and a high strength, high elastic modulus core [16]. These results were consistent with the study of Ontiveros which reported that Clearfil Photo Core had higher shear bond strength than LuxaCore and Core-Flo [30]. Furthermore, Wrbas et al. claimed that ClearfilCore had significantly higher bond strength than MultiCore Flow. Types of resin composite cores influenced on the tensile bond strength between post and composite abutment, while adhesive systems did not significantly affect the results [31].

Prefabricated Fiber Reinforced Composite Posts

The use of prefabricated posts and resin materials to fabricate the post and core system was introduced in the 1960s. The historic standard of custom cast post and core technique is decreasing due to high incidence of root fractures and the excess of sound tooth structure. Traditional prefabricated posts are made of metals such as stainless steel, titanium, titanium alloy, platinum-gold-palladium, chromium-containing alloys, and brass. There are many unfavorable characteristics including poor post retention, potential for post and root fractures, and risk of corrosion. The modulus of elasticity of the metallic posts is significantly higher than that of dentin (210 >> 14.2 GPa) [11]. This difference might create stresses at the root-cement-post interface.

An ideal intra-radicular restorative system should have biomechanical characteristics similar to natural tooth structure. Thus, the restoration should obtain a monoblock concept. Fiber posts have elastic moduli approximately 1-2 times to that of dentin. This may reduce the concentration of stresses in the remaining root and more equally distribute forces over the bonded interface. Fiber posts are less prone to cause root fractures when comparable to conventional posts. Moreover, if a root fracture occurs, it is usually less catastrophic, and mainly located in the coronal third of the root.

The mechanical properties of fiber posts depend on many factors such as the nature and properties of the fiber and matrix, geometry of reinforcement, fiber surface treatment and impregnation of fibers with resin, interface strength, volume ratio of fiber and matrix, quantity of fibers, orientation of fibers, position of fibers and water sorption of resin matrix [32]. For example, adhesion of fibers to the polymer matrix affects the stiffness and elasticity of the post, orientation of fiber influences the resistance of force to be applied as post with fibers parallel to the long axis of post has higher fracture load than post with oblique fibers [33]. Volume ratio of fiber and matrix relates to flexural strength [34]. Furthermore, the parallelism of fiber facilitates the guidance of removal drills [35]. Water sorption and solubility of fiber composites may affect the hydrolytic stability of the composite [36]. In addition, fiber posts have exhibited a decrease in flexural strength following thermocycling. Fibers used in fiber post may be composed of carbon, glass, or quartz fiber.

1. Carbon fiber reinforced composite post

Carbon fiber posts were developed in France in 1988 and introduced in the early 1990 by Duret et al. The matrix is an epoxy resin reinforced with unidirectional carbon fibers parallel to the long axis of the dowel. Its properties; for example, high fatigue strength, high tensile strength, high corrosion resistance, high fatigue resistance, lightness, biocompatibility, and a modulus of elasticity similar to dentin, make the carbon post a replacement for conventional metallic post. The use of this post has limited the esthetic demand due to their dark underlying color influencing the shade of gingival tissues and prosthetic restorations. Furthermore, the modulus of elasticity of the carbon fiber post is greater than that of dentin (120 >> 14.2 GPa) [11] which might create stress at tooth/ cement/ post interface with the possibility of unfavorable fracture of root. Purton and Payne reported that carbon fiber post was more rigid than metal post allowing smaller diameter of fiber post to be used for the same strength to metal post and could become as universal in applications. The effect of surface configuration of the posts significantly affected the bond strength to resin composite cores as serrations increased mechanical retention. The adhesion of the carbon fiber post to resin composite core depended on the mechanical retention and friction [37]. Example of this post is Composipost.

2. Glass fiber reinforced composite post

The primary advantage of the glass fiber post is its modulus of elasticity (~40 GPa) [11] which approximates closely to that of dentin. The similarity in elasticity may allow post flexion to mimic tooth flexion, so post acts as a shock absorber and transfers the stress placed on the tooth to dentinal walls and can decrease the incidence of root fracture. Clinical advantages are high esthetic potential, high translucence, and ready retrievability after failure. The glass fiber is fabricated from longitudinal glass fibers embedded in a resin matrix. The higher content of glass fibers contributed to the greater strength displayed. With adhesive bonding, the potential exists for integrating tooth structure, post, core, and restoration into a single unit, instead of heterogeneous material. Examples of theses posts are FRC Postec Post (Ivoclar-Vivadent), Fiber Kleer Post (Pentron Clinical Technologies), FibreKor Post (Pentron Clinical Technologies), ParaPost (Coltene/ Whaledent), and Rely X Fiber Post (3M ESPE).

3. Quartz fiber reinforced composite post

The modulus of elasticity of this post is similar to that of dentin (18 - 47 GPa) [38] which reduces the incidence of root fracture same as glass fiber post. Quartz fiber has lower thermal expansion coefficiency [39], has higher tensile strength than glass fiber posts. The esthetic feature having a similar tooth color eliminates discoloration under all-ceramic restoration systems. Furthermore, highly translucent property allows light to diffuse through without interference. Examples of these posts are D.T. Light-Post (Bisco Inc), Light-Post (Bisco Inc), and Aestheti-Plus (Bisco Inc).

The Purposes of This Study

1. To evaluate and compare the fracture resistance among various core build-up composites in restoring endodontically treated teeth with a fiber post and full metal crown restoration.
2. To select the appropriate resin core build-up for endodontically treated teeth.

Hypotheses

Null hypothesis: There were would be no statistically significant differences in the fracture load of the restorations among these composites**.**

Alternative hypothesis: There were would be statistically significant differences in the fracture load of the restorations among these composites.

Keywords

- Core build-up materials
- Endodontically treated teeth
- Fiber reinforced composite post (FRC post)
- Fracture resistance
- Modulus of elasticity (E)

Type of Research

Laboratory experimental research

CHAPTER III

MATERIAL AND METHODS

Materials Used in This Study (Figure 1-3)

1. Resin composite (Tetric N-Ceram, Ivoclar Vivadent, Schaan, Liechtenstein)
2. Core build-up composite (Clearfil Photo Core, Kuraray medical, Okayama, Japan)
3. Core build-up composite (MultiCore Flow, Ivoclar Vivadent, Schaan, Liechtenstein)
4. Core build-up composite (LuxaCore Z-Dual Automix, DMG, Hamburg, Germany)
5. Quartz fiber reinforced composite post (D.T. Light-post Illusion size 1, RTD, St-Egrève, France)
6. Resin cement (Panavia F2.0, Kuraray medical, Okayama, Japan)
7. Primer bonding agent (ED primer II A&B, Kuraray medical, Okayama, Japan)
8. 37% Phosphoric acid (Total Etch, Ivoclar Vivadent, Schaan, Liechtenstein)
9. Bonding agent (Tetric N-Bond, Ivoclar Vivadent, Schaan, Liechtenstein)
10. Bonding agent (Clearfil SE Bond, Kuraray medical, Okayama, Japan)
11. Bonding agent (AdheSE, Ivoclar Vivadent, Schaan, Liechtenstein)
12. Bonding agent (Luxabond-total etch system, DMG, Hamburg, Germany)
13. Silane coupling agent (mixture of Clearfil SE bond primer and porcelain bond activator, Kuraray medical, Okayama, Japan)
14. Autopolymerizing acrylic resin (Formatray, Kerr Corporation, California, USA)

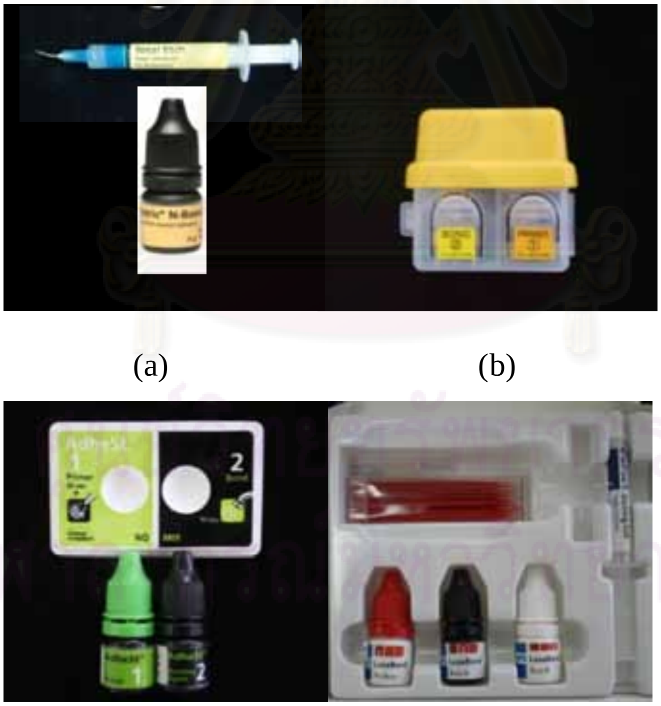
15. Pink base plate wax (Modelling wax, Dentsply/ Caulk, Milford, USA)
16. Vinyl polysiloxane impression material (Reprosil putty and light body consistency, Dentsply/ Caulk, Milford, USA)
17. PVC mold 22 mm in diameter and 20 mm in height
18. Type IV dental stone (Vel-Mix, Kerr Corporation, California, USA)
19. Casting wax (blue inlay casting wax, Kerr, USA)
20. Fit checker (GC Corporation, Tokyo, Japan)
21. Nickel-Chromium alloy (4all, Ivoclar Vivadent Williams #0123, USA)
22. Eugenol-contained root canal cement (C.U. Product, Chulalongkorn University, Thailand)
23. Gutta-percha points (Hygenic, Coltene/ Whaledent, USA)
24. 2.5% sodium hypochorite (NaOCl, C.U. Product, Chulalongkorn University, Thailand)
25. 17% ethylenediaminetetracitic acid solution (EDTA, C.U. Product, Chulalongkorn University, Thailand)
26. Provisional restoration (Cavit, 3M ESPE, Seefeld, Germany)

Instruments Used in This Study

1. High speed airotor 330,000 rpm (798 W&H, Australia)
2. Low speed cutting machine (ISOMET 1000, Buehler, Illinois, USA)
3. Visible light-polymerizing unit (Elipar Trilight 3M ESPE, Minnesota, USA)
4. Diamond rotary cutting instrument (ISO 314197, Intensiv, Switzerland)

(a) (b) (c) (d)

Figure 1. Resin composite core build-up materials used in this study: Tetric N-Ceram (a) Clearfil Photo Core (b) MultiCore Flow (c) and LuxaCore Z-Dual Automix (d).



(a) (b)

(c) (d)

Figure 2. Bonding agents used in this study: Tetric N-Bond (a) Clearfil SE Bond (b) AdheSE (c) and Luxabond-total etch system (d).

(a) (b) (c)

Figure 3. Resin cement (a) primer bonding agent (b) and silane coupling agent (c).

Tooth preparation

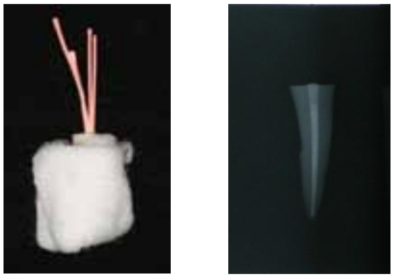
The protocol of this study was approved by the Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (NO.25/2009). Thirty-two extracted human lower first premolars with similar form and size of roots were selected by visual examination and translumination. Inclusion criteria were the teeth being free of cracks, dental caries, restorations or other defects. All teeth were cleaned of calculus deposits, debrided of soft tissues and stored in 0.9% normal saline (C.U. Product, Chulalongkorn University, Thailand) until used. The clinical crowns were decoronated perpendicular to the root axis 1 mm above the cemento-enamel junction (CEJ) on the facial surface by a low speed cutting machine (ISOMET 1000, Buehler, Illinois, USA) (Figure 4). The dimensions of the teeth were measured mesiodistally, faciolingually, and root length, using a digital caliper (micrometer, Mitutoyo, Japan). Teeth in the size range 5.0 to 6.0 mm mesiodistally, 7.5 to 8.5 mm faciolingually, and 14.0 to 15.0 mm in root length were chosen. All teeth were kept moist at room temperature during the study except the period of the operative procedures.

Figure 4. Low speed cutting machine (ISOMET 1000).

Root canal preparation

The pulpal tissue was removed with a barbed broach of appropriate size. A stainless steel K-file size 15 (Dentsply Maillefer, Ballaigues, Switzerland) was inserted into the canal through the apex and the working length was established by subtracting 1 mm from this measurement. All teeth were endodontically treated using a step-back technique. The root canals were prepared to a master apical file size 40; and coronal flaring to size 70 was achieved. In between instrumentations, the root canals were irrigated with 2.5% sodium hypochorite (NaOCl, C.U. Product, Chulalongkorn University, Thailand). Subsequently, alternating irrigation with 2.5% NaOCl and 17% ethylenediaminetetracitic acid solution (EDTA, C.U. Product, Chulalongkorn University, Thailand), and final irrigation with 0.9% normal saline was performed. The canals were dried with sterile paper points (C.U. Product, Chulalongkorn University). Root canals were obturated with gutta-percha cones (Hygenic, Coltène/ Whaledent, Germany) and eugenol-contained root canal cement (C.U. Product, Chulalongkorn University, Thailand) using a lateral condensation technique with a spreader and fine accessory gutta-percha points (Hygenic, Coltene/ Whaledent, USA) until the canals were completely obturated. The extracoronal excess of gutta-percha was removed with a hot instrument and sealed with provisional filling material (Cavit, 3M ESPE, Seefeld, Germany) to a depth of 3 mm (Figure 5). All specimens were stored at 37^0 C 24 hours for complete setting of cement [40].

After root canal treatment, a D.T. universal drill was used to prepare a dowel space to a depth of 10 mm, leaving 4 mm intact gutta-percha as the apical seal [41]. The canals were then shaped with D.T. finishing drill (Figure 6) corresponding to the translucent quartz fiber post with a coronal diameter of 1.5 mm and 0.9 mm at its apical tip (D.T. Light-post Illusion size 1, RTD, St-Egrève, France) [42].



(a) (b)

Figure 5. Root canal obturation with a lateral condensation technique (a) and radiograph after root canal treatment (b).

(a) (b)

Figure 6. D.T. universal drill (a) and D.T. finishing drill (b).

Acrylic resin block preparation and periodontal ligament simulation

Each root of the specimen was dipped into melted wax (Modelling wax, Dentsply/ Caulk, Milford, USA) to a depth of 2 mm below the facial CEJ, resulting in a thickness approximately equal to the 0.2 mm average of the periodontal ligament. The tooth was attached to a surveyor [43] (Dentalfarm, Torino, Italy) with the D.T. Light drill in the canal and was placed in a plastic mold (22 mm in diameter and 20 mm in height). Then the specimen was embedded in autopolymerizing acrylic resin (Formatray, Kerr Corporation, California, USA) to maintain 2 mm of root extending beyond the top of the block and perpendicular to the acrylic resin base. Before polymerization, each tooth was removed from the resin block using a vinyl polysiloxane impression material index (Reprosil putty consistency, Dentsply/ Caulk, Milford, USA) as an aid for repositioning the specimen into the mold. The wax spacer was removed from the root surface and replaced with vinyl polysiloxane impression material (Reprosil light body consistency, Dentsply/ Caulk, Milford, USA). Excess material was also removed with a scalpel blade providing a flat surface 2 mm below the facial CEJ of each tooth for simulation alveolar bone support.

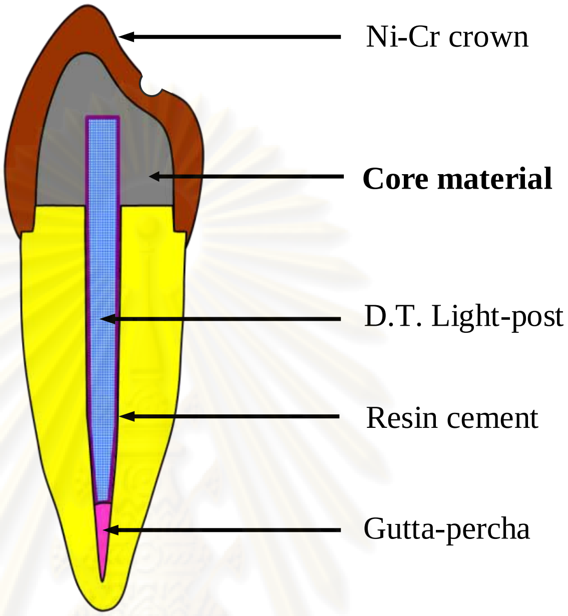


Figure 7. Schematic illustration of tooth specimen with resin composite used as core build-up material.

Post and core restoration

Specimens were then randomly divided into four groups, each comprising eight teeth (n=8). In each group, a different composite was used to build-up the abutment (Figure 7). The materials tested were group 1: Tetric N-Ceram (control group; Ivoclar Vivadent, Schaan, Liechtenstein); group 2: Clearfil Photo Core (Kuraray medical, Okayama, Japan); group 3: MultiCore Flow (Ivoclar Vivadent, Schaan, Liechtenstein); group 4: LuxaCore Z-Dual Automix (DMG, Hamburg, Germany). The coronal end of the post should be completely covered with the resin core by at least 1-mm to prevent failure of the restoration [44]. Therefore, each fiber post was cut with a high-speed diamond rotary cutting instrument (ISO 314197, Intensiv, Switzerland) before luting at a 14 mm length. This adjustment resulted in a post projecting 4 mm above the prepared surface and 10 mm in the root when post was fully seated. Post surface treatment with silane coupling agent (mixture of Clearfil SE bond primer and porcelain bond activator, Kuraray medical, Okayama, Japan) was performed. The root canal was irrigated with 0.9% normal saline and dried with paper points. The post space dentin was conditioned prior to cementation with self-etching primer (ED primer II A&B, Kuraray medical, Okayama, Japan) for 30 seconds. Canal space was then dried with gentle air and excess primer was removed with paper points. Post cementation with the dual-polymerizing resin cement (Panavia F2.0, Kuraray medical, Okayama, Japan) was done per the manufacturer’s instruction. In this study, a visible light-polymerizing unit (Elipar Trilight 3M ESPE, Minnesota, USA) was used with a continuous output 550 mW/cm^2 for 20 seconds per surface.

Each core build-up material was fabricated and bonded with dentin bonding agent according to the manufacturers’ recommendations (see appendix). Preparation of each core was performed using a transparent matrix band. In groups 1 and 2, the incremental core build-up was fabricated in 2-mm layer with each layer polymerized for 40 seconds using a light curing unit as they were light-polymerizing resin composites. In groups 3 and 4, a dual-polymerizing resin composite was injected around the post and then cured for 40 seconds. Each core preparation was standardized to a height of 6 mm above the facial and 3 mm above the lingual CEJ. Each tooth was prepared with a circumferential 0.5 mm chamfer finishing line at the CEJ level for full metal crown. Therefore, the total abutment height included 5 mm of core material and 1-mm ferrule (Figure 8, 9). These measurements were ascertained by using a digital caliper. An impression of tooth/ restoration was made with vinyl polysiloxane impression material (Reprosil, Dentsply/ Caulk, Milford, USA) and poured with type IV dental stone (Vel-Mix, Kerr Corporation, California, USA).

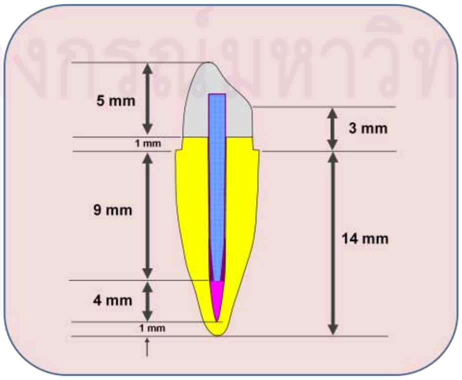


Figure 8. Schematic illustration of specimen dimension**.**

Figure 9. Tooth specimen before crown fabrication (mesio-distal and facio-lingual view).

Crown fabrication

The wax pattern of the crown was made with casting wax (blue inlay casting wax, Kerr Corporation, USA) on the die. A notch was prepared for testing on the center of the occlusal surface**.** Each pattern was invested and casted using Nickel-Chromium alloy (4all, Ivoclar Vivadent Williams #0123, USA). The crown was finished and polished before evaluating the fit to the die. All crowns were tried on the specimens and checked with fit checker (Fit checker, GC corporation, Tokyo, Japan) to assure a passive fit under visual inspection. The prepared tooth was conditioned with ED primer for 30 seconds and the crown was luted to the core using dual-polymerizing resin cement (Panavia F2.0). Each of the 4 surfaces was light polymerized for 20 seconds. An oxygen barrier (Oxyguard II gel, Kuraray dental, Okayama, Japan) was applied to the superficial margin of the crown for 3 minutes and then removed with a cotton roll and water spray. The specimens were stored at 37 ^{0}C 24 hours prior to testing (Figure 10).

(a) (b) (c)

Figure 10. The wax pattern of the crown on the die (a) the crown after casting and polishing (b) and the specimen prior to testing (c).

After storage, the fracture resistance was determined using a universal testing machine (model 8872, Instron, U.K.) at a 135-degree angle to the long axis of the tooth, as shown in Figure 11. The load tip was placed on the prepared occlusal notch. A continuous increasing compressive force was applied at a crosshead speed of 1 mm/min until failure; in the mode of crown debonding, post fracture, core fracture, or root fracture. The highest fracture load of each specimen was measured by a sudden drop in load magnitude as recorded in Newton. All specimens were visually examined for the mode of failure under a stereomicroscope (ML9300, Meiji, Tokyo, Japan) with camera (EOS 100, Canon, Japan).

Figure 11. Specimen mounted at 135 degrees in Instron Testing Machine**.**

Data collection and analysis

The data were analyzed using statistical software (SPSS Statistics 17.0, SPSS Inc, Illinois, USA). One-way analysis of variance (ANOVA) and Bonferroni multiple comparisons test were used for statistical analysis of the four groups and comparison of differences between groups (α=0.05) respectively.

CHAPTER IV

RESULTS

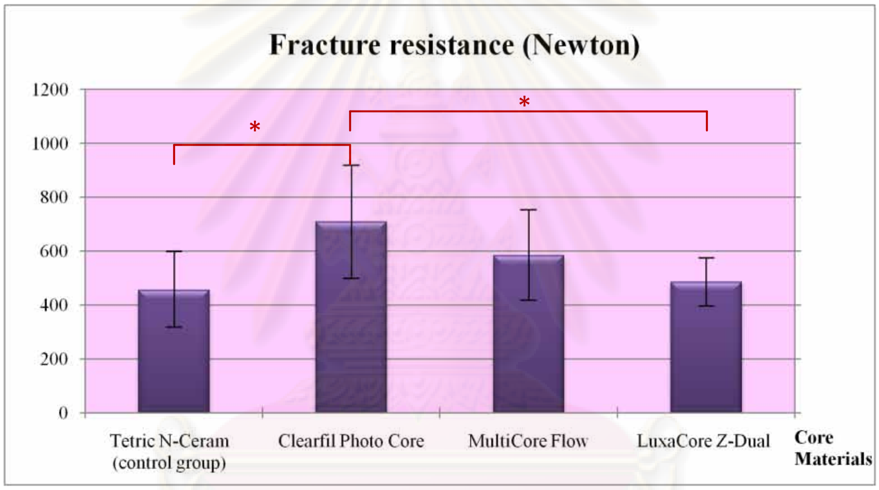
The materials tested were as following; group 1: Tetric N-Ceram, group 2: Clearfil Photo Core, group 3: MultiCore Flow, group 4: LuxaCore Z-Dual Automix**.** As seen in Table I, the fracture load was highest in group 2 (709.01 ± 207.22 N) followed by group 3 (584.15 ± 166.91 N), group 4 (484.77 ± 88.59 N) and group 1 (456.10 ± 140.06 N), respectively. From the data obtained, the fracture resistance among the four groups restored with fiber post and different core build-up materials were significantly different (Table II). The fracture resistance for Clearfil Photo Core was not significantly different from MultiCore Flow ($p>0.05$), but significantly higher than that of LuxaCore Z-Dual Automix and Tetric N-Ceram ($p<0.05$) (Figure 12).

Table I Means and standard deviations of the failures load in groups

Groups		**Mean ± SD (N)**
Group1: Tetric N-Ceram control group	(n=8)	456.10 ± 140.06
Group2: Clearfil Photo Core	(n=8)	709.01 ± 207.22
Group3: MultiCore Flow	(n=8)	584.15 ± 166.91
Group4: LuxaCore Z-Dual Automix	(n=8)	484.77 ± 88.59

Table II One-way analysis of variance (ANOVA) reveals the effect of various core build-up materials on fracture resistance

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	313872.578	3	104624.193	4.259	.013
Within Groups	687842.032	28	24565.787		
Total	1001714.609	31			



* significant difference, $p<0.05$

Figure 12. Results of fracture load for four groups studied.

When the specimens were examined under the stereomicroscope, the most common pattern of failure for all groups had its origin at the lingual crown margin and continued obliquely in an apical-facial direction as shown in Figure 13 and 14.

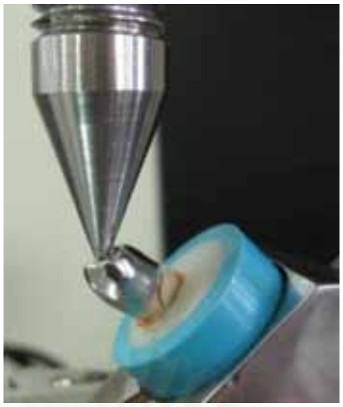


Figure 13. Fracture pattern was oblique, from the cervical-lingual to apical-facial direction.

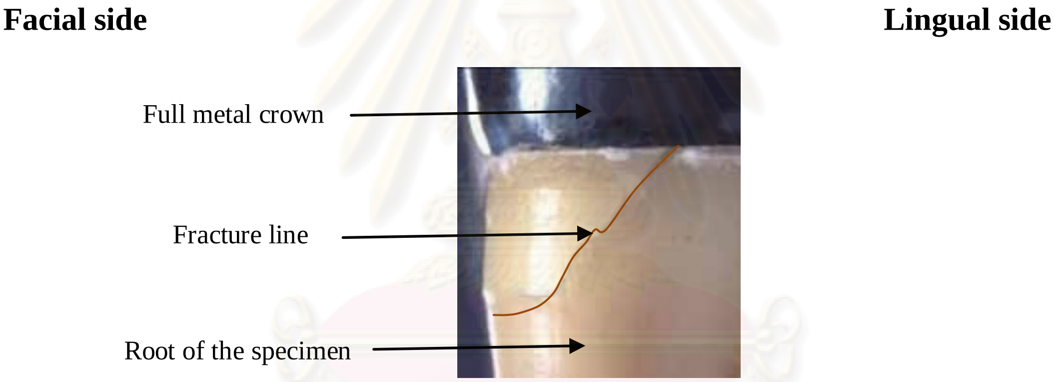


Figure 14. Specimen illustrating fracture pattern under stereomicroscope (x10)**.**

CHAPTER V

DISCUSSION

Based on statistical analysis, the null hypothesis was rejected since there were significant differences among fracture resistances of the resin composite core build-up materials in this study. The results indicated the fracture resistance of Clearfil Photo Core was not significantly different from MultiCore Flow, but significantly higher than that of LuxaCore Z-Dual Automix and Tetric N-Ceram. In this study, fiber posts with similar dimensions and structures were used; core material was the only variable. Possible reasons for the differences in fracture loads could be the mechanical properties of the materials such as modulus of elasticity of the materials, composition of filler and resin matrix, polymerization modes and the manufacturer.

The flexural modulus indicates the relative stiffness of the material within an elastic range and also reflects the strength and longevity of the restoration. The desired properties of core materials should be similar to those of dentin to uniformly distribute the masticatory forces to the post and root. Similar moduli minimize the interfacial stress which can result from different moduli between two different materials. Generally, most composite core materials are composed of organic polymer matrix, a compound of Bis-GMA and filler particles. Increased filler content results in a higher flexural modulus [45-46]. According to the manufacturers’ information, Clearfil Photo Core has the highest filler content (83 wt%) followed by MultiCore Flow (base 71.3 wt%, catalyst 70.6 wt%), LuxaCore Z-Dual Automix (70 wt%) and Tetric N-Ceram (63.5 wt%) respectively. These are consistent with the fracture resistance test as mentioned above. Previous studies noted Clearfil Photo Core demonstrated statistically significant differences in shear bond strength, flexural strength, [16] and fracture toughness compared to other core materials [29]. These results agreed with this study where Clearfil Photo Core showed the highest fracture resistance.

Another reason for dissimilar fracture resistances may be from differences in polymerization modes of light or dual curing. Clearfil Photo Core and Tetric N-Ceram are light-curing polymerization, while MultiCore Flow and LuxaCore Z-Dual Automix are dual-curing polymerization. Previous studies showed light-curing composite core material has higher bond strengths to dentin [47] and higher flexural strengths [16] than chemical and dual-curing composites. However, dual-curing core materials seem to be more preferable in using with fiber posts because it can be applied once, while the light-curing materials have to be applied incrementally to ensure complete polymerization. A study of MultiCore Flow showed higher bond strength than hybrid composite [17].

The compatibility of the materials used may have affected the results. Clearfil Photo Core and Panavia resin cement used in group 2 are produced by the same manufacturer (Kuraray medical, Okayama, Japan). These may be more compatible than the others. In addition, the modulus of elasticity of Clearfil Photo Core (18.5 GPa) was nearly similar to resin cement (18.3 GPa) [48], and dentin (18.6 GPa) [48] which may have resulted in more natural stress distribution [49].

Regarding mode of failures, the fracture lines of all groups studied were similar. The direction of the force applied obliquely to the occlusal surface of the simulated crown may cause the post to flex labially [50]. This generates a compressive stress in the labial dentin while the lingual dentin is under tension. A failure fracture of the cement should result in a marginal opening occurring initially on the tension side with resultant leakage and secondary caries [51]. The rotational axis is located at the upper border of the acrylic block simulating the facial alveolar bone crest. After crown loosening, tension forces may cause an adhesive failure of the post-cement-root dentin interface. Then, the post is loose within the root canal and consequently acts like a wedge. Loads exceeding the tensile strength of dentin lead to root fracture. Hence, the fracture pattern in this study was oblique, from the cervical-lingual to apical-facial direction [52]. This finding agrees with a three-dimensional finite element analysis (Figure 15) where stress concentration in the post region was observed at the interface between the lingual side of fiber post and resin core, and maximum stress in the remaining radicular dentin was on the inner side of the proximal wall at the cervical level [53].

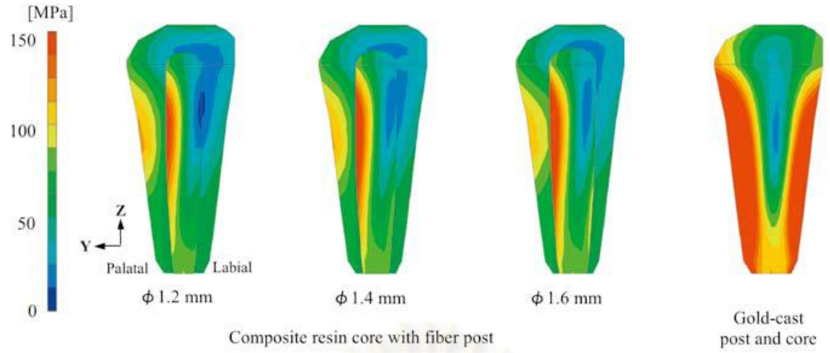


Figure 15. Distribution of von Mises stresses in the internal area of the post [53].

In this study, the fracture pattern observed indicated higher stress concentrations developed in the coronal third of the radicular dentin than at the apex. It can be concluded that there are high stress concentrations with increased lateral forces in the transitional area between a rigid and less rigid part in the cervical area i.e. the crown margin and the brittle dentin. This observation is in agreement with previous findings [9, 14, 54] that the simulation of crown on the post and core specimens is unlikely to block the effects of other factors. However, the placement of full metal crown used in this study might have different result from all-ceramic or porcelain fused to metal crown [55].

Several investigations document ferrule length plays an important role in the success of endodontically treated teeth. A 1.0-mm ferrule height was prepared in this study. The study of Libman showed the minimum coronal extension should be 1.5 mm for ensuring a favorable prognosis [56]. However, Akkayan has reported there was no significant difference between 1.0-mm and 1.5-mm ferrules length in specimens restored with quartz fibers and resin composite core [57].

In this study, Tetric N-Ceram was selected because it is a conventional composite-nanohybrid type. The trend of using nanohybrid resin composite is increasing. The nano-sized particles improve its physical properties contributing to improved esthetics, higher abrasion resistance and lower shrinkage, while the strength is as similar to the hybrid composite. The three other materials were resin composites specifically designed for core build-up. Clearfil Photo Core was selected due to its modulus of elasticity being similar to dentin. In addition, it has been shown that light-cured core materials released less monomer and might be less dangerous or toxic to oral tissue [58].

MultiCore Flow and LuxaCore Z-Dual Automix were chosen because of their ease in mixing and application methods. As both materials have the same clinical handling characteristics, their syringe technique probably produces less air incorporation [11] and their favorable performance indicate they can be used in post cementation. Moreover, LuxaCore Z-Dual Automix, the next generation of LuxaCore with zirconium dioxide added, has been recently released in the market. The selection of the incorporated dentin bonding agent was based upon the manufacturers' recommendations for each core material.

D.T. Light-posts were chosen for this study as being one of the most clinically popular with several clinical trials and in vitro studies conducted upon them [59-62]. They are made of unidirectional pre-tensed quartz fibers (60 vol%) bound in an epoxy resin matrix (40 vol%) [62]. A slightly double-tapered post contributes more precisely to canals and better adaptation. It has light-transmitting property and also offers an esthetic color [42]. Quartz fiber posts have a low thermal expansion coefficient and their modulus of elasticity is similar to that of dentin. Moreover, they are anisotropic materials with high fatigue and tensile strength [4, 7]. The higher fiber-matrix ratio of this dowel results in greater flexural strength [34, 63].

Surface treatment of the post is commonly used for improving the adhesion of the post and cement interface and may be achieved by mechanical or chemical treatment. Despite the efficacy of mechanical treatment such as airborne-particle-abrasion which improved bond strengths, this procedure had a risk of modifying the shapes and fit of the post due to its technique sensitivity [64]. Chemical surface treatment such as etching significantly enhanced the microtensile interfacial bond strength between fiber post and composite material [62]. Nevertheless, the use of a silane coupling agent to improve the interfacial bond strength between resin composite and fiber posts is still controversial. The chemical bond of silane may be achieved with exposed quartz fibers. Hence, the main function of silane is improving surface wettability of fiber post and compatibility among different organic and inorganic materials.

Concerning load capability, although obvious higher fracture resistance was shown by Clearfil Photo Core, fracture thresholds of the other groups still exceeded the average occlusal force on premolars (300 N) [65]. This suggests the resin composites used in this study restored with fiber post and full-coverage crown could resist normal occlusal forces. However, there are several factors which limit the application of this experimental study directly to clinical situations. A continuous single static load was applied to the test samples, which is not the same as the cyclical force of mastication. Nevertheless, static loading is a standard assay in the material evaluation process and is commonly used to obtain information about the potential for clinical success. Although nondestructive or fatigue testing may be more appropriate method for testing, no test methods used today are completely able to totally simulate the occlusion of patients including parafunctional habits such as bruxism. Other conditions, which may have influenced these results include the storage methods and thermal cycling [66]. Further researches on this subject should be ongoing.

CHAPTER VI

CONCLUSIONS

In this in vitro study, the fracture resistance of endodontically treated teeth restored with FRC post using different resin composite core materials was tested. Within its limitations, the following conclusions can be drawn:

1. Tetric N-Ceram tended to have the lowest fracture resistance.
2. The fracture resistance for Clearfil Photo Core was not significantly different from that of MultiCore Flow.
3. The fracture resistance for Clearfil Photo Core was significantly higher than that of LuxaCore Z-Dual Automix and Tetric N-Ceram.

REFERENCES

(1) Christensen, G. J. When to use fillers, build-ups or posts and cores. J Am Dent Assoc. 127 (1996):1397-1398.

(2) Qualtrough, A. J; and Mannocci, F. Tooth-colored post systems: a review. Oper Dent. 28 (2003): 86-91.

(3) Cormier, C. J.; Burns, D. R.; and Moon, P. In vitro comparison of the fracture resistance and failure mode of fiber, ceramic, and conventional post systems at various stages of restoration. J Prosthodont. 10 (2001): 26-36.

(4) Wilson, P. H.; Fisher, N. L.; and Bartlett, D.W. Direct core materials. Dent Update. 30 (2003): 362-368.

(5) Burke, F. J., et al. Fracture resistance of five pin-retained core build-up materials on teeth with and without extracoronal preparation. Oper Dent. 25 (2000): 388-394.

(6) Millstein, P. L.; Ho, J.; and Nathanson, D. Retention between a serrated steel dowel and different core materials. J Prosthet Dent. 65 (1991): 480-482.

(7) Cohen, B. I., et al. Pilot study of the cyclic fatigue characteristics of five endodontic posts with four core materials. J Oral Rehabil. 27 (2000): 83-92.

(8) Cho, G. C., et al. Diametral and compressive strength of dental core materials. J Prosthet Dent. 82 (1999): 272-276.

(9) Kovarik, R. E.; Breeding, L. C.; and Caughman, W. F. Fatigue life of three core materials under simulated chewing conditions. J Prosthet Dent. 68 (1992): 584-590.

(10) Combe, E. C., et al. Mechanical properties of direct core build-up materials. Dent Mater. 15 (1999): 158-165.

(11) Artopoulou, II; O'Keefe, K. L.; and Powers J. M. Effect of core diameter and surface treatment on the retention of resin composite cores to prefabricated endodontic posts. J Prosthodont. 15 (2006): 172-179.

(12) Tauböck, T. T., et al. Influence of light-curing protocols on polymerization shrinkage and shrinkage force of a dual-cured core build-up resin composite. Eur J Oral Sci. 118 (2010): 423-429.

(13) Ferrier, S.; Sekhon, B. S.; and Brunton, P. A. A study of the fracture resistance of nyyar cores of three restorative materials. Oper Dent. 33 (2008): 305-311.

(14) Gateau, P.; Sabek, M.; and Dailey, B. Fatigue testing and microscopic evaluation of post and core restorations under artificial crowns. J Prosthet Dent. 82 (1999): 341-347.

(15) Cohen, B. I., et al. Fracture strength of three different core materials in combination with three different endodontic posts. Int J Prosthodont. 7 (1994): 178-182.

(16) Ahn, S. G.; and Sorensen, J. A. Comparison of mechanical properties of various post and core materials. J Korean Acad Prosthodont. 41 (2003): 288-299.

(17) Salameh, Z., et al. Adhesion between prefabricated fiber-reinforced posts and different composite resin cores: a microtensile bond strength evauluation. J Adhes Dent. 8 (2006): 113-117.

(18) Sadek, F. T., et al. Bond strength performance of different resin composites used as core materials around fiber posts. Dent Mater. 23 (2007): 95-99.

(19) Duke, E. S. Reinforced core build-up materials. Compend Contin Educ Dent. 23 (2002): 328-329, 332.

(20) Robbins, J. W.; Cooley, R. L.; and Barnwell, S. Fracture resistance of reinforced glass ionomer as a buildup material. Oper Dent. 15 (1990): 23-26.

(21) Leevailoj, C., Chalermpol & Montri : Posterior Tooth Colored Restoration. In: Tooth color materials' continuum, 1st ed. (Bangkok: Sunta publishing, 2006), pp.42-72.

(22) Lutz, F.; and Phillips, R. W. A classification and evaluation of composite resin systems. J Prosthet Dent. 50 (1983): 480-488.

(23) Williems, G., et al. A classification of dental composites according to their morphological and mechanical charactertistics. Dent Mater. 8 (1992): 310-319.

(24) Bayne, S. C.; Heymann, H. O.; and Swift JR., E. J. Update on dental composite restorations. J Am Dent Assoc. 125 (1994): 687-701.

(25) Bayne, S. C., et al. A characterization of first-generation flowable composites. J Am Dent Assoc. 129 (1998): 567-577.

(26) Monticelli, F.; Goracci, C.; and Ferrari, M. Micromorphology of the fiber post-resin core unit:a scanning electron microscopy evaluation. Dent Mater. 20 (2004): 176-183.

(27) Monticelli, F., et al. Clinical behavior of translucent-fiber posts: a 2-year prospective study. Int J Prosthodont. 16 (2003): 593-596.

(28) Schmage, P., et al., Wear and hardness of different core build-up materials. J Biomed Mater Res B Appl Biomater. 91 (2009): 71-79.

(29) Ahn, S. G.; Berge, H. X.; and Sorensen, J. A., "Fracture toughness and flexural strength of various core materials," Paper presented at The IADR/AADR/CADR 80th General Session, San Diego, USA, 6-9 March 2002.

(30) Ontiveros, J. C., et al., "Core material and adhesive cure mode effects on bond strengths," Paper presented at The IADR/AADR/CADR 85th General Session and Exhibition, New Orleans, USA, 21-24 March 2007.

(31) Wrbas, K. T., et al. Influence of adhesive systems on bond strength between fiber posts and composite resin cores in a pull-out test design. Dent Mater J. 26 (2007): 401-408.

(32) Dyer, S. R., et al. Effect of fiber position and orientation on fracture load of fiber-reinforced composite. Dent Mater. 20 (2004): 947-955.

(33) Grandini, S., et al. Fatigue resistance and structural characteristics of fiber posts: three-point bending test and SEM evaluation. Dent Mater. 21 (2005): 75-82.

(34) Seefeld, F., et al. Resistance to fracture and structural characteristics of different fiber reinforced post systems. Dent Mater. 23 (2007): 265-271.

(35) de Rijk, W. G. Removal of fiber posts from endodontically treated teeth. Am J Dent.13 (2000):19B-21B.

(36) Drummond, J. L. In vitro evaluation of endodontic posts. Am J Dent. 13 (2000): 5B-8B.

(37) Purton, D. G.; and Payne, J.A. Comparison of carbon fiber and stainless steel root canal posts. Quintessence Int. 27 (1996): 93-97.

(38) Akkayan, B.; and Gulmez, T. Resistance to fracture of endodontically treated teeth restored with different post systems. J Prosthet Dent. 87 (2002): 431-437.

(39) Lassila, L. V., et al. Flexural properties of fiber reinforced root canal posts. Dent Mater. 20 (2004): 29-36.

(40) Mendonca, S.C., et al. In vitro study of the effect of aged eugenol on the flow, setting time and adhesion of Grossman root canal sealer. Braz Dent J. 11 (2000): 71-78.

(41) Zillich, R. M.; and Corcoran, J. F. Average maximum post lengths in endodontically treated teeth. J Prosthet Dent. 52 (1984): 489-491.

(42) Boudrias, P.; Sakkal, S.; and Petrova, Y. Anatomical post design meets quartz fiber technology: rationale and case report. Compend Contin Educ Dent. 22 (2001): 337-340, 342, 344 passim; quiz 350.

(43) Ma, P. S., et al. Load fatigue of teeth with different ferrule lengths, restored with fiber posts, composite resin cores, and all-ceramic crowns. J Prosthet Dent.102 (2009): 229-234.

(44) Grandini, S.; Balleri, P.; and Ferrari, M. Scanning electron microscopic investigation of the surface of fiber posts after cutting. J Endod. 28 (2002): 610-612.

(45) Li, Y., et al. Effect of filler content and size on properties of composites. J Dent Res. 64 (1985): 1396-1401.

(46) Braem, M., et al. Mechanical properties and filler fraction of dental composites. Dent Mater. 5 (1989): 346-349.

(47) Sanares, A., et al. Chemical-cured composite weakensbonding of adhesives by surface interaction. J Dent Res. 79 (2000): 357.

(48) Li, L. L., et al. Three-dimensional finite element analysis of weakened roots restored with different cements in combination with titanium alloy posts. Chin Med J. 119 (2006): 305-311.

(49) Tay, F.R.; and Pashley, D. H. Monoblocks in root canals: a hypothetical or a tangible goal. J Endod. 33 (2007): 391-398.

(50) Ichim, I.; Kuzmanovic, D. V.; and Love R.M. A finite element analysis of ferrule design on restoration resistance and distribution of stress within a root. Int Endod J. 39 (2006): 443-452.

(51) Morgano, S. M.; and Brackett, S. E. Foundation restorations in fixed prosthodontics: current knowledge and future needs. J Prosthet Dent. 82 (1999): 643-657.

(52) Naumann, M.; Preuss, A.; and Frankenberger, R. Reinforcement effect of adhesively luted fiber reinforced composite versus titanium posts. Dent Mater. 23 (2007): 138-144.

(53) Okamoto, K., et al. Three-dimensional finite element analysis of stress distribution in composite resin cores with fiber posts of varying diameters. Dent Mater J. 27 (2008): 49-55.

(54) Brandal, J. L.; Nicholls, J. I.; and Harrington, G. W. A comparison of three restorative techniques for endodontically treated anterior teeth. J Prosthet Dent. 58 (1987): 161-165.

(55) Salameh, Z., et al. Effect of different all-ceramic crown system on fracture resistance and failure pattern of endodontically treated maxillary premolars restored with and without glass fiber posts. J Oral Rehabil. 33 (2007): 848-851.

(56) Libman, W. J.; and Nicholls, J. I. Load fatigue of teeth restored with cast posts and cores and composite crowns. Int J Prosthodont. 8 (1995): 155-161.

(57) Akkayan, B. An in vitro study evaluating the effect of ferrule length on fracture resistance of endodontically treated teeth restored with fiber-reinforced and zirconia dowel systems. J Prosthet Dent. 92 (2004): 155-162.

(58) Polydorou, O., et al. Release of monomers from different core build-up materials. Dent Mater. 25 (2009): 1090-1095.

(59) Grandini, S., et al. Clinical evaluation of the use of fiber posts and direct resin restorations for endodontically treated teeth. Int J Prosthodont. 18 (2005): 399-404.

(60) Cagidiaco, M. C., et al. Clinical performance of fiber post restorations in endodontically treated teeth: 2-year results. Int J Prosthodont. 20 (2007): 293-298.

(61) Mekayarajjananonth, T., et al. The effect of fiber dowel heights in resin composite cores on restoration failures of endodontically treated teeth. J Oral Implantol. 35 (2009): 63-69.

(62) Monticelli, F., et al. Post-surface conditioning improves interfacial adhesion in post/core restorations. Dent Mater. 22 (2006): 602-609.

(63) Newman, M. P.; Yaman, P.; and Dennison, J. Fracture resistance of endodontically treated teeth restored with composite posts. J Prosthet Dent. 89 (2003): 360-367.

(64) Sahafi, A., et al. Retention and failure morphology of prefabricated posts. Int J Prosthodont. 17 (2004): 307-312.

(65) Powers, J. M. and Sakaguchi, R. L. CRAIG'S Restorative Dental Materials. In: Resin composite restorative materials, 12th ed. (St. Louis: Mosby, 2006), pp. 195-197.

(66) Drummond, J. L.; and Bapna, M. S. Static and cyclic loading of fiber-reinforced dental resin. Dent Mater. 19 (2003): 226-231.

APPENDIX

APPENDIX

Contents **Page**

Materials used in this study and their compositions

Material	Type	Composition		
Tetric N-Ceram (Ivoclar Vivadent, Schaan, Liechtenstein)	nano-hybrid resin composite	urethane dimethacrylate, ethoxylated Bis-EMA, Bis-GMA *(18.8 wt%)*, barium glass filler, ytterbium trifluoride, mixed oxide *(63.5 wt%)*, polymer *(17.0 wt%)*, and additives, catalysts, stabilizers and pigments *(0.7 wt%)*		
Clearfil Photo Core (Kuraray medical, Okayama, Japan)	light-cured core build-up composite hybrid resin composite	silanated silica filler, silanated barium glass filler, triethyleneglycol dimethacrylate, Bis-GMA, dl-camphorquinone, catalysts, accelerators, others filler content *(83 wt%, 68 vol%)*		
MultiCore Flow (Ivoclar Vivadent, Schaan, Liechtenstein)	self-cured core build-up composite with light-cured option	*(wt %)*	Base	Catalyst
		-Bis-GMA, urethane dimethacrylate, triethyleneglycol dimethacrylate	*28.1*	*28.4*
		-barium glass fillers, Ba-Al-fluorosilicate glass, highly dispersed silicon dioxide	*54.9*	*54.4*
		-ytterbium trifluoride	*16.4*	*16.2*
		-catalysts ,stabilizers and pigments	*0.6*	*1.0*
LuxaCore Z-Dual Automix (DMG, Hamburg, Germany)	dual-cured core build-up composite	Bis-GMA-based dental resins *(28 wt%)*, inorganic filler *(70 wt%)*, additives, pigments, catalysts *(2 wt%)*		

Materials	Type	Composition
D.T. Light-post Illusion (RTD, St-Egrève, France)	- post diameter 2.0 mm - fiber diameter 12 μm - fiber density 32 fibers/mm ^{2} -surface occupied by fiber per mm^2 of post surface 38.4%	- quartz fiber 60% - epoxy resin 40%
Panavia F 2.0 (Kuraray medical, Japan)	resin cement (self-curing adhesive bond system)	silanized barium glass, silanized silica, sodium fluoride, benzoyl peroxide, photosensitizer, MDP, hydrophobic and hydrophilic dimethacrylate, bisphenol A polyethoxy dimethacrylate
ED Primer (Kuraray medical, Japan)	self-etching primer	MDP, HEMA, N-methacryl 5-aminosalicylic acid, sodium benzene sulfinate, N,N-diethanol-p-toluidine, water

Composition, system, and technique of dentin bonding agents

Bonding agent	Adhesive system	Technique	Composition
Tetric N-Bond	light-curing	total-etching	phosphonic acid acrylate, HEMA, Bis-GMA, urethane dimethacrylate, ethanol, nanofillers, catalysts and stabilizers
Clearfil SE Bond	light-curing	self-etching	Clearfil SE Primer: 10-methacryloyloxydecyl dihydrogen phosphate (MDP), HEMA, hydrophilic dimethacrylate, dl-Camphorquinone, N,N- diethanol p-toluidine, water Clearfil SE Bond: 10-methacryloyloxydecyl dihydrogen phosphate (MDP), Bis-GMA, HEMA, hydrophobic dimethacrylate , dl- Camphorquinone, N,N- diethanol p-toluidine, silanated colloidal silica
AdheSE	light-curing	self-etching	AdheSE Primer: dimethacrylate, phosphonic acid acrylate, initiators and stabilizers in an aqueous solution AdheSE Bond: HEMA, dimethacrylate, silicon dioxide, initiators and stabilizers
Luxabond	dual-curing	total-etching	Prebond: ethanol arylsulfinate solution Bond A: hydrophile Bis-GMA-based resin matrix Catalyst Bond B: hydrophile Bis-GMA-based resin matrix, benzoyl peroxide

The core build-up materials with incorporated dentin bonding agents according to manufacturers' recommendation and their application procedures

Group	Resin composite	Bonding agent	Application procedure
1	Tetric N-Ceram	Tetric N-Bond	etch for 15 s, rinse, gently air dry, apply adhesive and agitate for 10 s, gently air dry, light activation for at least 10 s, place core
2	Clearfil Photo Core	Clearfil SE Bond	apply primer for 20 s, gently air dry for 5 s, apply adhesive, gently air dry, light activation 10 s, place core
3	MultiCore Flow	AdheSE	apply primer, air dry, apply adhesive and add more for another 15 s, gently air dry, light activation for 10 s, apply core
4	LuxaCore Z-Dual Automix	Luxabond	etch for 15 s, rinse, gently air dry, apply Prebond for 15 s, mix 1:1 Bond A and Bond B for 5 s and apply for 20 s, gently air dry, light activation for 10 s, apply core

Statistical analysis

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Material	Statistic	df	Sig.	Statistic	df	Sig.
Strength	1.00	.177	8	.200*	.875	8	.168
	2.00	.225	8	.200*	.888	8	.222
	3.00	.209	8	.200*	.920	8	.427
	4.00	.165	8	.200*	.906	8	.330

a. Lilliefors Significance Correction

* This is a lower bound of the true significance.

Test of Homogeneity of Variances

Strength

Levene Statistic	df1	df2	Sig.
2.276	3	28	.102

Bonferroni multiple comparison test between groups (α=0.05)

					95% Confidence Interval	
Group	Group	Mean Difference	Std. Error	Sig.	Lower Bound	Upper Bound
1	2	-252.91250*	78.36738	.019	-475.3922	-30.4328
	3	-128.05875	78.36738	.681	-350.5385	94.4210
	4	-28.67125	78.36738	1.000	-251.1510	193.8085
2	1	252.91250*	78.36738	.019	30.4328	475.3922
	3	124.85375	78.36738	.734	-97.6260	347.3335
	4	224.24125*	78.36738	.047	1.7615	446.7210
3	1	128.05875	78.36738	.681	-94.4210	350.5385
	2	-124.85375	78.36738	.734	-347.3335	97.6260
	4	99.38750	78.36738	1.000	-123.0922	321.8672
4	1	28.67125	78.36738	1.000	-193.8085	251.1510
	2	-224.24125*	78.36738	.047	-446.7210	-1.7615
	3	-99.38750	78.36738	1.000	-321.8672	123.0922

* The mean difference is significant at the 0.05 level.

BIOGRAPHY

NAME	Miss Prapaporn Panitiwat
DATE OF BIRTH	7 July 1981
PLACE OF BIRTH	Bangkok, Thailand
INSTITUTIONS ATTENDED	Chulalongkorn University, 2008 - present: Master of Science (Prosthodontics) Chulalongkorn University, 1999 - 2005: Doctor of Dental Surgery
WORK EXPERIENCE	2007-2008, Kluaynamthai Hospital, Bangkok, Thailand 2006-2007, Khueang Nai Hospital, Ubonratchathani, Thailand 2005-2006, Sirindhorn College of Public Health Ubonratchathani, Thailand
RESEARCH GRANT	Faculty of Dentistry, Chulalongkorn University Fund
CONTACT ADDRESS	212/177 Pattanakarn Road, Pravet, Bangkok 10250, Thailand E-mail: kapook_looks@hotmail.com