FRACTURE RESISTANCE OF ENDODONTICALLY TREATED PREMOLARS WITH DEEP

CERVICAL LESION RESTORED WITH AND WITHOUT POST IN DIFFERENT

RESTORATIONS

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ความต้านทานต่อการแตกหักของฟันกรามน้อยบนที่ผ่านการรักษาคลองรากฟันร่วมกับการ
สูญเสียเนื้อฟันบริเวณคอฟัน ภายหลังการบูรณะด้วยเดือยฟันและการบูรณะวิธีต่างๆ

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Thesis Title	FRACTURE RESISTANCE OF ENDODONTICALLY TREATED PRE MOLARS WITH DEEP CERVICAL LESION RESTORED WITH AND WITHOUT POST IN DIFFERENT RESTORATIONS
By	Miss Phrohphrim Suebsawadphatthana
Field of Study	Esthetic Restorative and Implant Dentistry
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เพราะพริ้ม สืบสวัสดิ์พัฒนา : ความต้านทานต่อการแตกหักของฟันกรามน้อยบนที่ผ่านการรักษา
คลองรากฟันร่วมกับการสูญเสียเนื้อฟันบริเวณคอฟัน ภายหลังการบูรณะด้วยเดือยฟันและการ
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FRACTURE RESISTANCE OF ENDODONTICALLY TREATED PREMOLARS WITH DEEP
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RESTORATIONS) อ.ที่ปรึกษาหลัก : รศ. ทพ.เฉลิมพล ลี้ไวโรจน์

วัตถุประสงค์: เพื่อศึกษาความต้านทานต่อการแตกหักของฟันกรามน้อยบนที่ผ่านการรักษาคลอง
รากฟันร่วมกับการสูญเสียเนื้อฟันบริเวณคอฟัน ภายหลังการบูรณะด้วยเดือยฟันและการบูรณะวิธีต่างๆ
วิธีการทดลอง: จำลองรอยโรคบริเวณคอฟันในฟันกรามน้อยบน 40 ซี่ภายหลังการรักษาคลองรากฟัน และ
แบ่งเป็น 4 กลุ่มโดยกลุ่ม COM-NP บูรณะด้วยเรซินคอมโพสิตไม่ใส่เดือยฟัน, ON-NP กลุ่มบูรณะด้วยออน
เลย์ไม่ใส่เดือยฟัน, COM-P กลุ่มบูรณะด้วยเรซินคอมโพสิตร่วมกับเดือยฟัน, CR-P กลุ่มบูรณะด้วยครอบฟัน
ร่วมกับเดือยฟัน หลังจากบูรณะนำชิ้นงานทั้งหมดไปทดสอบด้วยเครื่อง universal testing machine โดยให้
แรงขนานกับแนวแกนฟันจนกระทั่งเกิดรอยแตกหักด้วยความเร็วเครื่อง 0.5 มิลลิเมตร/นาที ผลการทดลอง:
แรงที่ทำให้เกิดการแตกหักของแต่ละกลุ่มเป็นดังนี้ (นิวตัน) : COM-NP (933.48±242.53); ON-NP
(1871.45±313.59); COM-P (1510.17±251.87); and CR-P (2189.97±600.38) โดย COM-NP มีค่า
ต้านทานต่อการแตกหักต่ำที่สุดและมีความแตกต่างอย่างมีนัยสำคัญทางสถิติเมื่อเปรียบเทียบกับกลุ่มอื่น
($p \leq 0.05$) พบความแตกต่างกันอย่างมีนัยสำคัญทางสถิติระหว่างทุกกลุ่ม ยกเว้น ON-NP เทียบกับ COM-P
และกลุ่ม ON-NP เมื่อเทียบกับ CR-P ($p=0.218$, $p=0.322$) ตามลำดับ นอกจากนั้นผลรูปแบบการแตกหัก
ของทุกกลุ่มเป็นการแตกหักแบบไม่สามารถบูรณะต่อได้ สรุป: การบูรณะฟันแบบคลุมปุ่มฟันทั้งหมดสามารถ
เพิ่มความต้านทานต่อการแตกหักของฟันกรามน้อยบนที่มีการสูญเสียเนื้อฟันบริเวณคอฟันร่วมกับการรักษา
คลองรากฟันได้ การใส่เดือยฟันชนิดผสมไฟเบอร์สามารถเพิ่มความต้านทานต่อการแตกหักในฟันกรามน้อย
บนที่มีการสูญเสียเนื้อฟันบริเวณคอฟันร่วมกับการรักษาคลองรากฟันแต่ไม่สามารถทำให้รูปแบบการแตกหัก
เป็นแบบบูรณะต่อได้

สาขาวิชา	ทันตกรรมบูรณะเพื่อความสวยงาม	ลายมือชื่อนิสิต ....
	และทันตกรรมรากเทียม	
ปีการศึกษา	2561	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....

5875826632 : MAJOR ESTHETIC RESTORATIVE AND IMPLANT DENTISTRY

KEYWORD:

Phrohphrim Suebsawadphatthana :
FRACTURE RESISTANCE OF ENDODONTICALLY TREATED PREMOLARS WITH DEEP
CERVICAL LESION RESTORED WITH AND WITHOUT POST IN DIFFERENT
RESTORATIONS. Advisor: Assoc. Prof. Chalermpol Leevailoj

Objectives: The purpose of this study was to evaluate the effects of fiber posts and different restorations on the fracture resistance of endodontically treated maxillary premolars with cervical cavities. Methods: In forty extracted human first maxillary premolars, cervical cavities were prepared simulating cervical lesions and randomly divided into four groups (n=10): COM-NP, endodontically treated teeth (ETT) restored with resin composite without fiber posts; ON-NP, ETT restored with CAD/CAM ceramic onlays without fiber posts; COM-P, ETT restored with resin composite and fiber posts; and CR-P, ETT restored with CAD/CAM ceramic crowns and fiber posts. After the fiber posts and restorations had been cemented with resin cement, all specimens were loaded onto the long axis in a universal testing machine until fracture at a speed of 0.5 mm/min. Fracture load (N) and fracture modes were evaluated in all specimens. The mode of failure was determined by visual inspection. Data were analyzed with one-way ANOVA and Scheffé's tests ($p < 0.05$). Results: Fracture load for all groups were (N): COM-NP (933.48 ± 242.53); ON-NP (1871.45 ± 313.59); COM-P (1510.17 ± 251.87); and CR-P (2189.97 ± 600.38). COM-NP had the lowest fracture resistance, significantly different from those of the other groups ($p \leq 0.05$). Statistically significant differences were observed among groups ($p \leq 0.05$), except in the ON-NP to COM-P and the ON-NP to CR-P groups ($p=0.218$, $p=0.322$). All groups showed the non-restorable fracture mode. Conclusion: Cuspal-coverage restorations significantly enhanced the fracture resistance of endodontically treated maxillary premolars with cervical cavities. Placement of fiber posts improved the fracture resistance of endodontically treated teeth but did not make the failure restorable.

Field of Study:	Esthetic Restorative and	Student's Signature ....
	Implant Dentistry	
Academic Year:	2018	Advisor's Signature ....

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Phrohphrim Suebsawadphatthana

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CHAPTER I

INTRODUCTIONS

Endodontically treated teeth (ETT) are usually characterized by essential coronal and radicular tooth structure loss as a result of dental caries, previous restorations, and endodontic access preparation that negatively influenced tooth strength.(1, 2) The primary cause of extraction among endodontically treated teeth is tooth fracture related primarily to improper prosthetic restorations.(3, 4) The longevity of endodontically treated teeth depends not only on the use of conservative endodontic procedures but also on appropriate coronal restoration of the tooth.(3, 5, 6) The remaining tooth structure is the most effective parameter in the selection of proper restorations because it is considered significance in resisting the fracture of ETT.(7-10) The greatest preservation of remaining tooth structure showed higher fracture resistance and also increased the survival rates of endodontically treated teeth.(7, 11-14) Among posterior teeth, the highest rate of clinical fractures was in maxillary premolars due to unfavorable anatomic shape, making them more susceptible to cusp fracture.(15, 16) In addition to the tooth structure lost during endodontic treatment, non-carious wedge-shaped cervical lesions are another factor reported to occur significantly in premolars, further

weakening tooth strength.(17-20) The association of these factors probably makes

premolar teeth more susceptible to fracture.(19)

Today, different principles and materials can be used to restore endodontically

treated teeth, from conservative alternative to progressive approaches. As a

conservative concept for endodontic preparation restricted to endodontic access, direct

composites can be used as definitive restorations to avoid further tooth preparation,

which weakens tooth strength.(8, 10, 14, 21, 22) *In vitro*, a high fracture resistance of

ETT restored with resin composite has been reported.(23, 24) However, as a protective

concept, posterior ETT should receive a cuspal-coverage crown restoration to protect

the teeth from fracture. Several studies have reported that cuspal-coverage restorations

significantly improved the success rate and longevity of endodontically treated posterior

teeth.(4, 6, 10, 14) Additionally, posts are another option being used to restore ETT.

Posts are normally used only to retain the core material of ETT, but they do not reinforce

the root.(4) Moreover, post space preparation can damage residual tooth structure,

causing the root to weaken and the mechanical resistance of treated teeth to be

decreased. However, several studies reported that posts increased the fracture

resistance of endodontically treated teeth.(25) Fiber posts have been suggested as an

alternative to metal posts because they have a modulus of elasticity similar to root dentin

which improves stress distribution and avoids force concentration at the post-dentin

interface.(26-28) One clinical study indicated significantly greater clinical success for

premolars restored with posts compared with teeth that had been restored without posts.(27) However, laboratory studies did not show significantly increased fracture resistance for molars and premolars restored with fiber posts. (12)

Although endodontically treated teeth have been extensively studied, the choice of an optimal restorative method (conservative or protective approach) and material to restore non-vital teeth remains controversial. Based on the author's literature review, there are no publications on the association between endodontically treated premolars and deep cervical lesions. Thus, the purposes of this study were to measure the different modes of restoration after endodontic procedures with deep cervical lesions to assess the resistance to fracture of these teeth under simulated occlusal load.

Research Objectives

The purpose of this study is to measure the different modes of restoration after

endodontic procedures with deep cervical lesions to assess the resistance to fracture

and mode of failure of these teeth under simulated occlusal load.

Hypotheses

The null hypotheses were that the restorations and fiber post have no effect on the

fracture resistance of restored endodontically treated maxillary premolars and no effect

on fracture modes.

Keywords

Fracture load, onlay, CAD/CAM, fiber post

Conceptual framework

Population: 40 Human maxillary premolars

Intervention: Four types of restorations: direct composite filling without fiber post, CAD/CAM onlay without fiber post, direct composite filling with fiber post, CAD/CAM full-coverage crown with fiber post

Outcome measurement: Record the loading force from universal testing machine that appear as a result of specimen fracture and classify fracture mode by evaluate fracture location
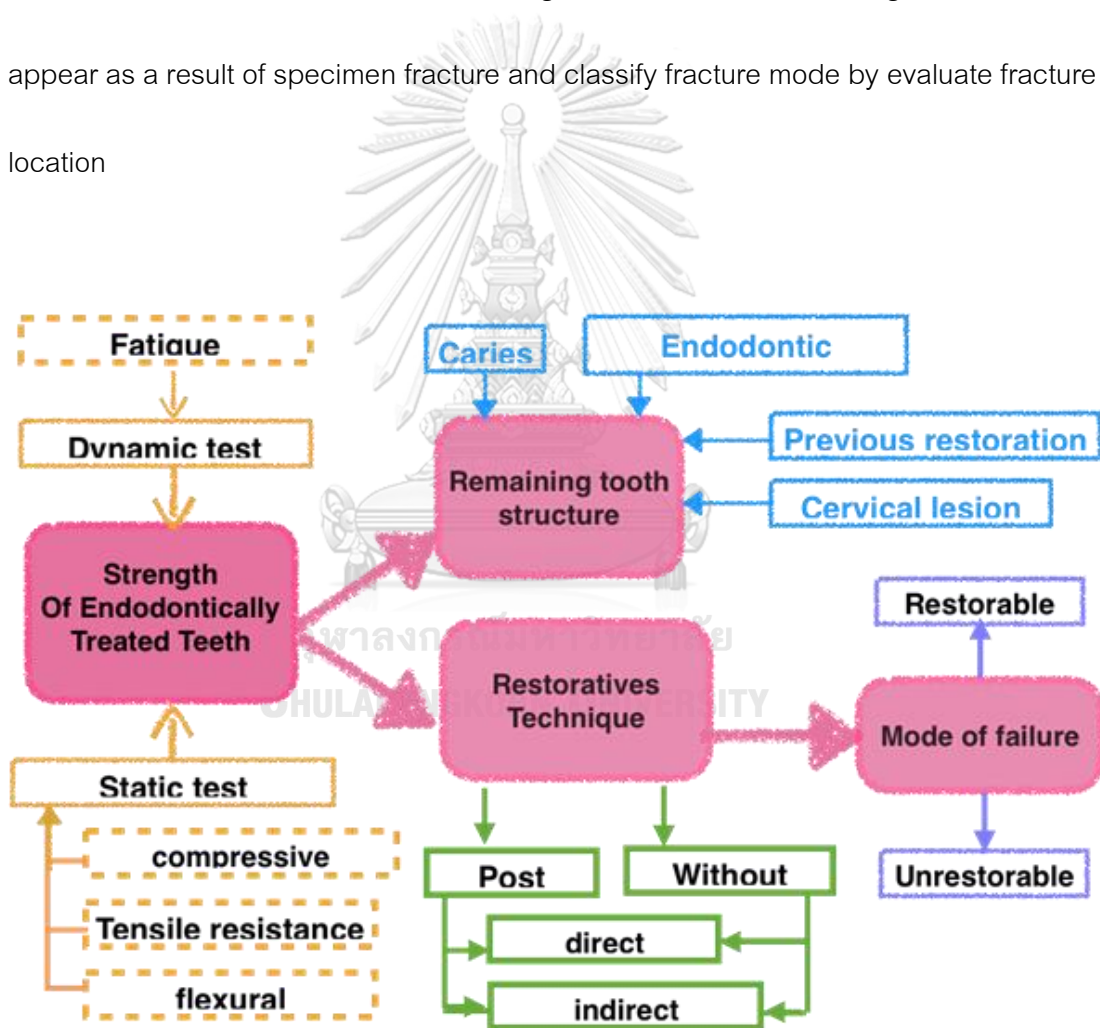

Figure 1 conceptual framework

Expected Benefit from the study

The results from this study will assist clinician to make a decision of which restoration

should be used after root canal treatment in deep cervical lesion teeth or even be the

background for a further clinical study in the same field of interest. Besides, enhance the

ability to restore an endodontically treated tooth to its original strength without

placement a full coverage crown restoration which provided periodontal and economic

benefits to patients.

Limitations

1. There are differences in each tooth size which could not be controlled due to

    natural variations in tooth morphology. However, the randomized process will

    reduce systemic bias.

2. One brand of post (D. T. Light post) and ceramic system (IPS e-max CAD) will

    be chosen to represent the conventional fiber post and lithium disilicate

    ceramics, so the results from this study may not be able to imply with other

    brands and other types of materials.

CHAPTER II

REVIEW OF LITERATURES

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Load type

Load application

Load speed

Load intensity

Angle of load application

Non-carious cervical lesions

        The term non-carious cervical lesion (NCCL) are defined as the loss of tooth

substance at the cemento-enamel junction.(29) Later, Grippo et al. classified NCCL into

four types of tooth wear. First, attrition is the wear away of tooth as a result of tooth to

tooth contact during mastication. Second, abrasion is tooth wear from biomechanical

frictional processes for example tooth brushing. Third, erosion is the loss of tooth

substance by acid dissolution of either an intrinsic or extrinsic origin. Finally, abfraction

is the pathologic loss of tooth substance caused by biomechanical loading forces.

These lesions were caused by flexure of the tooth during loading leading to fatigue of

the enamel and dentine at a location away from the point of loading.(30) Several studies

reported the prevalence of cervical lesion were found most frequently at buccal surface

of maxillary teeth. The prevalence and severity of lesions have been also related to

age.(18, 31) From Tomasik et al. study, they evaluated frequency of cervical lesions with

pulp exposure. The study was done in 124 patients, found that very deep defects with

pulp exposure were found in 44 teeth. This study also confirmed the relationship

between occlusal pathology and cervical lesions.(32) Supporting by Levitch et al. study

that also found an incidence of NCCL that involved pulp tissue.(31)

Abfraction

The word "abfraction" was derived from the Latin "to break away".(30) Theses lesions

have multifactorial etiology combining of occlusal stress, abrasion and erosion.(33, 34)

The primary factor that initiates these lesions is tensile stress caused by mastication and

malocclusion after that oral habit plays a secondary role in dissolution of the tooth

structure to create the lesion.(18, 34) The process starts from excessive forces

occurred, the tensile stresses transferred to cervical fulcrum area during bending

resulting in disruption of the enamel crystalline structures and underlying dentin leading

to cracks, chips and rupture. As a result, the disrupted tooth structure is more

susceptible to loss through dissolution, acid and abrasion then results in the

development of the typically wedge-shaped lesions. Moreover, this process continues

repeatedly over times making the lesion broader if it left untreated.(34, 35) Dental

structure loss from cervical lesion was assumed to reduce the resistance of tooth and

increasing the possibility of fracture.(19) In addition, the formation of a cervical wedge-

shaped lesion also adversely affects the dental biomechanical behavior leading to an

alteration in stress and strain distribution pattern when the tooth is loaded.(36) There

was a study confirmed that tooth structure loss at cervical area increase the stress

concentration at center of NCCLs by Soares et al. (19) The key characteristics to

diagnose abfraction are the lesion would be a wedge-shaped morphology with sharp

line angles frequents at subgingival location, mostly involving a single tooth, presence of

lateral occlusal force during mastication or parafunctional movements, loss of anterior guidance and the misorientation of the tooth's long axis in relation to occlusal forces. The size of the lesion would be directly related to the magnitude and frequency of the force.(34, 35, 37) The lesions found more severely affected in maxillary teeth and first premolars were the worst affected teeth. (18, 38) Restoration with resin composite with an appropriate modulus of elasticity with dentine adhesive system can be an effective and non-destructive means of restoring these lesions by prevent further stress concentration which may lead to pulpal exposure or fracture.(18, 19, 35)

Endodontically treated tooth

Canal configuration

The canal configuration can be classified in many systems. The first categories of root canal configurations presented by Weine *et al*. in 1969 into four types.(39) Later in 1984, Vertucci classified the canal configuration into eight types, which is more delicate and most commonly use as follow:(40, 41)

Type I : A single canal from the pulp chamber to apex.

Type II : Two canals separate from pulp chamber and join to form one canal to apex.

TypeIII : A single canal from pulp chamber and separate to form two canal at the middle of the root, and merge into one canal at the apex.

Type IV : Two canal separate from the pulp chamber to apex.

Type V : A single canal from pulp chamber and divides into two separate canals to

apex.

Type VI : Two canals separate from pulp chamber and join to form one canal at the

middle of the root, and divides into two separate canals to apex.

Type VII : A single canal from pulp chamber and divides into two separate canals, and

join canal before separate into two short canal again at the apex.

Type VIII : Three canal separate from the pulp chamber to apex.

 Although many studies from different nationalities found single root form was most

common in maxillary first premolar. (41-43) Recent study found most prevalent root

canal frequency was the two roots with two canals.(44, 45) Canal configuration type IV

tend to be most prevalent.(41-43)Over the years, many results found the canal

configuration varies from Vertucci's classification such as Gulabivala K et al., Sert S and

Bayirli GS., Peiris H et al., and Al-Qudah AA.(46-49)All classification had their

advantages and limitations. Therefore, new classifications were established by few

researchers to create a simple, accurate and practical system to identified. Ahmed

H.M.A. in 2016 created a system include tooth number, the number of roots, and the

root canal configuration.(49) Rashmi Bansal et al. in 2018 included a nomenclature of

tooth, the characteristic of tooth type, anatomic variations, and number of roots and

course of canal in each root.(50)There are various techniques to investigate the root

canal morphology such as tooth decalcification and dye injection, sectioning of the teeth

and radiographic studies *in vitro,*(51) alternative radiographic techniques,(52) and

radiographic assessment enhanced with contrast media.(53) The significance of canal

configuration studies in the maxillary first premolar is to acknowledge the complication

and difficulty of endodontic treatment. Variation in root canal anatomy is common and it

is important for successful endodontic treatment.(41) Maxillary first premolar is

considered to be the most difficult teeth to be treated endodontically from this following

factors; variation of roots, canal configuration, the direction and longitudinal depressions

of the roots and various pulp cavity configuration.(54) Study of root canal anatomy

could dictate the location of the initial entry of access and the size of the first files used

which help dentists diagnose precisely and also reduce error of endodontic

treatment.(42, 55) In the study of Vertucci and Gupta found that maxillary first premolar

was the only tooth that found all eight types of root canal configuration.(41, 55)

Cause of weakness of endodontically treated teeth

Some previous classic studies believed that dentine in endodontically treated teeth is

dramatically different from dentine in normal teeth because it was more brittle resulting

from water and collagen loss. Helfer et al. showed endodontically treated teeth

contained 9% less moisture compared to vital teeth. (56) Later, several studies

established evidence contrast to primary study. Huang et al. compared the physical and

mechanical properties of dentine specimens from teeth with and without endodontic

treatment. They concluded that both dehydration and endodontic treatment can cause

degradation of the physical or mechanical properties of dentine. (57) The tooth strength

is reduced in proportion to coronal dental structure lost resulting from either carious

lesions or restorative procedures. There is a direct relationship between the amount of

remaining tooth structure and the ability to resist occlusal forces mentioned in next

topic.(9)

In addition, not only extensive coronal dentine removal but also endodontic procedure

such as instrumentation of the root canal, irrigation of the canal with sodium

hypochlorite, obturation, post space preparation and final coronal restoration which lead

to a loss of tooth structure or may weaken the dentine. (58, 59)

Fracture rate are higher in endodontically-treated posterior teeth. There was a

report claimed that nearly one third of endodontically-treated maxillary premolars have

been fractured within the first 3 years.(60) Moreover, Fennis et al. showed more than

46,000 patients reported fractures in root canal treatment teeth and concluded a

positive correlation between history of endodontic treatment and subgingival fracture

location.(61)

Effect of remaining tooth structure on fracture resistance

Sound teeth hardly have been fractured under normal function. For endodontically

treated teeth, the amount of coronal dentine removal directly increase the potential of

fracture. (9) Therefore many studies have highlighted the essential of preserving

remaining coronal tooth structure to maintain the strength of the tooth. (9, 11, 13, 15)

There is study on endodontically treated premolars with only access preparation at

occlusal surface with intact marginal ridges showed similar compressive fracture

strength to an intact tooth. (22) Similarity to previous study by Reeh et al. revealed that

the loss of the marginal ridge integrity resulting in the dramatic loss of stiffness by

showing only 5% decrease in stiffness among premolars when only endodontic access

preparation. On the contrary, endodontic access cavity preparation with occlusal and

MOD preparation decreased tooth stiffness by 20% and 63% respectively (1) Also,

these findings are supported by a study performed by Caplan that teeth with two

proximal ridges were three times less strength than teeth loss one or no proximal

contact. (62) Nissan et al. evaluated fracture resistance of endodontically treated

maxillary first premolars by varying degrees of remaining coronal structure and found

that remaining coronal structure was the major factor that influenced the fracture

resistance. (13) Radicular dentine tissue (RDT) after post preparation is also considered

as an important factor because excessive removal of radicular dentine would

compromise the root. There is a direct relationship exists between the RDT and the

strength of the root.(63)

Cuspal deflection

The restorative and endodontic procedures can extent of cuspal flexure and has

consequences for fracture.(64) Nowadays, composite material has been used widely.

The main problem of this material is the polymerization shrinkage during curing as a

result found tooth structure and wall of cavity had an internal stress and deformation.(65,

66) This stress can lead bond failure, cuspal deflection, enamel microcracking, pulpal

irritation, secondary caries and postoperative sensitivity.(67) Cusp deflection is

movement of the cusp tips from polymerization shrinkage of the composite interact with

elastic deformation of the cavity wall.(68) With a masticatory load, the isthmus of the

preparation weakens the tooth.(69) It showed 10-45 μm of deflection depended on

measuring method and instrument, type of tooth and size of cavity.(70) There was a

study in premolars of direct and indirect MOD restorations compared to intact teeth and

unrestored teeth with an inlay preparation. This study revealed the same result between

both direct and indirect (with composite and lithium disilicate) restoration and sound

teeth. Therefore, the restoration decrease the cuspal deflection, and improve the cuspal

reinforcement than the unrestored teeth.(71) Same results were found in study by

Jensen et al and Cötert et al stated that both direct composite and indirect ceramic

restorations had resistance similar to intact teeth.(72, 73) When compare the teeth

restored with amalgam and composite, the results showed amalgam has 17% of cuspal

deflection while composite resin has 54 to 99%.(74) Indirect restorations have better

physical properties than direct composite restorations because they are well fabricated

under control condition in laboratory.(75) Ceramic inlays show biological compatibility,

adequate compressive strength, similar thermal conductivity to dental tissues, marginal

integrity, color stability and a resistance to fracture similar to other types of restorative

materials when used in MOD inlay restorations.(72) Furthermore, Zamboni et al. stated

that the adhesive is one of the crucial factor that affected to the cusp reinforcement

between inlay restorations and tooth.(71) In endodontically treated tooth, if marginal

ridges and dentin above the pulp chamber were removed it will increasing occlusal

loads, or deeper cavity preparation which can related to a higher cuspal deflection.(76-

78) The endodontic access increased cusp deflections 10 μm.(79) The study found that

glass ionomer significantly reduced tooth strain and marginal leakage. Therefore, a

placement of a glass ionomer base are recommended if endodontically treated teeth

directly restore with resin composite.(78) Temporary filling played an important role of

causing hygroscopic expansion and cuspal reflection while root canal treatment was in

process. It can leads to cusp fracture so Eskandarizadeh et al. recommended to use

temporary material in short time.(80) However, clinical longevity of endodontically

treated posterior teeth especially molars and bicuspids is significantly improved with

coronal coverage. (4, 6, 14, 79) There are a relation between the type of coronal

reconstruction and the survival rate of endodontically treated teeth. Teeth without full cusp coverage had 5 or 6 times of failure than fully restoration teeth.(3, 6, 81, 82) Sorensen and Martinoff (4) further investigated the survival rate according to the group of teeth and found that the rate of clinical success was significantly improved with coronal coverage of posterior teeth but not for anterior. In conclusion, the key factor of success is proper select the best technique and material to support remaining tooth structure for optimum strength and suitable for functional demands.

Success and failure of endodontically treated tooth

Endodontic treatment reported success rates up to 86–98% (83) and an initial non-surgical endodontic treatment are estimates as 97% .(81) An successful endodontically treated tooth should be frequent follow up clinically and radiographically after treatment.(84) The criteria that describe success of endodontically treated tooth are 1)The treated tooth is asymptomatic and functional. 2) Soft tissue appears normal and responds normally to manual examination. 3) Radiograph reveals a normal lamina Dura.(85) Failure of endodontically treated teeth can be presented with dental pain and lead to tooth extraction. The teeth that failed most frequently were mandibular first molars (86-88)and the teeth that failed least frequently were maxillary third molars.(86)

Vire et al. divided failures after root canal treatment base on etiology into three types; unrestorable tooth fractures, periodontal problems and endodontic failures. These

researchers also found that 59% of failure were prosthetic failure which related with

improper final restoration.(3) Failure of posterior endodontically treated teeth without

cusp coverage has been reported.(4) The evidence showed 6 times greater rate of

failure of uncrown tooth than crown restoration of endodontically treated tooth.(6) The

extraction of teeth without full cuspal coverage were explained as loss of tooth

structure.(1) Teeth with crown restoration had better success outcome of longevity more

than uncrown teeth because crown enhance the resistance of posterior teeth to

fracture.(3, 4) Some studies showed that the most common reason for the extraction was

from prosthetic reasons. (3, 86, 89)In contrast, a prospective study of Touré in 2011

revealed periodontal disease was the most factor for extraction but 94% of extracted

teeth had restoration without full cuspal coverage, followed by endodontic failure, and

nonrestorable tooth damage caused by fracture or caries.(87) During endodontic

treatment, many factors can initiated a failure, for example, persistence of intra and

extra-canal bacteria (intra-canal and extra-canal), inadequate filling of the canal,

overextensions of root filling materials, leakage from improper coronal seal (leakage),

untreated canals (both major and accessory), iatrogenic procedural errors,

complications of instrumentation.(84) The failure of true endodontic origin is less

frequent but occurs faster than other problem.(3)

There are many factors described success and failure other than main factors;

gender, education, smoking status, as well as tooth type and coronal restoration are

indicated for extraction procedure.(88) On the contrary, gender, educational level, or

smoking status did not show any differences when compared with reasons for extraction

in Touré's study.(87) Age of patient is one factor of success in endodontic treatment.

Younger group patient had failure rate more than elderly because in young patient has

large-diameter canals and older patient has the tighter apical foramina, lack of

completely patent auxiliary canals and dense periapical bone in older teeth.(90)

Restorative techniques for endodontically treated tooth

A successful clinical outcome for endodontically-treated teeth depends not only

on a successful root canal treatment but also subsequent restorative treatment.(91)

Therefore, researcher has been focused on finding the optimal post and core

system,(92) luting agent(93)and crown type.(94) Ray et al. established the relationship

between the quality of the coronal restoration and root canal filling by examining

radiographs of endodontically-treated teeth. They observed a combination of proper

restorations and good endodontic treatments resulting in absence of periapical

inflammation in 91.4% of the teeth, whereas poor restorations and poor endodontic

treatments resulted in periradicular inflammation in 82.9% of the teeth they studied. (95)

Several studies advocated different effective coronal reinforcement of tooth structure

with bonded restorations in order to increase fracture resistance

.

Post Placement

The primary purpose of post placement is to retain a core in a tooth with extensive loss

of coronal tooth structure in order to support final restoration.(8, 96-98) Some studies

believe that post does not increase fracture resistance of restored teeth and also

weaken tooth strength in some degree from removal radicular structure for post space

preparation.(97) Placing post to reach its purpose, several contributing factors should

be considered: post diameter; post length; canal configuration and post material. Post

and core selection should be based on the maximum of tooth structure could be

preserved.(13) The placement of posts may increase the chances of root fracture and

lead to treatment failure.(99) For reason mention earlier, post was used restrictively only

when core retention are required.(28) Endodontic posts have been classified according

to fabrication into major two groups: custom-made cast post and cores (laboratory-

fabricated) and prefabricated post and cores for direct-placement. The disadvantage of

the cast post and core is its rigidity tend to increase chance of root fracture. The ideal

post and core material should have modulus of elasticity and coefficient of thermal

expansion similar to dentin. Also, the material should bond easily and firmly to dentin to

preserve radicular dentin removal so that the entire unit of a post and core resembles

the original tooth. Introducing fiber-reinforced post which are fabricated to bond with

most resin cements and resin-based composite core materials. From these benefits,

fiber posts tend to decrease occurrence of root fracture.(2, 96) Many studies confirmed

that failure when endodontically treated teeth restored with fiber post teeth are more

likely to be restorable such as displacement or detachment.(2, 100) In addition, fiber

posts can be removed and replaced easily without the risk of perforating the root.(25) In

2015, Parasi et al. conducted a retrospective study that evaluated clinical outcome of

fiber post, the results showed no root fracture were found and the success rate were

85% in average 6 years after post placement. The most failure was post debonding and

after restored again found that overall survival rate were 98%.(101)

Resin Composite restoration

In recent years, there is an increasing trend toward minimal intervention dentistry.

Physical properties of composite resin have been improved and the introduction of

adhesive systems have offered new potential for the restoration of endodontically

treated teeth. Also, resin composites with good bonding ability transmit and distribute

functional stresses and hold the potential to reinforce weakened tooth structure. Oliveira

et al. concluded that the most important factor influencing the strength of endodontic

treated teeth especially premolars was the amount of remaining tooth structure. When

tooth is not experienced to fracture or dramatic damage, simple restoration like resin

composite is sufficient to restore an endodontic access. Supporting by Reeh et al.

evaluated the potential for alternative restorative techniques with non-vital teeth. The

results showed that composite restorations with adhesives had relative mechanical properties close to sound tooth.(77) Likewise, Steele et al. study found that fracture resistance in endodontically treated premolars with canal access only is similar to natural teeth so direct composites restoration associated to bonding agents may succeed when no other structural loss.(22) These materials have been preferred instead of very rigid materials such as full-coverage ceramics crown when restoring non-vital teeth with no extensive loss of structure.(21, 102) The major advantage of resin composite is the ability to bond to tooth structure and fiber posts so it can be the component that was allowed ceramic crown bonded.(28) On the contrary, resin composite showed its disadvantage from shrinkage during polymerization causing gap formation and also undergoes plastic deformation under repeated loads due to water absorption.(103) When there is adequate dentin, resin composite restorations showed better clinical performance in preventing tooth fractures in endodontically treated teeth than amalgam restorations.(60)

Ceramic onlay

Indirect full coverage restorations have some disadvantages including: the high cost of the laboratory procedure; the significant amount of sound tooth structure that has to be removed and the considerable treatment time spent on such complex

restorations.(104) Partial coverage restorations conserve more tooth structure than a

complete coverage restoration. Only few studies have been published addressing the

advantages and disadvantages of partial coverage restorations for teeth. There are

several studies compared the differences in the amount of tooth structure removal of

partial restoration in comparison with conventional complete coverage restorations.

Edelhoff et al. showed that preparation for onlay could decrease 67.5–72.3% tooth loss

resulting from conventional crown preparation to only 5.5–27.2% when onlay preparation

were performed.(105) The greater remaining tooth structure remain, the more strength

he endodontically treated teeth occupied. (1, 6, 7, 16, 106) In addition, placing margin

supragingivally for onlay avoid periodontal irritation, gingival inflammation and easily

detected margin.(107, 108) According to Aquilino and colleagues in 2002 stated that

other forms of coronal coverage, such as gold, ceramic or resin composite onlays could

provide RCT teeth with protection against fracture compared to full coverage crown.(6)

Moreover, several studies support that endodontically treated maxillary premolars

should restore with cuspal coverage restorations to protect and reduce the risk of

fracture. (6, 7, 10) When fracture occur, cuspal coverage were considered to avoid

vertical fracture at the cemento-enamel junction especially when teeth experienced

lateral forces because fractures in cuspal coverage mostly occurred within the

restorative materials.(109, 110) Currently, evidence for the relative effectiveness of

conventional fillings over crowns for the restoration of root canal treated-teeth is

inconclusive. Until more clinical data available clinicians will base their decisions on their own clinical experience, taking into consideration the individual circumstances and preferences of their patients.

Ceramic crown

There is a strong conclusion from available data that cuspal coverage restorations should be final restoration for posterior root-canal treated teeth especially when the cusps have been weakened.(28, 111) Cuspal coverage with bonded resin composite, amalgam, cast metal alloy, or high-strength ceramic materials is essential to prevent tooth fractures. An *in vitro* study by Panitvisai and Messer(64) showed that access preparations result in greater cuspal flexure, increasing the probability of cuspal fracture. A systematic review 150 of single restorations in endodontically-treated teeth reported that the estimated survivals were 81% for crowned teeth and 63% for direct restorations (resin composites, amalgams, cements) at 10 years. Aquilino and Caplan(6) found a strong association between crown placement and the survival of endodontically-treated teeth. They reported that root-filled teeth without crowns were lost at a six times greater rate than teeth with crowns. They suggested cusp coverage to restore the fracture resistance because they protect cusps from the outward deflection. Smales and Hawthorne(112) reported lower 15-year survival rates for complex cusp-covering

amalgam restorations (48%) compared to crowns (89%). One of the most often cited

series of studies on endodontically-treated teeth by Sorensen and Martinoff1(4, 99)

evaluated the effect of tooth location, coronal coverage, and intracoronal reinforcement

on the success of 1273 root-canal treated teeth over an observation period of 1 to 25

years. The results indicated that crown placement had no significant effect on the

success of anterior teeth but significantly improved the clinical success rates of

posterior teeth. This was in agreement with another independent, retrospective study of

608 endodontically-treated teeth that evaluated the factors affecting their survival during

a 10-year period.(113)
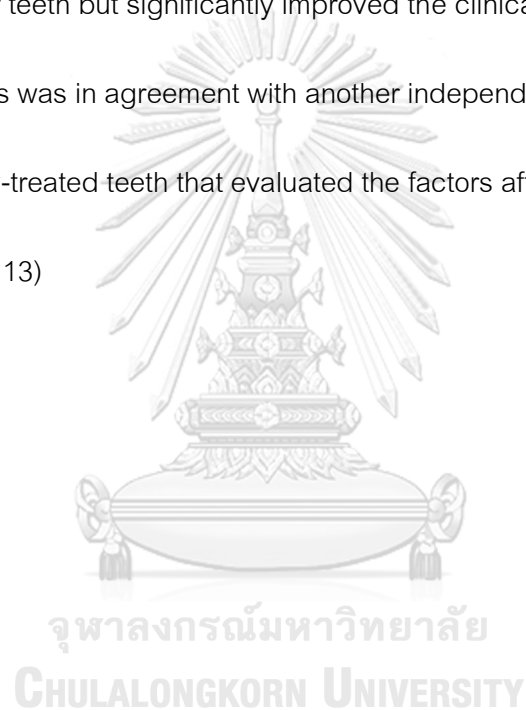
Digital technology

CAD/CAM

CAD/CAM systems are composed of three components: a scanner, software that

processes the data for fabrication of a restoration and milling machine. The first two

parts of the system were called CAD phase while the third were the CAM phase.(114)

The overall process started from Omnicam record video with natural color from the

patient's intraoral with a scanner and saved data as STL file then software began

converting the data to milling machine to mill restoration.(115)

CEREC System

The CEREC 1 System by Sirona was introduced in year 1987. Currently the most

predominant CEREC system is CEREC OmniCam which marketed in 2012. The

Omnicam imaging technology is a continuous imaging mode with powder-free

scanning. The advantages of powder-free is easier for large working area such as

quadrant or entire arch. Moreover, it provides precise 3D images with natural

color.(116)The camera tip should be held a few millimeters away from the tooth surface

or should slightly touch the surface. After scanning, the preparation is projected on the

monitor and analyzed in different views then biogeneric suggests an ideal restoration

design. After that dentist approves the restoration then inserts a block in milling

machine. (117)

e.max CAD

In 2006, A monolithic lithium disilicate CAD/CAM ceramic e.max CAD (Ivoclar Vivadent) was launched in market with their flexure strength at 350-450 MPa which are three times greater than leucite-reinforced dental ceramics.(118) These blocks are fabricated in pre-crystallized blue state with A–D and bleach in 3 degree of translucencies available. The blue ceramic has a flexural strength of average 130 MPa but after milling, re-crystallization takes place under ceramic oven for 20–25 min. After this process the block changes its color to the chosen shade and translucency and strength increases dramatically to 360 MPa.(119) e.max CAD is recommended for inlays, onlays, veneers, anterior and posterior crowns, implant supported crowns and anterior bridges.(120) There are several studies showed short-term clinical trials for this material using as single crowns and demonstrated survival rates between 97.4% 115 and 100%. (121-123)

Compressive fracture resistance test

Loading conditions used to investigate fracture resistance of endodontically treated

teeth, there are many features should be reviewed as following.

Load type

There are two options which are static and dynamic loads that could be applied for

testing fracture resistance of endodontically treated teeth. Static forces are used to

evaluate mechanical properties of a material such as toughness, stiffness or static

strength whereas dynamic forces are used to evaluate mechanical properties during

function over time. Advantages of static test are easier to use, less time consuming and

less expensive. (12)

Load application area

Load application are related to tooth anatomy and type of tooth. The direction of loads

used in testing premolar teeth varies in reported studies and includes being applied to:

the triangular ridge of the functional cusp, supporting cusp or to the center of the

occlusal surface in contact with both cusp inclines parallel to the long axis of the tooth.

(12, 124) From previous studies when the fracture resistance of endodontically treated

maxillaray premolars were examined, the load from the center of occlusal surface has

been achieved as the best load simulation of occlusion.(12, 14, 124, 125) Hannig et al.

suggested the importance of applying loads in unaltered areas of teeth not

tooth/restoration interface to achieve reliable results and to avoid the influence of other

factors. (125)

Load speed

Speed of load application should simulate oral condition during functions. Most studies

are performed with crosshead speed ranging from 0.5 to 2 mm/min which considered as

optimal speed.(124, 125)With high crosshead speed, it would be difficult to generate

homogeneous stress for both tooth tissues and restorative materials whereas low speed

would not be representative of the oral functions.(12)

Load intensity

In static load applications, teeth have always been loaded from 0 Newtons until fracture

occurred in order to record the maximum fracture resistance data. On the contrary, in

dynamic tests a proper load has been chosen based on material. (12, 124, 125)

Angle of load application

According to teeth anatomy and location, each tooth is subjected to different loading

condition due to their specific function. As a consequence, posterior teeth have to

withstand vertical forces in term of masticatory forces whereas anterior teeth are

responsible for non-axial forces. (14) It has been well documented that fracture

resistance of teeth depends on the angle of applied load and axial forces are less

detrimental compared to non-axial load. Direction of loads is an important factor to the

longevity of endodontically treated teeth. Reviewing the literature, experimental load

angulation remains a controversial subject. When load was applied directly to the cusps,

it may lead to mechanical failure of adhesive restorative systems.(14) Moreover, natural

variations in tooth morphology may affect the long-term success of restorations. Different

kind of forces could be applied to assess fracture resistance such as compression,

shear and tension. However, by using static load, resistance to fracture have usually

been performed with compressive tests till fractures occurred. When anterior teeth are

tested such as maxillary incisors, the load have been usually placed at 130° to the

longitudinal axis of teeth which described as a simulation of incisor guidance. On the

contrary, when posterior teeth are investigated, forces usually placed either at

supporting cusps in angulation ranging between 130°-150° to the longitudinal axis or

applied loads parallel perpendicular to cusp slopes. Many authors applied loads

parallel to teeth longitudinal axes in order to distribute the stresses more evenly between

the residual dental tissues and the restorative material simulating a physiological

occlusion. Also it was claimed that fractures occurred from teeth itself and avoided the

influence from restorative material.(12, 94, 124, 125)

CHAPTER III

MATERIALS AND METHOD

Research Design

The experimental study will be carried out as a randomized controlled trial.

Interventions of this study are type of restorations. Dependent variable is load to crack

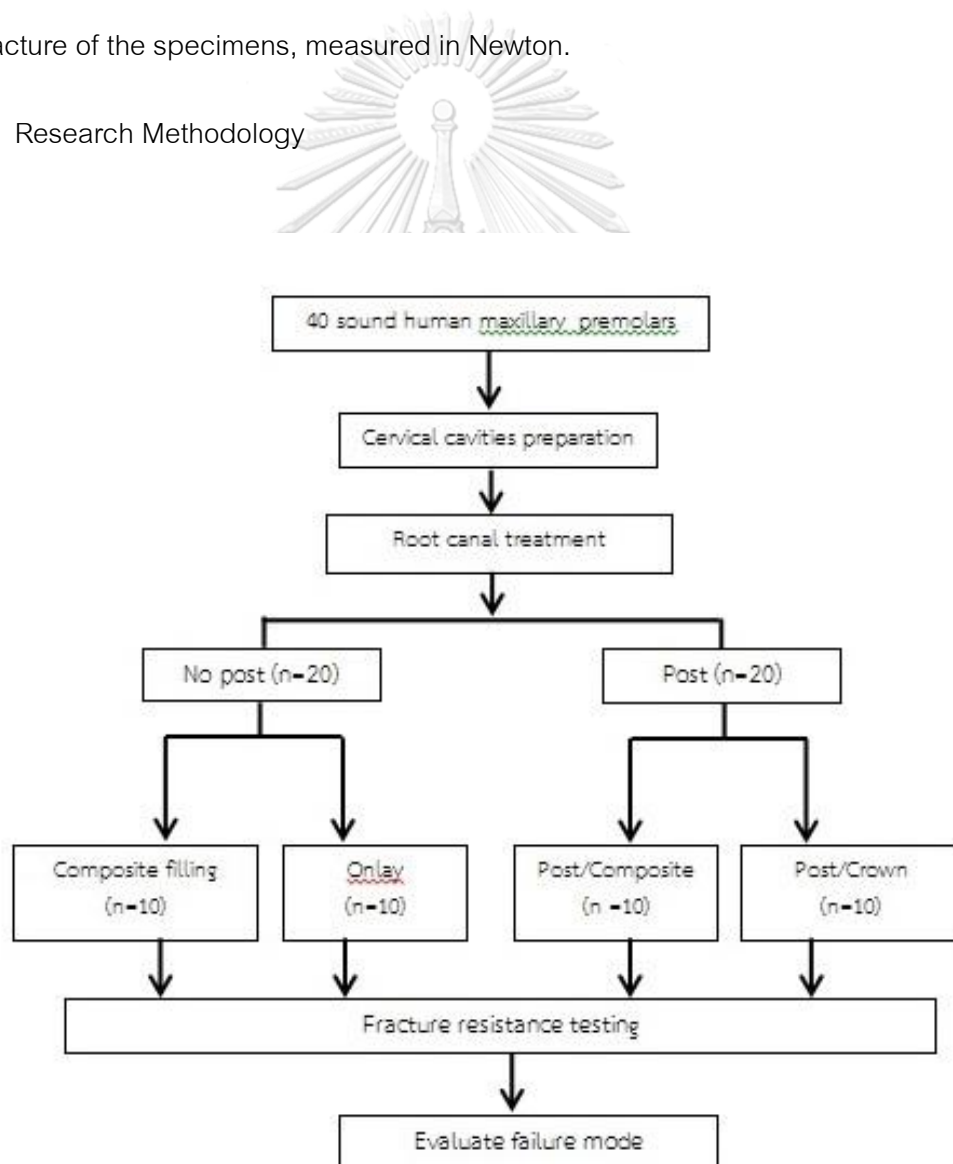or fracture of the specimens, measured in Newton.

Research Methodology

Figure 2 Research Methodology

Dental Materials

Table 1 Materials used in the study

Materials	Manufacturer
ProTaper Next	Dentsply Maillefer, Ballaigues, Switzerland
K-Flex file	Kerr Sybron, Romulus, MI, USA
AH Plus	Dentsply, DeTrey, Konstanz, Germany
D.T. Light-Post	Bisco Inc., Schaumburg, IL, USA
Panavia SA Cement Plus	Kuraray, New York, USA
IPS e.max CAD block A1 LT	Ivoclar Vivadent, Schann, Liechtenstein
Premise, syringe type A2	Kerr, Orange, CA
NX3 Nexus(clear) 3rd Generation	Kerr, Orange, CA
Gel Etchant : 37.5% $H_3(PO)_4$	Kerr, Orange, CA
OptiBond FL Primer and Adhesive	Kerr, Orange, CA
OptiBond Solo Plus	Kerr, Orange, CA
Silane Primer	Kerr, Orange, CA
9.5 % HF Porcelain etchant	Bisco,Schaumburg, IL, USA)

Table 2 Equipments used in the study

Equipment	Manufacturer
Periodontal probe 23/UNC 15	Hu Friedy, Chicago, IL, USA
Cerec AC Omnicam	Sirona Dental Systems GmbH
Cerec 4 CAD/CAM system	Sirona Dental Systems GmbH
Vernier caliper	Hu-Friedy CLP1, Frankfurt am Main, Germany
Ceramic fernance : Programat P700	Ivoclar Vivadent, Schann, Liechtenstein
Universal Testing Machine (Instron model 5566)	Instron, Canton, MA
DemiPlus (LED light Curing Unit)	Kerr, Orange, CA

จุฬาลงกรณ์มหาวิทยาลัย

Tooth preparation and root canal filling CHULALONGKORN UNIVERSITY

The study used forty human two-rooted maxillary first premolars with straight canals

extracted for orthodontic reasons and stored at 37°C in a solution of 0.1 % Thymol. The

time from extraction to the mechanical testing of teeth was less than 6 months. Inclusion

criteria were: sound teeth with a bifurcated canal at the middle third of the root; no sign

of cracks, defects, and caries on visual examination under 2.8x magnifying loupes, with

fully developed apices and complete root length. The average lengths of teeth used in

this study were 22±1 mm, with bucco-lingual coronal dimensions of 9±1 mm and mesial-

distal coronal dimensions of 7±1 mm, measured by means of a caliper at the labial

midpoint of the cemento-enamel junction (CEJ) level. Initial preparation of the teeth

involved the removal of any superficial staining, calculus, and adhering soft tissue with

an ultrasonic scaler. The specimens were assigned to four groups (n=10) (*Figure 1*) as

follows: COM-NP, ETT with cervical cavity restored with resin composite without post;

ON-NP, ETT with cervical cavity restored with ceramic onlay without post; COM-P, ETT

with cervical cavity restored with resin composite and fiber post; and CR-P, ETT with

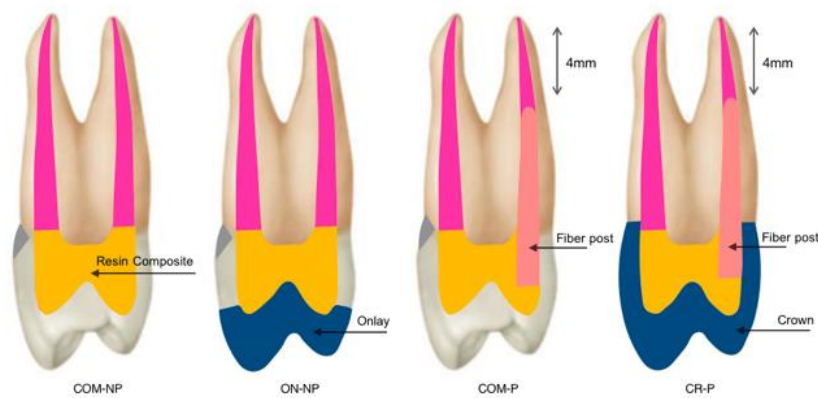cervical cavity restored with full-coverage crown and fiber post.

Figure 3 The division of specimens into groups

COM-NP, ETT with cervical cavity restored with resin composite without post; ON-NP, ETT with cervical cavity

restored with ceramic onlay without post; COM-P, ETT with cervical cavity restored with resin composite and fiber

post; and CR-P, ETT with cervical cavity restored with full-coverage crown and fiber post.

Cavity preparation mimicked cervical lesions that were wedge-shaped with divergent walls located in enamel (occlusal margin) and cementum (cervical margin). The cavities were prepared by means of a cylinder diamond bur (835 023 Intensiv, Grancia, Switzerland) at 45° to the buccal surface to create wedge-shaped lesions at the CEJ until a bur depth of 2.0 mm was reached as an outline forming and creating a sharp internal line angle of 90°. For standardization, preparation dimensions were finalized again in all specimens: 2.5 mm deep, 5 mm wide occluso-cervically, 4 mm long on the occlusal wall, and 3 mm long on the cervical wall. A periodontal probe was used to verify the depth (23/UNC 15, Hu Friedy, Chicago, IL, USA). After cavity preparation, teeth were etched with 37.5% phosphoric acid (Kerr, CA, U.S.A.), rinsed, Optibond FL Adhesive (Kerr, Orange, CA, USA) was applied and restored the cavities with resin composite (Premise, Kerr, Orange, CA, USA). Light-curing was performed with a LED light-curing unit for 20 seconds. (DemiPlus, Kerr Corporation, Middleton, WI, USA)

An endodontic access cavity was prepared in the center of the occlusal surface with a high-speed handpiece with a round diamond bur until the root canal orifices were identified. The access opening was oval on the occlusal surface and in the middle third of the tooth. Buccal and palatal cusps were not undermined during access opening preparation. After that use low-speed round steel bur to remove the residual of chamber roof. Using a non-end cutting high-speed diamond bur to finish and flare the cavity. The root canal length was determined by a #10 K-Flex file (Kerr Sybron, Romulus, MI) until

the tip of the file was visible at the apical foramen. Teeth with initial apical files (IAF) 20-25 were included in this study. The working length was established 1 mm short of the apex. The root canals were instrumented by means of K-Flex file and prepared up to X4 using ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland) to the working length. Each file was used with a brushing motion and a 3-mL of 2.5 % NaOCl was used to irrigate at each change of instrument. Each instrument was used to enlarge eight canals only. Apical patency was performed by a No.10 K-Flex file. Final irrigation was done by 1 mL of 17 % EDTA and 3 mL of distilled water and dried with 3 absorbent paperpoints for 3 seconds each (Dentsply, Maillefer, Ballaigues, Switzerland). After instrumentation, all canals were obturated by the lateral condensation technique with AH Plus (Dentsply, DeTrey, Konstanz, Germany). Digital x-rays confirmed the quality of canal obturation. The excess gutta percha was removed from the pulp chamber with a heated instrument, and the access cavities were wiped with alcohol. Endodontic access was etched with 37.5 % phosphoric acid for 15 seconds followed by adhesive preparation by Optibond FL and restored with resin composite (Premise) according to the manufacturer's instructions. Light-curing with a LED curing light for 20 seconds.

Post space preparation

Gutta percha was removed to prepare post spaces in the COM-P and CR-P groups at the palatal canal with a Largo drill No. 1 (Largo; Dentsply Maillefer, Ballaigus,

Switzerland) Post spaces were prepared with pre-shaping drills followed by D.T. drill No. 1 (D.T. Light-Post Double Taper; Bisco Inc., Schaumburg, IL, USA) to achieve a post space length with at 4 mm of gutta percha remaining in the apical third. Syringe irrigation was performed with distilled water (3 mL in 3 minutes), then 3 absorbent paperpoints were used for 3 seconds each. The prefabricated fiber post no.1 (DT Light Post Illusion X-RO, Bisco, Schaumburg, USA) was wiped with alcohol according to the manufacturer's recommendation.

Fiber post luting procedure

Before placing fiber posts, a digital x-ray was used to check the quality of post space preparation. Cavity and canal were etched with 37.5 % phosphoric acid 15 seconds, rinsed with water spray and dried with paper points. Subsequently, adhesive agent OptiBond Solo Plus was applied by disposable microbrush and immediately rubbed on all surfaces of root canal walls in the canal. The solvent was removed by air blown gently. The posts were prepared with the same adhesive agent and placed with a dual-cured resin cement (Panavia SA Cement Plus, Kuraray, New York, USA), seated in the root canals, and stabilized. Excess cement was removed with a brush. The cement was light-cured for 20 seconds from occlusal direction with the tip directly contact with the post. Each post was cut to an adequate length with a diamond rotary cutting instrument to cover its occlusal end with resin composite up to at least 2 mm. The resin composite

(Premise) was restored followed by light-curing with a LED curing light for 20 seconds. A

digital x-ray was taken to check the quality of post placement. Samples were inserted in

polyvinyl chloride (PVC) mold with 18 mm internal diameter, 22 mm external diameter

and 40 mm height. The molds were filled with auto polymerizing acrylic resin (Palapress;

Heraeus Kulzer GmbH, Hanau, Germany). Teeth were placed 3 mm up from

cementoenamel junction (CEJ). (*Figure 4*)
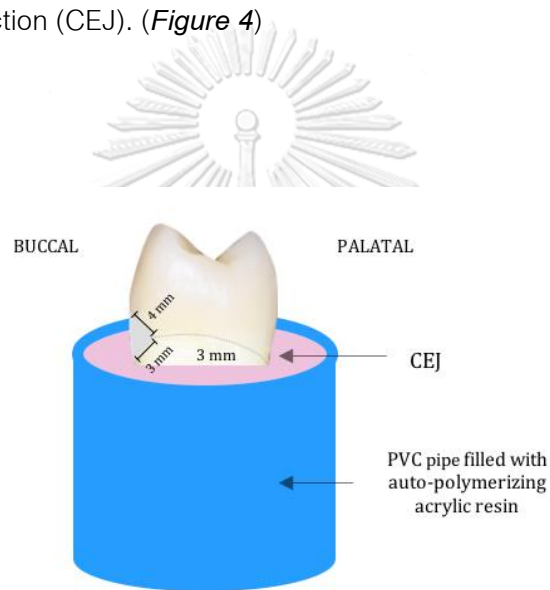
Figure 4 Teeth were placed 3 mm up from cementoenamel junction (CEJ)

Onlay preparation

Before the preparations, an impression of each tooth was made with a heavy-body

silicone impression material (Zhermack Elite HD, Badia Polesine, Rovigo, Italy) as an

anatomic guide to obtain an original form while the restoration was applied. All

specimens in the ON-NP group were prepared by an initial occlusal reduction.

The anatomical shape by generating 2 mm of clearance for the onlay. Preparation

dimensions were done according to manufacturer's instructions as follows: 1.0 mm

buccal and lingual reduction with 1.0 mm-deep chamfer. All angles were rounded

approximately 10 to 30 degrees and all prepared surface were refined using fine and

superfine diamond cutting instruments (Intensiv, Montagnol, Switzerland). Onlays were

scanned by intraoral scanner (Cerec AC Omnicam; Sirona Dental Systems, Bensheim,

Germany) and generated with the CAD/CAM system (Cerec SW v. 4.5.2; Sirona Dental

Systems GmbH, Bensheim, Germany). All specimens were fitted with the anatomy of a

first maxillary premolar with cusp tips parallel to the preparation surface. Teeth were

scanned, and onlays were designed. On the basis of this scan, a virtual onlay with

defined wall thickness was constructed. The onlays were milled with lithium disilicate

(e.max CAD blocks, Ivoclar Vivadent, Schaan, Liechtenstein) and crystallized in a

ceramic furnace (Programat P700, Ivoclar Vivadent) according to the

crystallization/Glaze LT program. All restorations were polished mechanically by means

of a commercial polishing kit (Jota All Ceramic Kit 1369, Jota AG, Rüthi SG,

Switzerland). The bonded surfaces of the ceramic onlays were etched with 9.5

% HF (Porcelain etchant, Bisco, Schaumburg, IL, USA) for 90 seconds in accordance

with the manufacturer's instructions. After onlays were rinsed thoroughly, Silane Primer

(Kerr, Orange, CA) were applied to etched surfaces; after 1 minute, the restorations

were hot-air-dried for 2 minutes. After the surface treatment and before insertion, the

restoration was protected from light to prevent premature setting. Tooth preparations were treated by 30 second etching with 37.5 % phosphoric acid, then rinsed with water and dried. Restoration and tooth surfaces were coated with adhesive resin (Optibond Solo Plus) and left unpolymerized until the application of the luting material. The dual-cure resin cement system (NX3, Kerr, Orange, CA) was applied to the inner surfaces of restorations and seated on their corresponding prepared teeth with vertical seating pressure and residual cement was removed. Buccal, lingual, mesial, distal, and occlusal surfaces were light-polymerized for 20 seconds for each surface. The restored teeth were stored in distilled water at room temperature for 7 days prior to being tested.

Crown preparation

For the CR-P group, ten premolars were conventional prepared by means of round-ended tapered diamond cutting instruments D2, D8, and D16 (Intensiv, Montagnola, Switzerland) to obtain a 6-degree convergence between walls. Preparation dimensions were done according to manufacturer's instructions as follows: 1.0-1.5 mm buccal and lingual reduction, 2-mm reduction was performed on the occlusal surface and 1.0 mm-deep chamfer placed 0.5 mm occlusal to the CEJ except buccal surface margin was placed below the restoration. Crowns were fabricated with lithium disilicate (e.max CAD blocks) and cemented with NX3 resin cement. Surface treatment and tooth surface preparation were followed by method mentioned earlier.

Compressive Fracture Resistance Testing

Specimens were tested using a universal testing machine (Instron 5566, London, UK).

Each specimen was inserted perpendicular to the horizontal plane in the holding device.

A controlled load was applied by means of a stainless steel tip (2-mm diameter) in a

direction parallel to the longitudinal axis of the tooth. Pressure from the rod tip was

applied at the central fossa contact of both buccal and lingual inclines, to simulate an

occlusal load. The load was applied at a crosshead speed of 0.5 mm/minute. All

samples were loaded until fracture, and the maximum breaking loads were recorded in

Newtons (N). (*Figure 5*)

Figure 5 specimens were tested using a universal machine

The mode of failure was recorded and classified as restorable or non-restorable. The

failure mode was visually inspected, fracture that presented above the CEJ were

classified as restorable and fracture that presented below CEJ were classified as non-
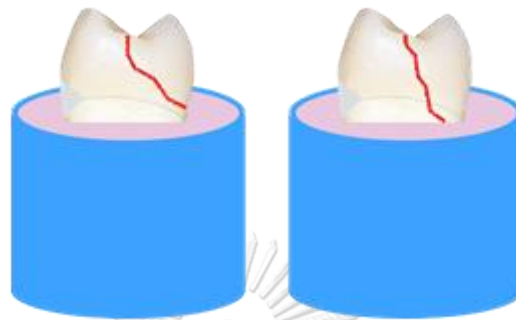
restorable.(*Figure 6*)

Figure 6 Mode of failure classification

Data of fracture load and mode of failure were collected by the author and analyzed

using statistical software (IBM SPSS Statistics version 20.0). One-way ANOVA was used

to compare the mean failure load for each group. Significant ANOVA results were also

tested with the Scheffe test, with the statistical significance of $p<0.05$. Pearson chi-

square test was used in this study for fracture modes with the statistical significance of

$p<0.05$.

CHAPTER IV

RESULTS

   The highest fracture resistance was 2189.97±600.38 N, recorded for the CR-P

group, followed by 1871.45±313.59 N for the ON-NP group and 1510.17±251.87 for the

COM-P group, with the lowest fracture resistance (933.48±242.53 N) recorded for the

COM-NP group. One-way ANOVA showed significant differences between COM-NP and

all test groups ($p \leq 0.05$). However, there were no significant differences between the

ON-NP and COM-P groups ($p=0.218$) and also between the ON-NP and CR-P groups

($p=0.322$). The fracture loads (mean±SD) are presented in Table 3.

Table 3 Mean value of fracture resistance of the tested groups

Group	Mean±SD (N)
COM-NP (Composite WITHOUT fiber post)	933.48±242.53^{a}
ON-NP (Onlay WITHOUT fiber post)	1871.45±313.59^{bc}
COM-P (Composite WITH fiber post)	1510.17±251.87^{b}
CR-P (Crown WITH fiber post)	2189.97±600.38^{c}

Means with the same superscript letter are not significantly different

from each other (p>0.05).

The failure mode was determined by visual inspection and was classified into two major types relative to the CEJ (Table 2). Specimens that presented fracture above the CEJ were classified as restorable, whereas those that presented fracture below the CEJ were classified as non-restorable. Although most of specimens showed non-restorable mode of failure and there were no significant differences in mode of failure among all groups ($p>0.05$), only fiber post groups showed restorable fracture.

Table 4 Fracture modes of the tested groups

Group	Restorable (%)	Non-restorable (%)	Pearson chi-square test
COM-NP (Composite WITHOUT fiber post)	0	100	A
ON-NP (Onlay WITHOUT fiber post)	0	100	A
COM-P (Composite WITH fiber post)	30	70	A
CR-P (Crown WITH fiber post)	20	80	A

Fracture modes followed by different upper case letters are significantly different at p<0.05.

CHAPTER V

DISCUSSION

This study investigated the fracture resistances of ETT with deep cervical lesions

restored with fiber posts and various restorations. The mode of failure of ETT with

various types of restorations was also examined. Based on our results, we found that

cuspal-coverage restorations are composed of crowns and onlays showed higher

fracture resistance compared with composite restorations. Also, it was determined that

fiber post influences fracture strength when teeth are restored with composite

restoration but does not affect the mode of failure significantly.

In this study, the fracture resistance of ETT restored with fiber posts and crowns

(CR-P) did not differ significantly from that of those restored with onlay without fiber

posts (ON-P). In 2002, Aquilino and Caplan stated that other forms of coronal coverage,

such as gold, ceramic, or resin composite onlays, could provide RCT teeth with

protection against fracture compared with full-coverage crowns.(6) Moreover, several

studies reported that endodontically treated maxillary premolars should be restored with

cuspal-coverage restorations to protect and reduce the risk of fracture.(6, 7, 10) When

fractures occurred, cuspal coverage was considered to avoid vertical fracture at the

cemento-enamel junction, especially when teeth were subjected to lateral forces,

because fractures in cuspal coverage mostly occurred within the restorative

materials.(109, 110) In 1984, Sorensen and Martinoff demonstrated that endodontically

treated maxillary premolars with crowns showed significantly increased success rates of

93.9 %, whereas post-endodontic restorations without crowns showed success rates of

only 56 %.(4) Also, several studies compared teeth with and without crowns and

reported significant differences in longevity. Crown placement extended the average

time before extraction in ETT.(3, 6, 14) Recently, a retrospective study by Suksaphar

and colleagues in 2018 reported that the survival rates of premolars in relation to

fracture of full-coverage crowns were higher than those of direct resin composite

restorations.(10) According to our results, cuspal-coverage restorations tended to

achieve more desirable outcomes than direct resin composite restorations. This finding

is consistent with the previous recommendation for post-endodontic restorations in

posterior teeth. However, that finding differs from that of Ibrahim and colleagues, in

which tooth preparation for crowns in maxillary premolars significantly decreased

fracture resistance due to remaining tooth structure destruction; maximal thickness of

axial tooth structure at the crown margin is necessary to resist fracture. (9)

Nevertheless, in our study, fracture resistance after restoration with crowns and

onlays showed similar results. From this point of view, considering on tooth structure

preservation, onlays are superior in terms of reductions in the amount of tooth loss,

especially in the cervical area. Preparation for onlays could reduce tooth loss from 67.5–

72.3 % with conventional crown preparation to 5.5–27.2 %.(105) The greater the amount

of remaining tooth structure, the more fracture resistance the ETT have.(1, 6, 7, 16, 106)

In addition, supragingival location of the margin for onlays avoids periodontal irritation and gingival inflammation and makes the margin easily detected.(107, 108)

The drawback of this study was the lack of data from group restored with fiber post and onlays which would be beneficial to draw a better conclusion. However, several studies have already investigated fracture resistance and failure mode between lithium disilicate onlay restorations with and without fiber post. The results showed no significant differences were found in the groups with fiber posts in terms of fracture resistance. The conclusion from both studies were made saying that ceramic onlays increased the fracture strength of endodontically treated teeth, whereas insertion of fiber posts did not increase the fracture resistance significantly which was consistent with our results. (126, 127)

From the results of this study, the group restored with composite without fiber posts (COM-NP) showed the lowest fracture resistance. In terms of physical and mechanical properties, Soares and colleagues reported that direct composite resin restorations are inferior to ceramic restorations due to the side effects of composite polymerization shrinkage and also the process of fabrication in the laboratory of ceramics could enhance fracture resistance.(17, 128) In contrast to many studies that supported resin composite as a post-endodontic restoration for endodontically treated premolars with limited loss of tooth structure or where marginal ridges are preserved.(8, 96, 129) There are evidence that resin composites perform better in stress distribution

under occlusal force compare to ceramic restoration.(97, 130) Also, advantages of this

conservative protocol as a final restoration can reduce treatment times and costs for

patients.(10)

Compared with the composite-only group, fiber post placement significantly

increased the fracture resistance of direct restorations.(7, 8, 12, 25, 94) Fiber posts

improved stress distribution along the adhesive interface because their elastic modulus

was close to dentin, (27, 127) contradictory from previously published results which

showed no differences in fracture resistance after fiber post insertion.(16, 97, 130)

Moreover, post preparation by the removal of dentin from the canal decreases tooth

strength and leads to fracture.(97) It has been recommended that posts be inserted only

when insufficient tooth structure is present, with the goal of facilitating the retention of

restorative materials.(4)

No difference was found in modes of failure among the four groups in this study,

we failed to reject the second null hypothesis. Several classifications for mode of failure

have been proposed either mechanical cause which is adhesive/cohesive or clinical

implications which is restorable/unrestorable. In this study we observed based on the

extent of fracture compared to CEJ level. Almost all specimens fractured in an

unfavorable mode. Likewise, studies by Fokkinga and colleagues in 2005(124) and

Forberger and Gohring in 2008(131) indicated that failure modes in post-restored

groups were 90 % unrestorable and involved deep root fracture. However, the results

that some restorable fracture were found only in both fiber post groups was interesting, which might imply that fiber post could somehow enhance and affect the mode of failure. Further carefully designed studies are needed to confirm this finding.

In the present study, the means of fracture resistance in all groups were higher than 100–400 N, which is the range of normal forces in normal occlusion for maxillary premolars. So the minimum threshold in the premolar area which might be capable of withstanding bite force is 400 N.(9, 132) The mean fracture load was at least more than 2 times greater than this threshold, suggesting that all restorations in this study could withstand forces during function.(133) However, this study was a static laboratory test, measuring fracture resistance that could not simulate dynamic oral conditions in many respects, such as magnitude, direction, and rate, but Sorrentino and colleagues proved that static and fatigue loading conditions showed comparably high stress concentration areas and similar failure patterns.(12, 133) Different forces have been applied to investigate mechanical resistance including compression, shear and tension. However, static analyses of resistance to fracture have usually been performed with compressive tests until fractures occurred(14, 124, 125) When maxillary premolars are tested with an optimal size of stainless steel tip are considered to reproduce the mean width of antagonist teeth present in the simulated clinical situation.(12) Most static mechanical fracture tests reported in the literature are characterized by a loading of the premolars at 130°-150° to the longitudinal axis which simulates non-axial forces.(7, 124, 131) On the

contrary, this study was decided to load the specimens in a direction parallel to the

longitudinal axis of the tooth simulating a physiological occlusion in order to distribute

the stresses more evenly between the residual dental tissues and the restorative

material.(12) Load application area could vary from the center of the tooth to supporting

cusps. Some studies load was applied either at the palatal cusp(12) or the buccal

cusp(16) to represented parafunctional oral habits, this study investigated loads placed

at the center of the tooth to simulate normal occlusion.(12, 17, 21, 94) Hannig et al.

pointed out the importance of applying loads in unaltered areas of teeth in order to

achieve reliable data and avoid the influence from tooth/restoration interface.(125)

Limitations of this study were our inability to recreate, in the laboratory, cervical

lesions occurring in natural teeth, and the variations in depth in the natural process.

Additional factors which might have affected the results include tooth anatomy, the lack

of a simulated periodontal ligament, and the simulation of biting force from only one

direction instead of the multiple directions of actual biting force. Further studies are also

needed to include the use of a thermal cycling machine and the simulation of the

periodontal ligament.

CHAPTER VI

CONCLUSION

Within the limitations of this study, the following conclusions can be drawn:

1. Cuspal-coverage restorations significantly enhanced the fracture resistance of endodontically treated maxillary premolars with cervical cavities.

2. Placement of fiber posts resulted in a significant improve the fracture resistance of endodontically treated teeth with cervical lesions but did not significant make the failure restorable
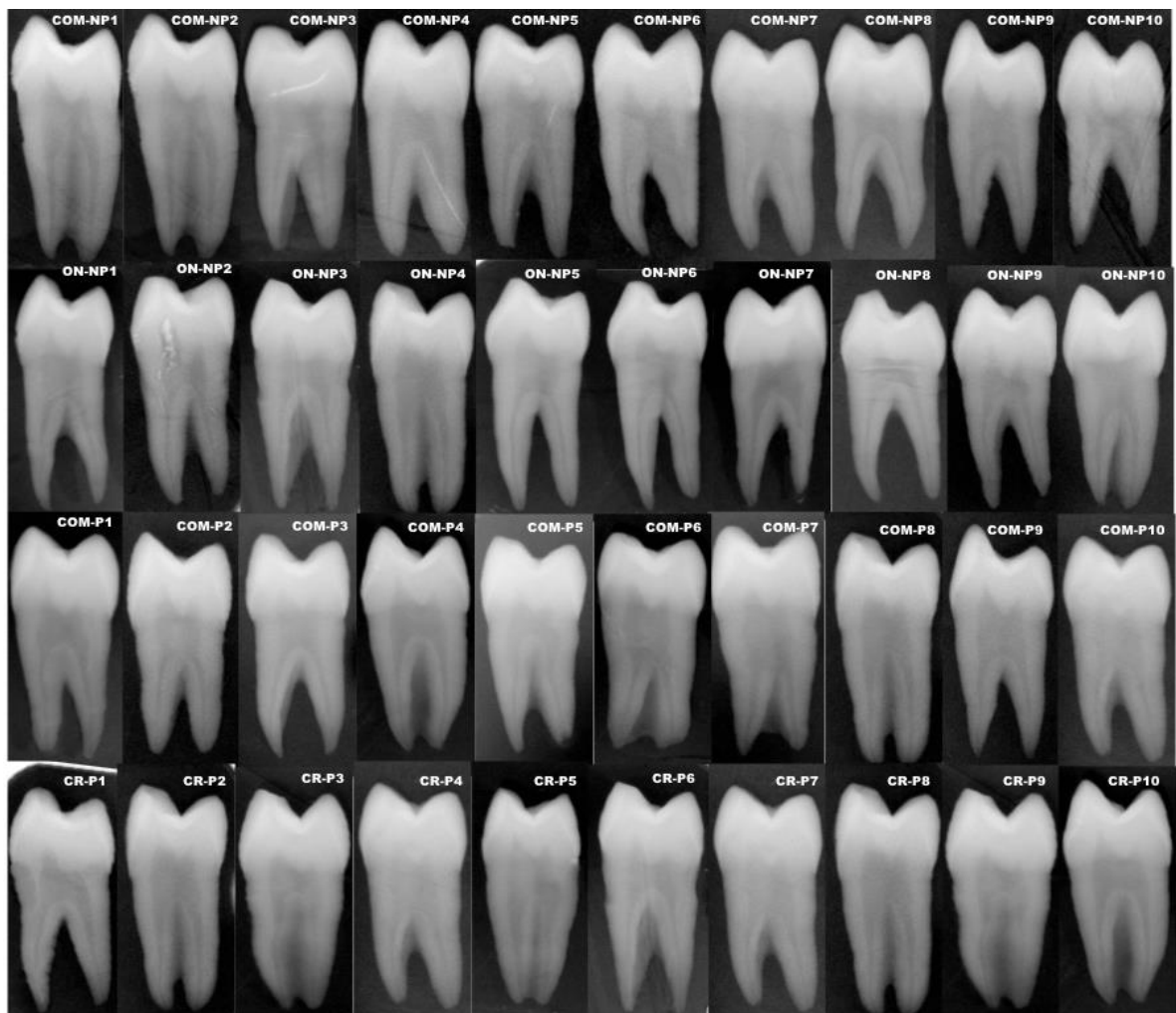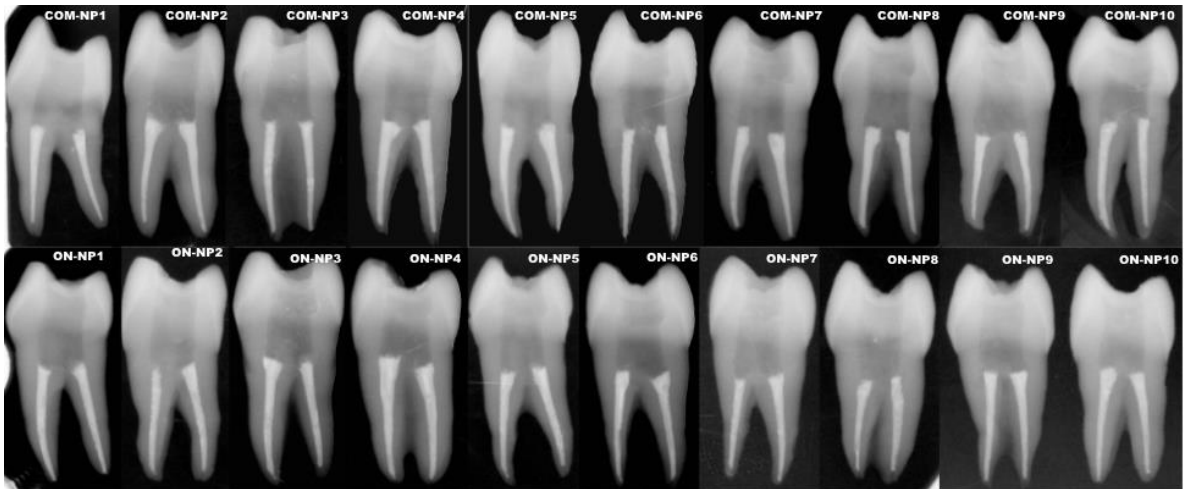
APPENDIX

Figure 7 Initial films in tooth selection

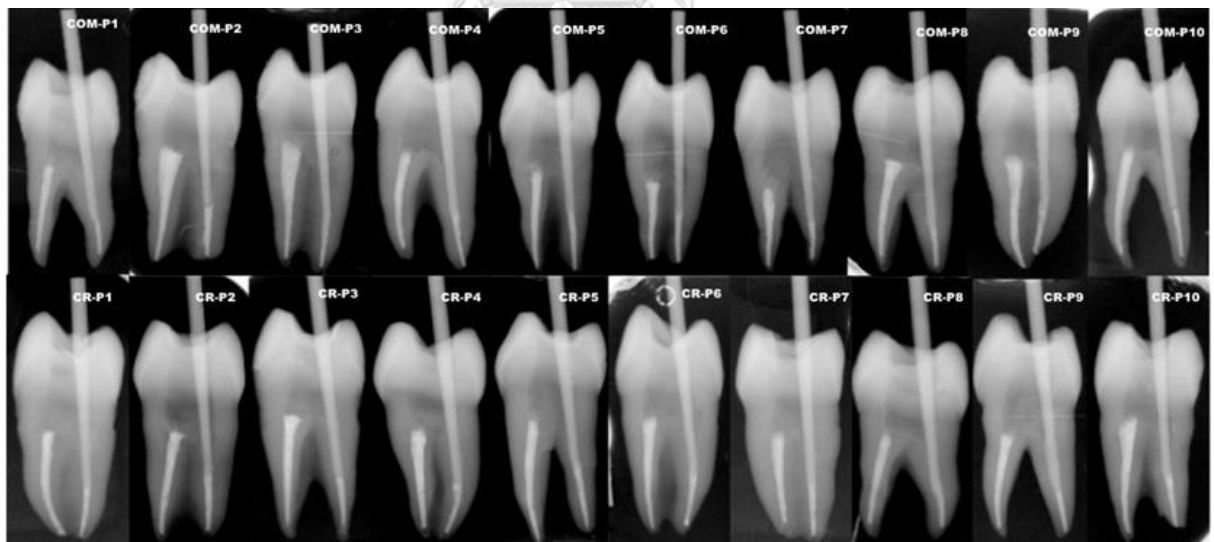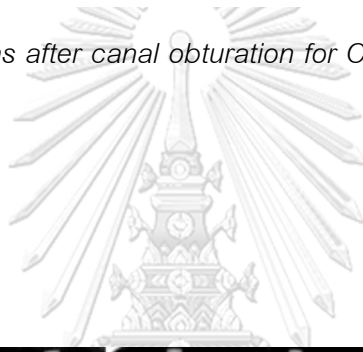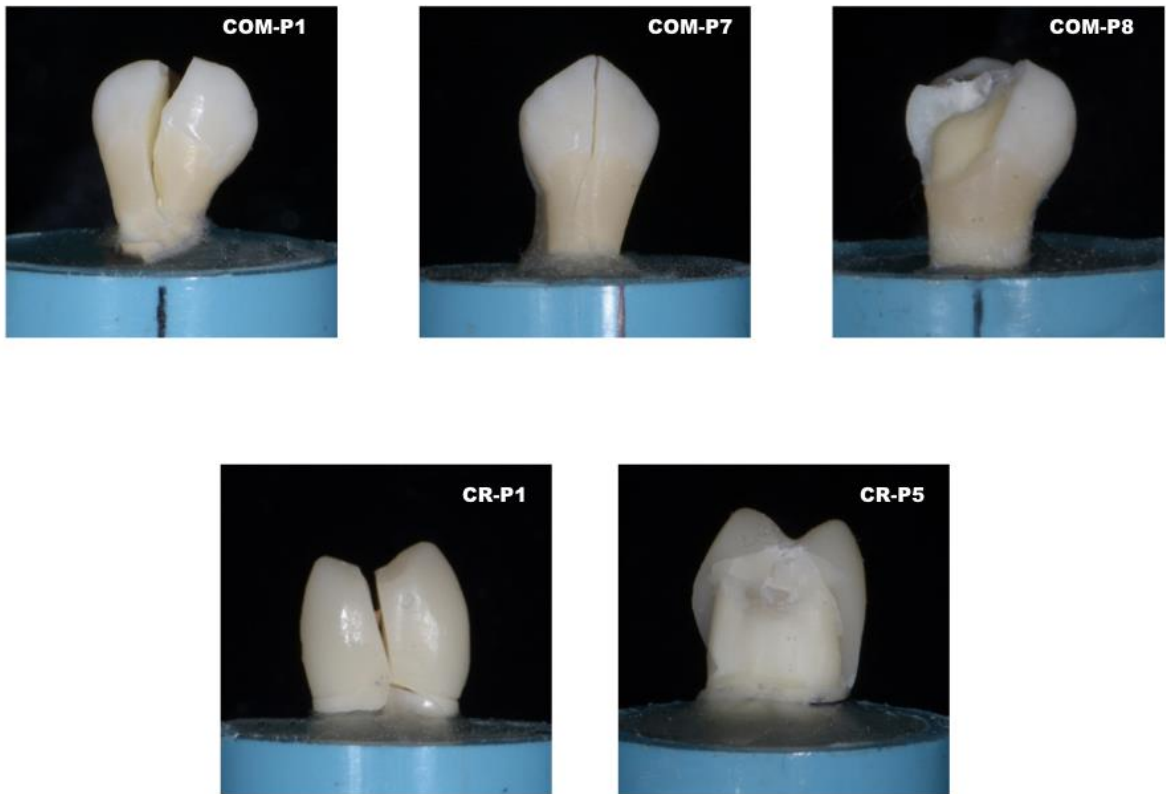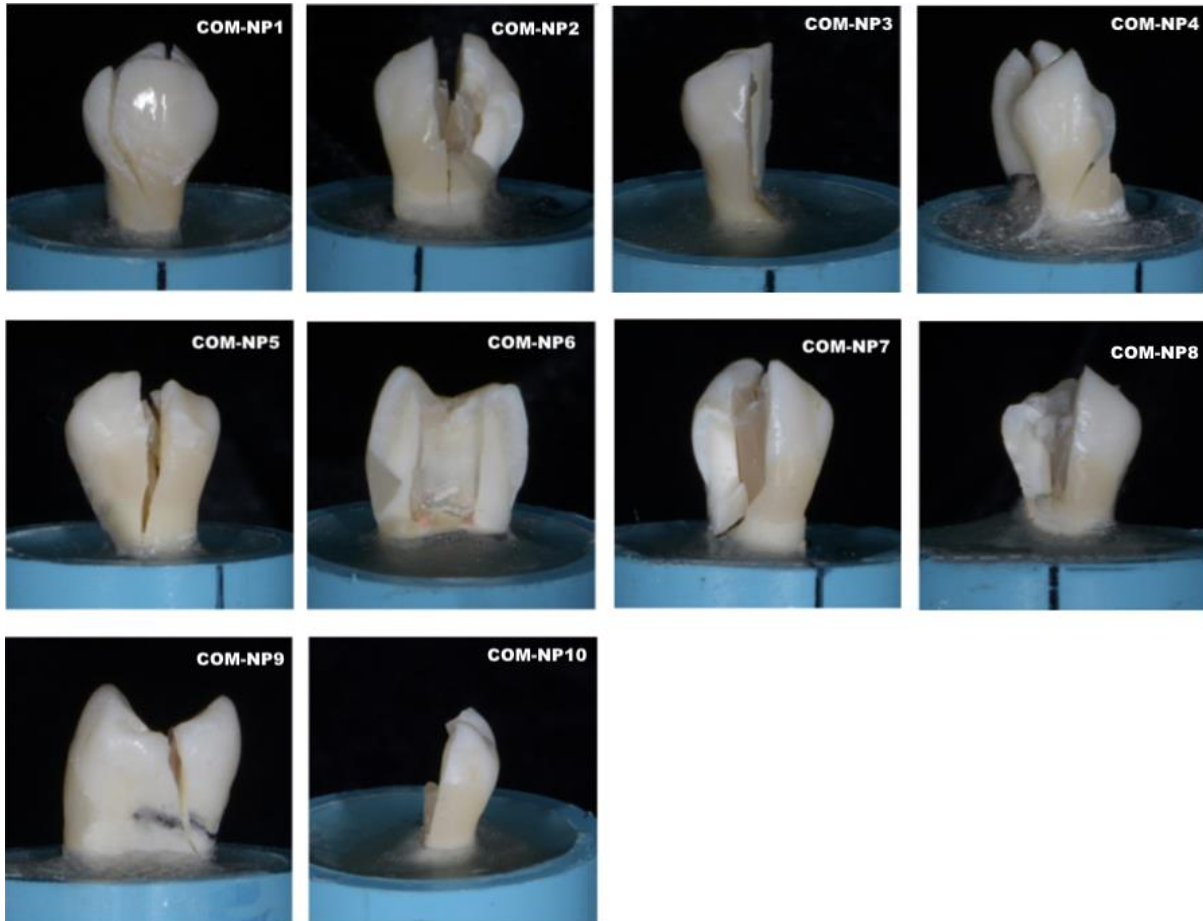*Figure 8 Specimens after canal obturation for COM-NP and ON-NP group*

Figure 9 Specimens after try fiber post for COM-P and CR-P

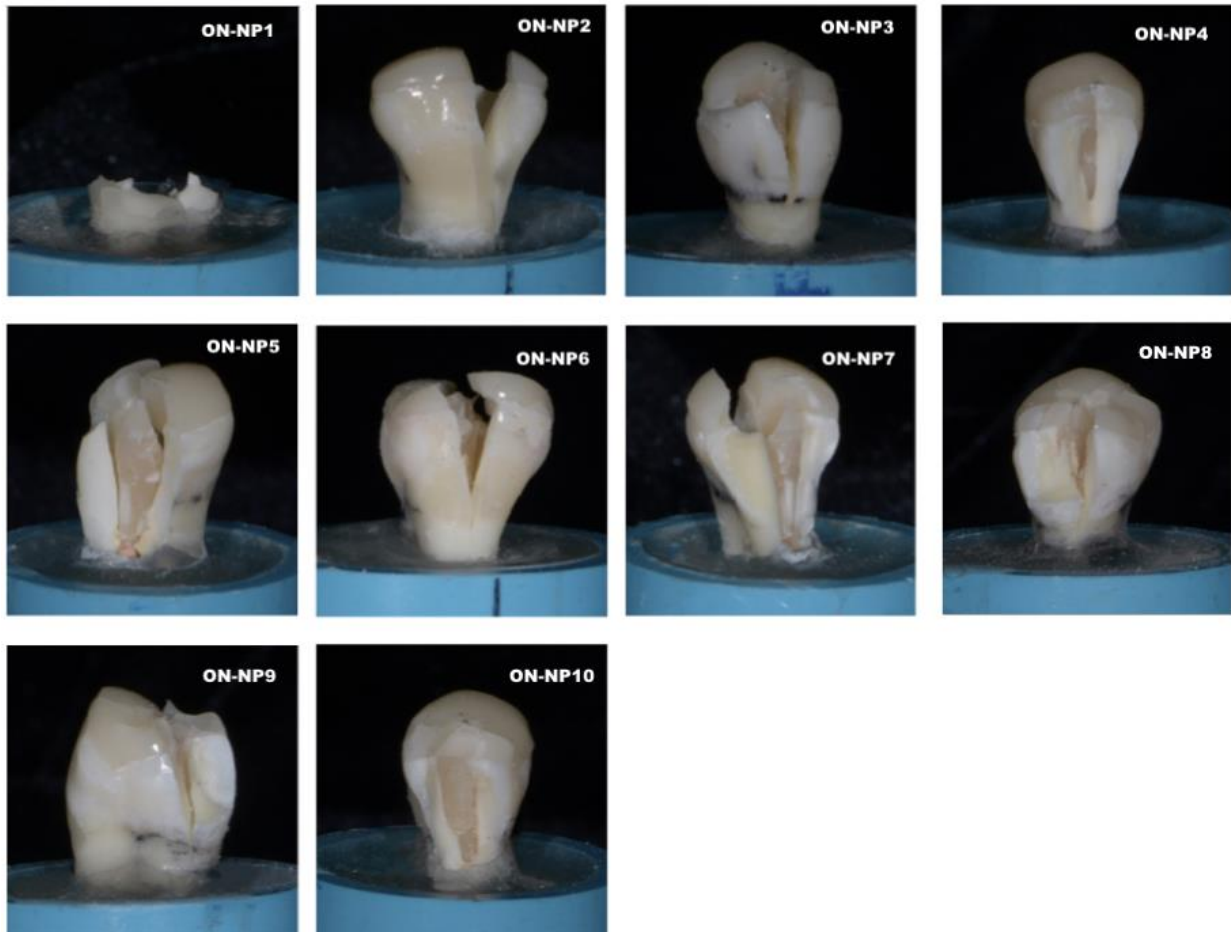*Figure 10 Restorable specimens*

Figure 11Unrestorable specimens in COM-NP

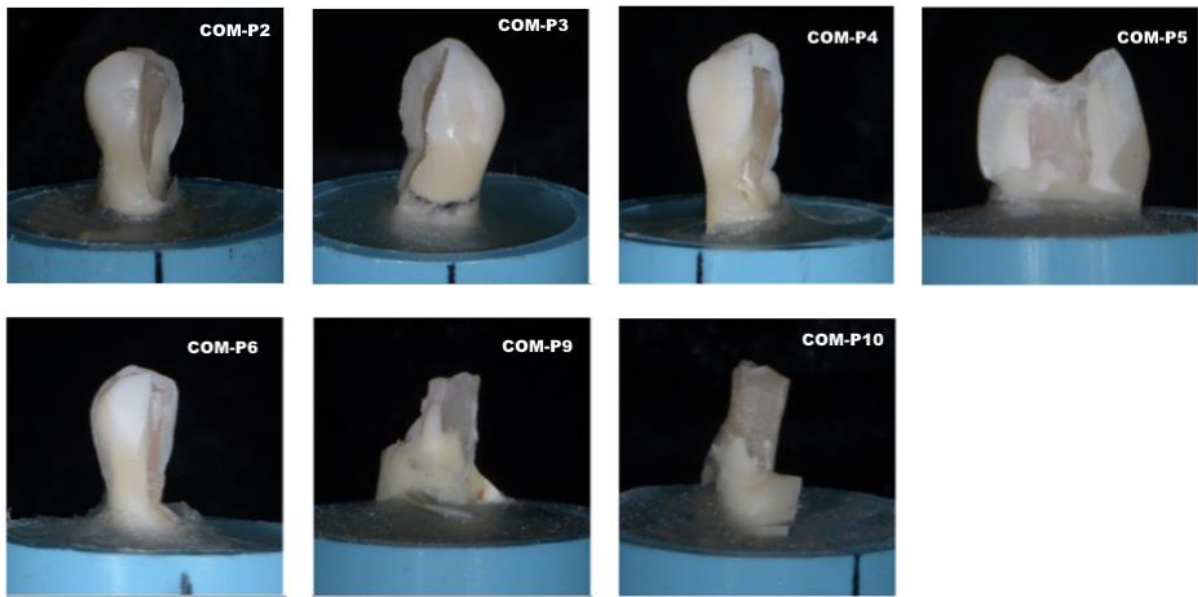Figure 12 Unrestorable specimens in ON-NP

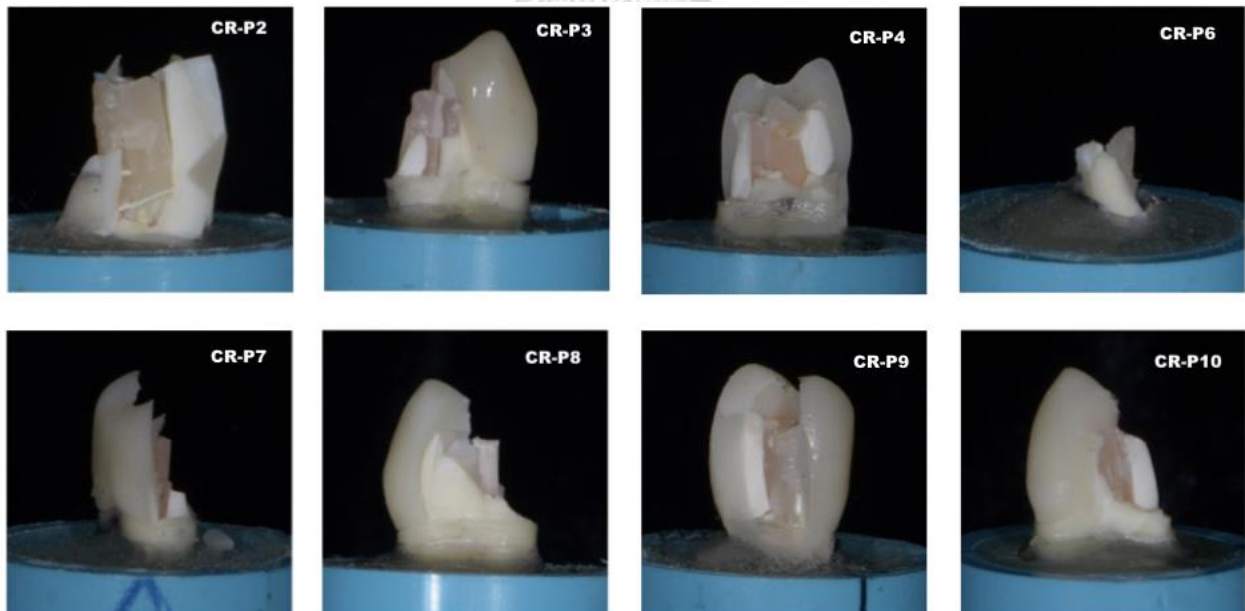*Figure 13Unrestorable specimens in COM-P*

Figure 14 Unrestorable specimens in CR-P

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