CHAPTER II

LITERATURE REVIEW

Fracture resistance of endodontically treated teeth restored with post

In endodontically treated teeth, the remaining tooth structure was minimized from large caries and restorations, resulting in decreasing the strength of the tooth (1). To prevent the fracture and retained core materials, restoration with posts and core is the treatment of choice (2, 3). Over the past decades, restoration with metal cast post and core was popular, but the disadvantage of this type of post was the unrestorable fracture (20-22). From the study of Fuss et al, the results showed that restoring with cast post resulted in vertical root fracture at cervical third more than middle third. The long cast post distribute the force better than the short post (23), so the greater post space had to be prepared and this might affect the strength of the tooth. Moreover, the result of Sorensen and Martinoff suggested that cast posts required less fracture resistance force compared with FRC posts and amalgam or resin composite core build-up (24). In addition, restoration with post and core combined with crown was more advantageous since the stress could be distributed to the cementoenamel junction, and decreased the wedging effect in post and core materials (25).

Fiber reinforced composite post (FRC)

The materials used in FRC post composed of two components: carbon or silica fiber and polymer resin matrix. The mechanical properties of carbon fiber post were much more advantage than metal cast post such as stiffness, lightness, corrosion resistance and fatigue resistance (26). Moreover, carbon fiber posts which had small diameters were rigid comparable to stainless steel posts with larger diameters (27). However, the carbon fiber post was opaque and did not lend to aesthetic with all-ceramic restoration. This disadvantage was introduced to the silica-fiber posts which were translucent and more esthetic than carbon fiber posts. The silica fiber had two types: glass fiber and quartz fiber. The mechanical properties of silica fiber post were quite similar to carbon fiber post. The modulus of elasticity was 18 - 47 GPa which was nearly the same as that of dentin (28). Furthermore, the thermal expansion coefficient of silica fiber post was quite low (29).

The mechanical properties of FRC post depended on many factors such as the properties of materials used for fiber and matrix, fiber surface treatment and impregnation of fibers with resin, adhesion of fibers to the polymer matrix, quantity of fibers, orientation of fibers, position of fibers and water sorption of resin matrix (30). These factors affected the properties of FRC post such as increasing of adhesion of fibers to matrix which led to higher stiffness and modulus elasticity (31). The orientation of fibers was important in fracture resistance force. Any fiber direction diverging from the longitudinal axis of the post resulted in a stress transmission to the matrix (32). In contrast, the parallel fibers were advantageous when removing the post if the root canal retreatment was required (33).

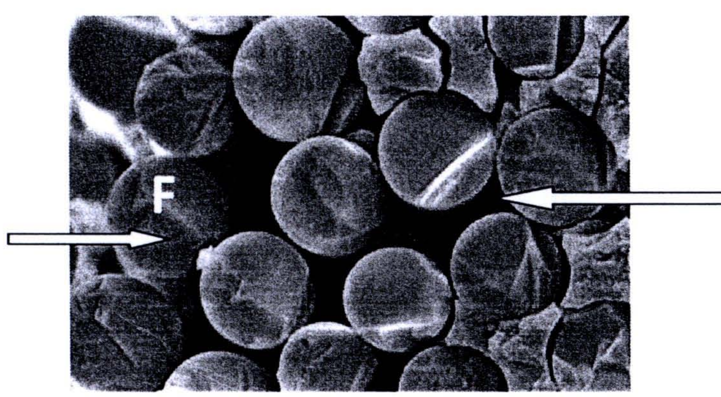


Fig. 1 Fiber impregnanted in epoxy resin matrix

(J Endod 32(1); 44-47) (34)

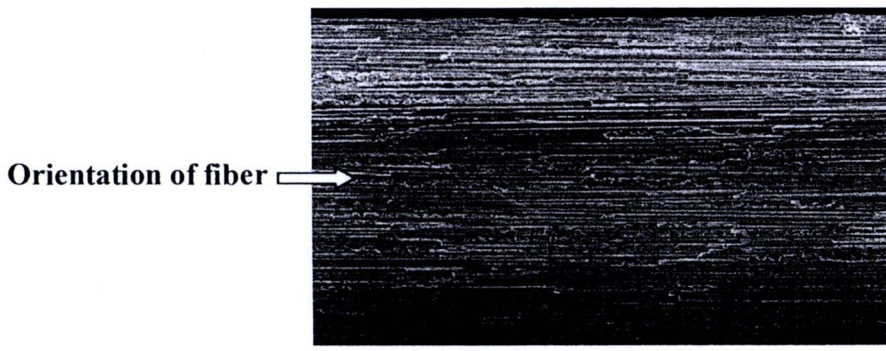


Fig. 2 Fiber orientation in FRC post

(J Endod 33(3); 264-267) (35)

Mechanical properties of FRC posts

1. Fracture resistance

The fracture resistance force of FRC post was less compared with that of cast post (36). When considering the failure modes, debonding or fracture of core materials were observed. These failures were more favorable compared with the failure of vertical root fracture in cast post (36-38). The study of Lassila et al showed that in the same post space, large posts contribute more favorable to the fracture resistance than small posts (29). Hayashi et al suggested that under conditions of vertical and oblique loading, the combination of a FRC post and composite resin core with a full cast crown is the most protective method for maintaining tooth structure (39).

2. Stiffness and flexural strength

The post which had modulus of elasticity or stiffness close to dentin could distribute the force along the post to the root and decreased the risk of root fracture (40). This property was found in FRC post and was important in restoration of anterior teeth because the occlusal force is not directed to their long axis. Furthermore, the FRC post which had high flexural strength could withstand bending force (41). In contrast, too high flexural strength of FRC post was disadvantageous since the force was concentrated at the post, resin cement and root canal dentin interface and this stress caused fracture of restoration (42).

There were many factors affected the flexural strength of FRC posts such as fiber size, fiber density, fiber distribution, adhesion between fiber and matrix, and thermocycling (43). In addition, the strength decreased after soaking posts in wet condition compared to dry condition. This might be because of hydrolysis reaction which caused the swelling and degradation of the matrix layer. In thermocycling processes, the stress concentration was increased within the post materials and debonding between fiber and resin matrix and crack of resin matrix might occur. These processes caused decreasing the flexural strength (44) and make the post more flexible. Furthermore, when the post was loaded by the occlusal force, the stress increased in the post-cement-dentine interface. Then, the resin cement cracked and introduced to debonding of post and core to root canal dentin. This process is precautionary in clinical failure (42).

3. <u>Retention</u>

3.1 Core retention

The retention between post and core materials was the important factor in restoration with FRC post. Purton and Payne compared tensile bond strength of resin composite core bonded with prefabricated stainless steel post (Parapost®) and carbon fiber post. The result suggested that tensile bond strength in Parapost® was much more superior to the other groups. The author claimed that the serrated surface of stainless steel post could increase mechanical retention with resin composite core better than smooth surface of carbon fiber post. From this study, if the smooth surface of FRC post was roughened, it might not be significantly different (27). The recent study of Artopoulou et al claimed that the diameter of resin composite core on FRC post was not significantly different in retention to post since it depended on the contact surface between post and core materials. In contrast, the retention between composite core and serrated metal post was mechanical retention, so the diameter of resin composite core significantly affected the retention (45).

3.2 Post retention in the root

There are many surface treatment of FRC post that increase retention to resin cement such as acid etching with hydrofluoric acid, air-borne particle sandblasting with aluminium oxide and silane coupling agent (46). In the study of sandblasting with air-borne particle, Balbosh and Kern claimed that airborne-particle abrasion significantly improved the retention of FRC posts and resin cement (47). However, the study of Soares et al which found that airborne-particle abrasion produced undesirable surface changes and decreased the retention (48). Concerning silane coupling agent, it was found that the application of a silane coupling agent onto the post surface prior to building up the flowable resin composite core significantly increased the post–core bond strength (49). Furthermore, the silane application combined with sandblasting could increase the retention between quartz fiber post and resin composite core (50). However, many investigations did not suggest that silane coupling agent would increase retention between post and resin cement (47, 51, 52). In 2008, Yenisey and Kulunk studied the surface treatment of glass and quartz fiber post using chemical solvents. The result suggested that the surface treatment with 10% hydrogen peroxide for 20 minutes significantly increased the shear bond strength of the FRC post due to its ability to dissolve the epoxy resin matrix and increase surface roughness which produced micromechanical retention with resin composite core (53). However, there was no study investigated the effect of hydrogen peroxide on mechanical properties of the post.

4. Materials used for bonding and reinforced of post

The retention between post and root canal dentin were related with materials used for bonding and reinforcement which were conventional cement, resin composite and resin cement. Mendoza et al suggested that resin cement was significantly increased the resistant to fracture than conventional cement (54). Moreover, the silane application onto the post surface and core build- up with the flowable resin composite significantly increased the post–core bond strength (49).

Resin cement was classified by polymerization process into auto-polymerized, light-polymerized, and dual-polymerized. When restored with FRC post, dual-polymerized resin cement was more reliable than light-polymerized in bonding with root canal at the apical third since limitation of light transmission of the post (55). The self-etch 10-MDP-based cements resulted in a higher push-out bond strength than the etch-and-rinse two-step cement and the self-adhesive cements (56). Furthermore, to achieve maximum bond strength between quartz fiber post and root canal dentin, the film thickness of resin cement should be 0.1-0.3 mm (35).

The study of Moosavi et al suggested that the flared root canal reinforced with resin cement showed a lower fracture resistance than reinforced with resin composite or Reforpin® which is glass fiber intraradicular accessory posts. The reason of this results may come from high polymerization of the luting cement which resulted in overstress within the materials when the space between the post and canal wall was large (57). However, this study did not compare between the ferrule and non ferrule tooth restored with FRC post which not fit to the root canal.

Regarding restoration with resin composite, the bonding agent should be a point of concern, Mannocci et al found that restoring with self-etching primer and resin cement was popular because of the advantage in moisture control (58). In contrast, the study of Goracci et al concluded that the bond strength of FRC post using dual-cure self adhesive without dentin conditioning was weaker than using total-etch adhesive combination with dual-cure resin cement (59).

The space between root canal dentin and FRC post filled with resin composite could increase the strength of fiber post (60). From the result of Saupe et al, it was demonstrated that the FRC post reinforced with resin composite could tolerate more occlusal force than the FRC post alone (18). Furthermore, the result of Turker et al showed that using polyethylene fiber ribbon-reinforced post could achieve appropriate clinical situation (61).

Effect of ferrule on teeth restored with FRC post.

Saupe et al showed that the fracture resistance of structurally compromised endodontically treated teeth restored with FRC post which have ferrule and no ferrule were not significantly different (18). However, the failure modes were quite different. The failure mode of the tooth which had ferrule was root fracture. In contrast, those which had no ferrule was debonding of post since fracture of resin cement (13). The study of Morgano and Brackett suggested that restoring the non ferrule teeth with flexible post caused microleakage since the bending of post and core from occlusal force resulted in fracture of resin cement(62).

The remaining tooth structures are important in restoration of endodontically treated tooth. From study of Akkayan, the tooth which had 2 mm ferrule restoring with different post system had more resistance to fracture than 1.0 to 1.5 mm ferrule(9). This result was consistent with the study of Ng et al which showed that the fracture resistance of tooth 2 mm ferrule restored with quartz fiber post was significantly higher than the tooth which had no ferrule (13). However, in clinical situation, the endodontically treated tooth might have partial ferrule which might affect the fracture resistance of the tooth. The study of Ng et al showed that anterior maxillary incisors which have only palatal wall restored with FRC post was more effective to resist fracture load than the labial wall (63). The reason was that the failure load in anterior maxillary incisors was the tensile stress from the lower anterior rather than the compressive stress (64).

In the study about ferrule, there are many investigations claimed that the effect of complete crown will block out the effect from the other factors (65, 66). But the other studies suggested that using specimens restored with crowns could refer to the clinical situation (17, 19, 22, 67). In addition, the materials used for crown were varied such as full metal crown (13, 38, 68) or all-ceramic crown (12, 68).

Angulation in fracture resistance test on central maxillary central incisor

There were many studies investigated factors influencing fracture resistance in restoring with FRC post in maxillary central incisors (7, 8, 12, 19, 69-72) such as type of post materials, type of crown materials and angle of loading force. Pegoretti et al studied stress distribution in restoring anterior teeth with FRC post by finite element analysis using 0, 45 and 90 degree to simulate force from bruxism, normal occlusal force and external force from accident, respectively. The results showed that in 0 degree model, the stress concentrated at post dentin interface, in 45 degree model, the stress concentrated on labial site at post dentin interface in cervical to middle third of root and in 90 degree, the stress concentrated at crown margin (73). However, in the studies of mechanical properties of endodontically treated teeth, most loading force were 45 degree to long axis (12, 13, 17, 19, 22, 38, 57, 68, 72, 74) to stimulate biting force of normal occlusion (14).

The purposes of this study

1. To investigate and compare fracture resistance of restoring technique of endodontically treated teeth with and without ferrule.
2. To investigate and compare fracture resistance of restoring technique of endodontically treated teeth which have different post diameters.
3. To investigate and compare fracture resistance of restoring technique of endodontically treated teeth with and without ferrule which have different post diameters
4. To select the appropriate FRC post technique restoration for endodontically treated teeth
5. To gain the knowledge for further study in restoration of endodontically treated teeth.

Hypotheses

Hypothesis 1

Null hypothesis: There would be no significant difference between the endodontically treated teeth restored with FRC post which have ferrule and no ferrule.

Alternative hypothesis: There would be significant difference between the endodontically treated teeth restored with FRC post which have ferrule and no ferrule.

Hypothesis 2

Null hypothesis: There would be no significant difference between the endodontically treated teeth restored with FRC post which properly fit and not fit to the post space.

Alternative hypothesis: There would be significant difference between the endodontically treated teeth restored with FRC post which properly fit and not fit to the post space.

Hypothesis 3

Null hypothesis: There would be no significant difference between the endodontically treated teeth which have ferrule and no ferrule restored with FRC post which properly fit and not fit to the post space.

Alternative hypothesis: There would be significant difference between the endodontically treated teeth which have ferrule and no ferrule restored with FRC post which properly fit and not fit to the post space.

Keywords

- Endodontically treated teeth
- Ferrule
- Fiber reinforced composite post (FRC post)
- Fracture resistance
- Post diameter

Type of research

Laboratory experimental research

Materials used in this study

1. Quartz fiber reinforced post (DT light post, Bisco Inc, Lançon De Provence, France)
2. Resin cement (Panavia F2.0, Kuraray medical, Okayama, Japan)
3. Primer bonding agent (ED PRIMER II A&B, Kuraray medical, Okayama,Japan)
4. Resin composite (Tetric N Ceram, Ivoclar Vivadent, Schaan, Liechtenstein)
5. 37% Phosphoric acid (Total Etch, Ivoclar Vivadent, Schaan, Liechtenstein)

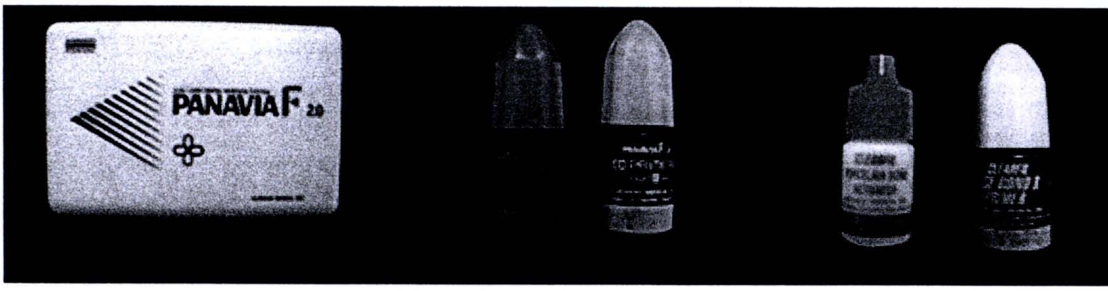
6. Bonding agent (Excite, Ivoclar Vivadent, Schaan, Liechtenstein)
7. Silane coupling agent (mixture of Clearfil SE bond primer and porcelain bond activator, Kuraray medical, Okayama, Japan)
8. Self cured acrylic resin (Formatray, Kerr, USA)
9. Additional polyvinyl siloxane impression materials putty and light body type (Reprosil, Dentsply/Caulk, Milford, USA)
10. Pink baseplate wax (Modelling wax, Dentsply, USA)
11. PVC mold 22 mm in diameter
12. Stone type IV (Vel-Mix, Kerr Corporation, Califonia, USA)
13. Blue inlay wax (blue inlay casting wax, Kerr, USA)
14. Fit checker (Fit checker, GC Corporation, Tokyo, Japan)
15. Base metal alloy (4all, Ivoclar Vivadent Williams #0123, USA)
16. Root canal sealer (CU Product, Chulalongkorn University, Bangkok, Thailand)
17. Gutta percha point (Hygenic Guttapercha Points, Coltène/Whaledent Inc., Ohio, USA)
18. 2.5% Sodium hypochlorite (CU Product, Chulalongkorn University, Bangkok, Thailand)
19. Provisional restoration (Cavit, 3M ESPE, Seefeld, Germany)

Instruments used in this study

1. High speed airoter 330,000 rpm (high speed airotor, 798 W&H, Australia)
2. Light curing unit (Elipar Trilight 3M ESPE, Minnesota, USA)
3. Diamond burs (ISO 314197, Intensiv, Switzerland)

Table I Materials used in this study

Materials	Type	Composition
DT light post (Bisco Inc, France)	- Fiber density 32 fibers/mm2(32) - Post diameter 2.0 mm(32) - Fiber diameter 12 μm(32) - Surface occupied by fiber per mm^2. of post surface 38.4%(32)	- Quartz fiber 60% - Epoxy resin 40%(57)
Panavia F 2.0 (Kuraray medical, Japan)	Resin cement	Silanized barium glass, silanized silica, sodium fluoride, BPO, photosensitizer, MDP, hydrophobic and hydrophilic dimethacrylate, bisphenol A polyethoxy dimethacrylate(46)
ED Primer (Kuraray medical, Japan)	-	MDP, HEMA, N-methacryl 5-aminosalicylic acid, sodium benzene sulfinate,N,N-diethanol-p-toluidine, water(46)
Tetric Ceram (Ivoclar Vivadent, Liechtenstein)	Nanohybrid composite	Percentage by weight Catalysts, stabilizers and pigments 0.8%, Monomer 20.2% -> Bis-glycidylmethacrylate (Bis-GMA), Urethane dimethacrylate, Triethyleneglycol dimethacrylate, Mineral fillers 79%: Barium glass, Ytterbium trifluoride, highly dispersible silicon dioxide, Ba-Al-silicate glass containing fluoride mixed spheroidal oxide(75)



(a) **(b)** **(c)**

Fig. 3 Resin cement (a) ED primer (b) and silane coupling agent (c)

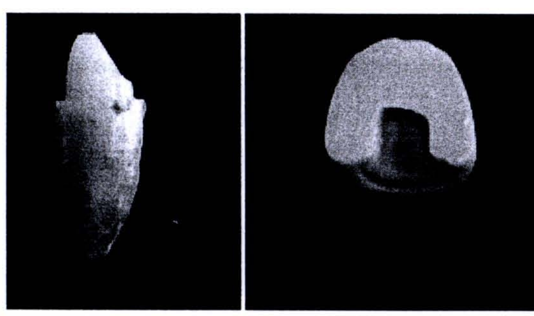


Fig. 4 Resin composite core build-up by using silicone index