CHAPTER V

DISCUSSION

The hypothesis that there would be no difference in the fracture resistance of the specimen with and with no ferrule was rejected. Analysis of the results indicated the preparation of ferrule on endodontically treated teeth significantly increased the fracture resistance of the teeth restored with FRC post and cores. The results of the present study may be explained due to the fact that greater remaining tooth structure results in a stronger tooth (9, 12, 76). Ma et al. reported a 1.0 mm ferrule on teeth restored with FRC post and ceramic crown could resist fatigue loading cycle 1.7 times more compared with teeth having a 0.5 mm ferrule. Furthermore, there was significant difference between the no ferrule group and the 0.5 and 1.0 mm ferrule groups. The no ferrule group had mean fatigue loading cycle 1,234 times less than 1.0 mm ferrule and 728 times less than 0.5 mm ferrule groups(11). A 2.0 mm ferrule was found to enhance fracture resistance 3.5 times compared with no ferrule and it was suggested the ferrule could reduce the load transmitted onto the post system (13) and redistribute the stress to the outer surface of the coronal third of the root (77). In addition, when the ferrule was absent, forces were shown to concentrate at the junction of post and core instead (15). In teeth with an incomplete ferrule, the location of the remaining tooth structure may affect fracture resistance. Indeed, anterior maxillary incisor with only a palatal wall was better able to resist fracture load than that with only the labial wall (13). In contrast, another study found the labial ferrule design resulted in the highest fracture resistance (12).These conflicting results suggest further investigations are needed.

The hypothesis that there was no significant difference in the tooth restored with the post which properly fit and not fit to the post space was accepted. Within the parameter of this hypothesis, there are two main factors to consider. The first is the difference in post diameter and the second is the difference in resin cement thickness. Considering differences in post diameter, a correlation was shown between the diameter of FRC post and loading force when testing with flexural properties (29) meaning larger posts should resist the force more than smaller ones. A finite element analysis study

indicated the maximum von Mises stress in the FRC post slightly increased with an increase in post diameter. This advantage might help in reducing stress distribution to the remaining radicular tooth structure (78). But in the present study, the results did not show a significant difference in fracture resistance on the basis of post size. One reason might be due to the presence of the metal crown which may overcome the effect of the post diameter. When a crown is present, it could directly distribute the load to the root more effectively than the resin composite core due to its homogeneity and higher elastic modulus than resin composite. Another reason might be from the use of resin cement as a luting material which could increase the retention between the post and root canal dentin. Our results are in agreement with a study showing post fit did not have a significant influence on fracture resistance in specimen using a resin composite core to simulate the crown (79). Other studies suggested the use of composite as a luting material did not decrease the retention when the post did not properly fit the canal (80, 81). This contrasts with another study showing there was a significant difference in failure resistance between teeth where the post was properly fit and a smaller post when cemented with resin cement in specimens without crowns (8). Comparing differences of resin cement thickness, the present study used 2 sizes of DT light post with 0.1-0.3 mm differences in diameter. So the resin cement gap was in the range recommended for luting quartz fiber posts with a dual-cured resin luting agent (35).

The clinical use of a post smaller than the canal space might be found with a flared root canal, where the space between root canal and FRC post is important. When resin cement is used, it acts as a stress breaker under compressive load. If the post does not fit to the root canal, especially at the coronal level, the resin cement layer would be excessively thick and may contain bubbles, which could allow debonding to occur (82). Therefore, with wider cement gaps, the higher yield strength of the resin cement is required (83). In our study, the fracture resistance of a tooth with a smaller post reinforced with resin composite was comparable to a post which properly fit to the canal. While the smaller post reinforced with resin cement had significantly low fracture resistance (8). Similarly, reinforcement with resin composite in flared root canal had higher fracture resistance than reinforcement with resin cement (57). The resin composite could transfer low levels of stress to the cervical region of the root (57, 84). Thus using

reinforced materials with a modulus of elasticity close to that of radicular dentin plays an important role in increasing fracture resistance with wider cement gaps (85).

When combining the factors of ferrule and post diameter together, the result of the present study showed the fracture resistances of the teeth with 2 mm ferrule were 1.8 to 2 times more than the teeth with no ferrule, while the effect of post diameter was not significantly different. This indicates the effects of ferrule preparation are more important in restoring endodontically treated teeth than the effect of post diameter. The result agreed with concluded prior study where the strength of the tooth was directly related to the remaining bulk of dentin and was more important than the type of core, post materials (3) and post length (40).

While there have been many reports comparing the effect of ferrule in endodontically treated teeth (11-13, 63, 74), the results have been controversial. Most of those studies were not conducted using crowns on the post and core specimens because they wanted to investigate the direct effect of bonding between materials of post and core and they claimed the placement of a crown may block the influence from other factors (12, 86). However, in clinical situations, the remaining tooth structures of endodontically treated teeth are minimal and prone to crown or root fracture, therefore, the guidelines of such treatment normally require crowns on post and core. The placement of a crown on the specimen might affect both fracture resistance and mode of failure especially in comparing specimens with and with no ferrule. Thus, the results of the studies with crown can be considered more practical to evaluate likely clinical outcomes.

The maximum forces of anterior teeth in healthy young adults are reported to range from 75 to 190 N (87). In the present study, fracture loads in all groups were found to be superior (668.47–1474.67 N) than this. This suggests anterior teeth with or with no ferrule restored with FRC post and full-coverage crown can resist normal occlusal forces (38, 74). The stress distribution in maxillary central incisors is quite different from the posterior teeth because loading occlusal forces are oblique to the long axis of the root. Under a 45° oblique load, teeth behave as a cantilever(38). The horizontal axis of the load has a greater influence on these teeth than the vertical axis (88) thus the flexural strength of the post is important (41).

The failure mode of the specimens in this study was classified into three patterns; pattern 1: horizontal root fracture at cervical root dentin, pattern 2: horizontal root fracture at cervical crown margin and pattern 3: debonding of margin combined with cervical root fracture. Group 1 (ferrule with properly fit post) failures mainly fell in pattern 3. This may be because the stress distributed from the coronal crown dentin through the cement interface directly to the post since the modulus of elasticity of resin cement (Panavia F 2.0) was nearly similar to dentin (18.3 and18.6 GPa) (89). This combination of restorative materials was able to distribute the stress more naturally. The failure mode started at the palatal crown margin through the cement core /crown interface along to the post, then the post bent as the diameter decreased apically leading to the oblique root fracture on the labial side. In group 2 (ferrule with small post), failure mainly occurred as a horizontal root fracture at cervical third of root. This may occur as when loading force is at 45^0 to the long axis of the root, the ferrule effect could help resist cement/crown failure. Therefore, the crown remain attached to the core but the small post bent easier allowing root flexion at the fulcrum point at the level of upper border of acrylic block simulating the alveolar crest. So the fracture started in the root dentin at the alveolar crest level and a horizontal root fracture occurred. In the non-ferrule groups (groups 3 and 4), the failure occurred in patterns 2 and 3. One reason for pattern 2 may be due to the failure at the cement crown/core interface which did not distribute stress along the post. So the fracture propagated along the crown margin at the labial side. The reason for pattern 3 may be stress concentrated at the cement core /crown interface which had differences in elastic modulus which was distributed to the cement post/root interface. So failure started from the lingual margin through the post and distributed apically through the post cement interface since the post detached from the cement. .

These results were similar to a prior study using composite cores with and without FRC post, failure occurred at the margin line of full crowns or between the margin and the embedded root in the resin block (90). When oblique force was applied to teeth restored with FRC post and core crown, the stress concentrated at the labial cervical margin of the crown and strain occurred at the lingual margin. The cervical region of the restored tooth was subjected to the highest strain and stress concentrations, and the higher the rigidity of the crown and core materials the more apically the stress and strain concentrated along the adhesive interfaces (91). In a study of finite element analysis of

FRC post the maximum von Mises stress in the FRC post slightly increased with an increase in post diameter. This should help to reduce stress distribution to the remaining radicular tooth structure (78).
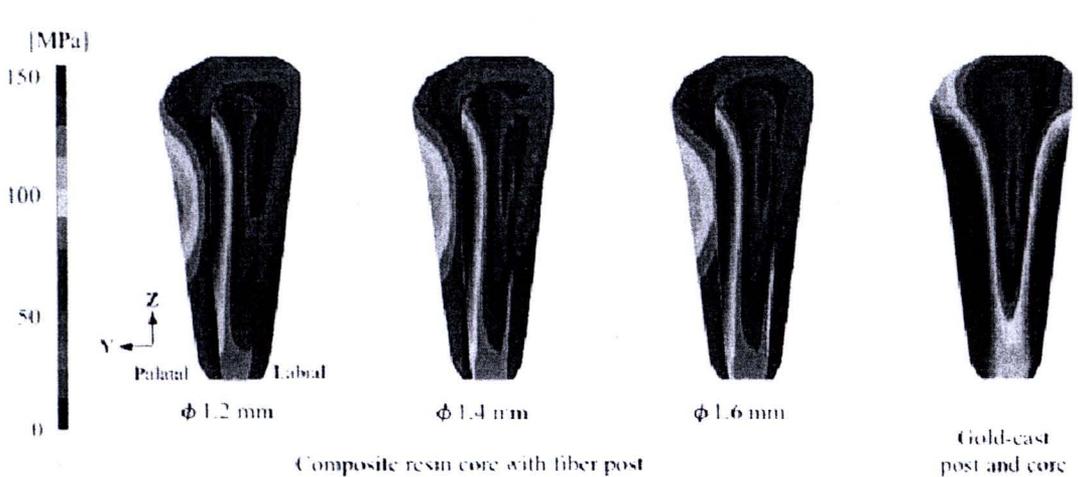
Fig. 14 Distribution of von Mises stresses in the internal area of the post
(Dent Mater J 27(1): 49-55.)(78)

However, The failure mode in the present study were quite different from the study of Ng et al which found the initial mode of failure in non-ferrule group was debonding at the crown margin, then vertical root fracture occurred when the load continued beyond the initial failure(13).The reason might be from in this study, the mode of failure was observed when initial failure just occurred which considered to the failure of specimens.

In several studies of FRC post and core without crown, the restorable failure was observed (8, 90). But in the present study with simulated crown, the non-restorable failure was observed. This might be because of the use of resin cement in cementing crown, which provided a strong bond to the composite core and root. If the cement was changed to a conventional one such as zinc phosphate cement, the restorable failure might be observed with lower fracture resistance (54). However, fatigue study might show the different mode of failure in the same protocol.

The failure mode in the present study were quite different from a study which found the initial mode of failure in the non-ferrule group was debonding at the crown

margin, followed by vertical root fracture when the load continued beyond the initial failure (13).In this study, however, the mode of failure was determined when initial failure occurred, and not beyond that point.

In this study, the DT light posts were used. These posts are made of pure silica with a modulus of elasticity similar to other glass fibers (32, 92). In addition, the quartz fibers used in this post type are pre-stressed and soaked with resin and released after curing. This procedure causes compression in the glass fibers which are then able to absorb tensile stresses when the post is exposed to flexural stress (31). Panavia F 2.0 resin cement was used because it contains phosphate-based monomer (10-MDP). Its low solubility of the MDP-calcium salt in water can make a stable bond to the tooth structure (93).

The bond between FRC post and root canal dentin is affected by the fiber post surface. Non treated FRC posts have a relatively smooth surface which limits mechanical retention with resin cements and purely adhesive failure modes commonly occurred at the post/cement interfaces (94). The conditioning of the post should be advise in order to roughen the post surface and enhance the bond strength of the FRC posts (95). Surface treatment with silane coupling agent is the most common surface conditioning method. The function of silane is to increase surface wettability of FRC post which is a key role for improved adhesion resulting in chemical bridges formation with OH-covered substrates such as glass or quartz fibers. The surface wettability of silane coupling agent was important since its low viscosity would assist substrate wetting provided physical adhesion. However, interfacial strength is still relatively low (96, 97). Using silane coupling is considered a sensitive technique. The primary factors influenced its efficiency included the type of silane (pH, solvent content, silane molecule, molecule size) and the application mode used (98). Unfortunately, the chemical bond of silane coupling agent may be achieved only between the resin composite and the exposed glass fibers of the post (94). From the result of Cheleux et al, the mechanical action of sandblasting combined with chemical coupling with silane and bonding agent resulted in improving interfacial strength between epoxy resin and resin composite (50).

Eugenol root canal sealer was used in this study. Some previous investigations concluded that eugenol had negative effects on resin compound since its phenolic

components influence the polymerization and adversely affects their adhesive properties (81, 99, 100). In contrast, the study of Schwartz et showed that the root canal sealer with or without eugenol did not affect the retention of resin cement used in post bonding (101). From the study of Vassiliadis et al, the result showed that sealer was found deepest in the middle third of the root up to 200-900 microns from the root canal walls (102). In addition, the study of Peutzfeldt and Asmussen attempts decontaminate eugenol in the dentin and they showed that the use of alcohol, EDTA, chloroform and 37% phosphoric acid could eliminate the effects of eugenol on resin-dentin bonding (103, 104). In the present study, the drilling bur which was 1.00-1.77 mm in diameter was used in post space preparation. At the coronal dentin, dentin conditioning with 37% phosphoric acid was used. So the negative effect from eugenol penetration in root canal and coronal dentin on polymerization of resin cement might have been eliminated.

There are several limitations to the present study. Static loading represents a worst case situation and does not directly replicate forces in the oral cavity, regarding to both sizes of the load and nature of the load. In clinical situation, most pulpless teeth probably fail as a result of fatigue due to chewing forces. So resistance to static loads is not the only issue of interest. Further study should be analyzed using a cyclic load or under the thermocycling conditions.