สำนักงานวิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

CHAPTER V

DISCUSSION

The results of push out bond strength showed that different luting cements affected the bonding of fibre reinforced post and root dentin, therefore, the null hypothesis was rejected. While cyclic loading did not affect the bonding of fibre reinforced post and root dentin, therefore, the null hypothesis was confirmed.

These four luting cements; Superbond C&B, Panavia F 2.0, Maxcem Elite, and Rely X Unicem represent four commercially available systems which are etch and rinse, self-etching, self adhesive, and resin modified glass ionomer cement respectively. The result revealed that cyclic loading decreased the bond strength in all groups compared to without cyclic loading.

Bonding of luting cement to FRC posts and root dentin, the dentin/resin/post can be joined via resin adhesion into one unit, therefore, the stresses produced during cyclic loading were probably uniformly distributed along the fiber post/ cement/root dentin interface. Adhesively luted fiber posts have a greater ability to absorb stress with a more homogeneous redistribution of stresses to the remaining tooth structure. This is because its modulus of elasticity (E) is similar to that of dentin, which may not induce or degrade the adhesion (27).

The result of this study showed that Superbond C&B provided the highest bond strength which significantly different from Panavia F 2.0, Maxem Elite and Rely X Unicem ($p<0.01$, $p<0.01$ and $p=0.03$ respectively). Rely X Unicem presented significantly higher bond strength than Panavia F 2.0 and Maxcem Elite ($p=0.029$ and $p=0.005$ respectively), from SEM of Rely X Unicem demonstrated that the failure interface was at post-cement interface. Maxcem Elite provided the lowest bond strength which was not significantly different from Panavia F 2.0.

Regardless of cyclic loading, Superbond C&B is an etch and rinse luting cement which provided the highest bond strength in this study. This luting cement utilizes an aqueous solution of 10% citric acid/3% ferric chloride (10-3 solution) in green solution to remove smear layer and demineralize dentin. The hybrid layer is created by the infiltration and impregnation of the adhesive monomer into calcium depleted collagen substrate and polymerization in situ. The ferric chloride plays an important role to induce complete adhesion without depleted collagen in dentin conditioning. The ferric ions promote diffusion of monomer into the demineralized dentin produce continuous thick hybrid layer with more resin tags penetration (10, 11, 12, 13). This thick hybrid layer with more resin tags penetration provided highest bond strength when using Superbond C&B. This was confirmed by SEM that 10-3 solution of Superbond C&B etched root canal dentin more uniformly than Panavia F 2.0, Maxcem Elite, and Rely X unicem.

Panavia F 2.0 is a self-etching system which one advantage of this system is that it demineralizes and infiltrates the monomer into the dentin simultaneously. However, the moderate self-etching primer in Panavia F 2.0 (ED primer) was less effective in dissolution of the thick smear layer observed after preparation with burs (8, 14). It was also assumed that the minerals presented in the smear layer were able to neutralize the acidity of self-etching primer may cause the incomplete infiltration of resin around collagen fibrils led to the present of microgaps which may contribute to breakdown of the bond (22, 89). As the smear layer was left, the bacterial byproducts such as acids and enzymes may slowly disintegrate and dissolve the filling material. This also confirmed by SEM observation of Panavia F 2.0 which etched through smear layer and partially opened the dentinal tubules and smear plugs were observed in the tubules and moderate push out bond strength.

Maxcem Elite is a self-adhesive resin cement which does not require any tooth surface pretreatments, and its application is accomplished through a single clinical step. In this study, Maxcem Elite showed the lowest bond strength. This result supported Monticelli's study which demonstrated that self-adhesive cements were unable to demineralize/dissolve the smear layer completely, and no decalcification/infiltration of coronal dentin was observed (9). The SEM observation in this study also confirmed that

Maxcem Elite could not etch through the smear layer resulting in irregularity, non uniform of tubules and small amount of smear plugs were observed sporadically. This might be the result for low bond strength obtained in the self-adhesive group.

Rely X Unicem is a resin modified glass ionomer cement, which showed better performance to Panavia F 2.0 and Maxcem Elite. There was no significant difference between bond strength of Rely X Unicem compared with Superbond C&B, however, the microleakage result showed the greatest in distance and failure interface resulted between post and cement which was not the actual bond strength between dentin and adhesive cement. Therefore, it was quite doubtful that the high bond strength obtained from Rely X Unicem in this study and other studies (14, 19, 20) reflected the real bond strength between dentin and adhesive cement. Rely X Unicem is a glass ionomer cement so it does not bond to the post. Unlike the other 3 luting cements which did not show fracture between cements and posts.

Some luting cements are claimed to be technique sensitive. The low bond strength may be affected by the moisture content after rinsing the root canal which is difficult to control because of the poor visibility even though the root canals were dried carefully using paper points. Furthermore, the narrow canal holds water by surface tension, making it difficult to displace water with bonding agents (90). There was a study revealed that Rely X Unicem exhibits a moisture tolerance because of water forming during a neutralization reaction of phosphoric acid methacrylate, basic filler and hydroxyapatite. This may explain why Rely X Unicem presented good bond strength with root dentin and had the narrow standard deviation.

The density of dentinal tubule is less and non uniform in the apical region of intraradicular dentin (21). Therefore, hybridization is also affected due to the lower tubule density. The tubule diameter was also gradually decreased toward the apical direction (7). With etch and rinse technique as in Superbond C&B, acid etching opened the tubule surfaces effectively so it created more opportunity to obtain the thicker hybrid layer and more resin tags penetration than Panavia F 2.0 and Maxcem Elite. This was confirmed by SEM that Superbond C&B etched root canal dentin more uniformly than Panavia F 2.0 and Maxcem Elite (Fig 7a and b). When comparing number of opened

tubules per mm^2, Superbond C&B were much more than Panavia F 2.0 and Maxcem elite, this observation suggested that the 10-3 solution of Superbond C&B was effective in etching the intraradicular dentin. Drummond et al (91) measured pull-out strength of various endodontic posts and reported that shear bond strengths to root canal dentin was below 10 MPa with a wide standard deviations which were closed to the bond strength reported in this present study. This also reflected the diversity of root canal dentin characteristics as mentioned above.

Polymerization mode of luting cement also affected the bond strength. As shown in the study, self-curing in Superbond C&B demonstrated better bond strength than dual cured luting cements; Panavia F2.0 and Macxem Elite. This was in agreement with Monticelli et al (9) whose study demonstrated that chemical cured is better than dual cured. Dual-cured resin contain components that provide rapid light polymerization in those areas where the curing light penetrate effectively and slower chemical polymerization in those areas where the light is not effective. Self-curing resin (Superbond C&B) provided slower polymerization process allows the material to flow in pre-gel stage, which provides some stress relief from polymerization contraction at the resin/dentin interface (92). Self-cured resin have less polymerization shrinkage than light-cured resins, which lessens the forces from polymerization contraction and air bubbles, incorporated into resin during the mixing process, provide a stress relief mechanism (93). Polymerization contraction force often exceeds the bond strength of dentin adhesives to dentin, resulting in gap formation along the surfaces with the weakest bonds (75). The low degree of conversion of Panavia F 2.0 and Maxcem, (the earlier generation of Maxcem Elite) were not only affected the intrinsic properties of the cements, leading to cohesive failure, but also showed impaired adhesion (94, 95, 96). The use of different type of initiator system might play role in a different polymerization behavior, which may involve in a low initial degree of conversion. Maxcem was found to have the lowest degree of conversion in the dual-curing mode (97). This might be the cause of lower bond strength compared to Panavia F 2.0 and Rely X unicem shown in this study. The SEM observation from this present study also supported the result from Zicari et al (98) which demonstrated that Rely X Unicem was the only material that demonstrated some 'cohesive' failure inside the post. In these cases, bond strength to the

dentin, as well as to the post, was higher compared with the stability of the post itself (98). In this present study, the cohesive failure was also observed.

The results of microleakage showed that the mechanical cycling and luting cements did affect the bonding of fibre reinforced post and root dentin, therefore, the null hypothesis that 'cyclic loading has no significant effect on microleakage of fibre reinforced post bonded to intraradicular dentin among various luting cements' was rejected.

Microleakage is the diffusion of substances, such as bacteria, oral fluids, molecules and/or ions into a fluid-filled gap or into a structural defect that is present or one that occurs between restorative materials and tooth structure (80). If there were gaps between root dentin and filling material or any voids or air bubbles along the surface of adhesive area or within the cement itself, they would lead to further microleakage. Every factor that mentioned above which cause reduction in bond strength can also lead to microleakage.

In this study, when comparing between the groups without cyclic loading, Superbond C&B demonstrated the lowest microleakage among 4 luting cements but statistically significant only exist between Superbond C&B and Maxcem Elite ($p=0.02$). Panavia F 2.0 also presented significantly lower microleakage compared with Maxcem elite ($p=0.03$). Microleakage of Rely X Unicem was not significantly different from the other three luting cements. Maxcem Elite showed the greatest microleakge. Placing an even layer of luting cement in the canal walls of post space is difficult. If a spot in the canal is left without a coat of luting cement, when the polymerization reaction occurred, it could create microgaps in the canal and eventually microleakage. The hybrid layer created by Superbond C&B was intact which did not allow permeability of oral fluid. This might be the reason why Superbond C&B showed the least microleakage. Panavia F 2.0 used moderate concentration of acidic monomer penetrated through the smear layer and created thin hybrid layer ,while Rely X Unicem formed an ionic bond to the hydroxyapatite at the dentin surface and also obtained mechanical retention from microporosities in hydroxyapatite (99), that is why the microleakage of all these three luting cement were not significantly difference in this study. Maxcem Elite could not etch through the smear layer caused the

lowest bond strength and the greatest microleakage compared to the other three luting cements. This showed that self-adhesive resin cement were not suitable in luting post to root dentin. The morphological of intraradicular dentin, the density and direction of the dentinal tubule, have also led to great variability in microleakage between root dentin and luting cements.

Polymerization shrinkage is a main factor that causes microgaps between adhesive surfaces of luting cements and root dentin which resulted in increasing microleakage. There was a study revealed that the microgaps were found between luting cement and root dentin which was a consequence of light- polymerization shrinkage which happened rapidly (92). Superbond C&B, is an auto-polymerization resin, provided slow polymerization process which can relief stress from polymerization contraction at the resin/dentin interface (92, 93). Thus lessen polymerization shrinkage and less air bubbles were anticipated. This resulted in the lowest microleakage in this study, while other three luting cement are dual- cured. This result was in agreement with Nagas et al (87) who revealed that the penetration of dye to the microgaps between luting cement and root dentin happened because of the rapid light polymerization shrinkage (92). Gorgul et al also demonstrated that auto polymerization (self-cured) luting cement could induce less microleakage than dual cured resin cement (100).

Comparison whithin the same luting cements, the microleakage in the group with cyclic loading was higher than the groups without cyclic loading in all four luting cements. While statistically difference only existed in Panavia F 2.0. The moderate self-etching primer in Panavia F 2.0 (ED primer) was less effective in dissolution of the thick smear layer and the minerals presented in the smear layer which can be able to neutralize the acidity of self-etching primer might cause the incomplete infiltration of resin around collagen fibrils led to the present of microgaps. Moreover, the rapid light polymerization of this resin cement could increase the microgaps which further lead to microleakage. Hand mixing of base and catalyst paste could also create voids or air bubbles in resin itself. While the specimens were submitted under cyclic loading for a period of time, these microgaps acted as a weak point and created the crack propagation joining into the

larger microgaps. Therefore, the microleakage after cyclic loading was higher than the groups without cyclic loading.

Selecting an appropriate adhesive and luting procedure for bonding posts to root dentin is challenging because of anatomy of substrates and limitations in physical and mechanical properties of the adhesive materials. Adhesive materials were frequently compared in terms of bond strength and microleakage. Microleakage is perhaps more important for endodontic applications than bond strength. Even if a material has relatively low bond strength to dentin it may be a good obturating material if it is effective in preventing microleakage.

When considering both bond strength and microleakage properties, Superbond C&B was the proper choice. Superbond C&B demonstrated the highest bond strength compared with every groups with the lowest microleakage than the other 3 groups. The wide range of standard deviation may result from the morphological of root dentin, the difficulty in controlling moisture in root canal, manipulation and the technigue sensitivity.

Within the limitation of the study, the use of etch and rinse adhesive in combination with a self-cured resin cement to lute fibre posts is the most stable luting procedure when compared with a self-etch resin-based cement, a self-adhesive cement and a resin modified glass ionomer cement. Further study should be performed to evaluate bond strength and microleakage between these luting cements after cyclic loading with creating core and crown coverage to simulate the real situation in clinical practice.