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Influence of Fabrication Techniques on Retention Force of Fiber-reinforced Composite Posts

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The purpose of this study was to compare the retention force of FRC posts which were built up using direct and direct-indirect fabrication techniques with two fiber-reinforced core build-up systems (FibreKor and i-TFC). Posts were cemented in endodontically treated bovine single roots with resin cement using either direct or direct-indirect technique. Following which, the retention force of post-and-cores and fracture sites were examined. It was found that both the retention force and fracture site depended on the fabrication technique and resin cements. Post-and-cores built up with direct-indirect technique had greater retention force than those fabricated using direct technique. Fracture modes most frequently observed were adhesive failure at Resin/Dentin interface, a mixture of adhesive failures at Post/Resin and Resin/Dentin interfaces as well as cohesive failure of resin cements. Based on the results of this study, we concluded that when it comes to post-and-core build-up for endodontically treated tooth, the direct-indirect technique is more effective than the direct technique on the retention force of FRC posts.

Key words: Post, Retention force, Resin cement

INTRODUCTION

Crown and bridge restorations are often used to restore endodontically treated teeth. The restorations are supported by individually cast core or a prefabricated metal post-and-core system[1]. However, the difference in elastic modulus between dentin and metallic posts induced stress in the root structure, thereby increasing the risk of root fracture[2]. Furthermore, the grayish color of metallic posts may impair or mar the esthetic aspect of the restoration.

Recently, fiber-reinforced composite (FRC) post-and-core systems have been introduced as a new option for the restoration of endodontically treated teeth. FRC posts are composed of unidirectional carbon or glass fibers embedded in a resin matrix[3], and they have two favorable characteristics. First, the elastic modulus is approximately the same as dentin, whereas metallic posts have an elastic modulus nearly 20 times greater. Second, FRC posts are superior in esthetic quality. Such advantages make FRC posts a good alternative to metallic posts[4,5].

Three principal techniques are used to fabricate FRC post-and-cores: direct technique, direct-indirect technique, and indirect technique. The direct and direct-indirect techniques can be performed at chairside by the dentist, while the indirect technique is performed by the technician in the laboratory. Which of these systems results in the best retention force of a FRC post into a root canal have not yet been demonstrated systematically. Therefore, we hypothesized these fabrication techniques as influencing the retention force of the FRC post-and-core system.

The purpose of this study was to elucidate the influence of different post-and-core fabrication techniques on FRC post retention. In this study, direct and direct-indirect techniques were selected because they offer the advantage of adequate restoration fit without prior laboratory preparation. Retention force of fabricated posts was then examined using a universal testing machine, and the fracture site was observed.

MATERIALS AND METHODS

Root preparation

Intact bovine incisors and canine teeth were cleaned and stored in water at 4℃. Crowns of the teeth were sectioned at the cementoenamel junction using a low-speed handpiece with a water-cooled diamond disk. Each tooth was then cut perpendicular to the long axis. Twenty-eight root canals, each less than 2.0 mm in diameter, were selected.

Roots were endodontically treated with a No. 35K file (Dentsply-Sankin, Tokyo, Japan) until 1 mm from the apex. Prepared root canals were obturated with thermoplasticized and injectable gutta-percha (Obtura II, J. Morita Corporation, Tokyo, Japan). A 2.0-mm diameter drill was used to remove about 5 mm of gutta-percha to standardize the size of prepared root canals. The canals were irrigated with distilled water and dried with paper points. Then, the roots were fixed with self-cure resin (Tray Resin, Shofu, Tokyo, Japan) in an acrylic pipe (17 mm in

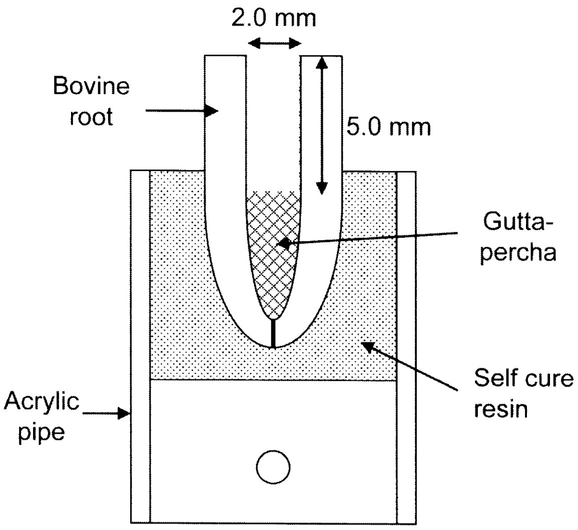

Fig. 1 Schematic illustration of prepared bovine tooth. An endodontically treated bovine tooth was embedded in self-cure resin in an acrylic pipe.

diameter, 30 mm in height), as shown in Fig. 1. Endodontically treated roots were randomly divided into four groups of seven roots each.

Post-and-core fabrication

Fig. 2 shows two kinds of FRC post used in this experiment: a FibreKor® post (Jeneric/Pentron Inc., USA) which was 1.25 mm in diameter and made from resin composite-impregnated straight glass fiber, and an experimental i-TFC post (Sun Medical Inc., Shiga, Japan) which was 1.20 mm in diameter and made from resin composite-impregnated woven glass fiber. The posts were denoted as FK for FibreKor® and i-TFC for experimental i-TFC.

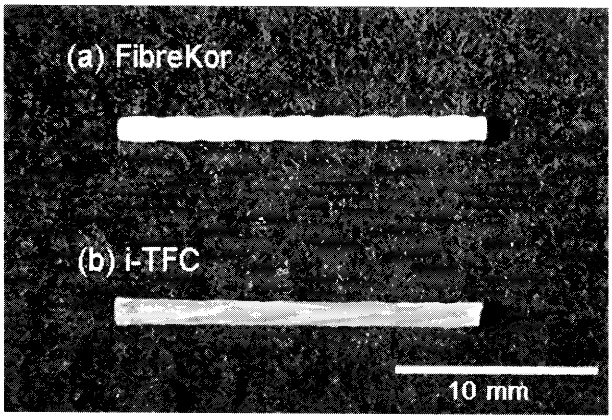

Fig. 2 Two kinds of fiber-reinforced composite post system used in this study: (a) FibreKor and (b) Experimental i-TFC.

The posts were cemented in endodontically treated roots with resin cement (Lute-it for FK post, Jeneric/Pentron Inc., USA) or resin composite (Post Resin for i-TFC, Sun Medical Inc., Japan) by direct or direct-indirect technique. Table 1 lists the four combinations of post-and-core, luting agent, and fabrication technique. Codes "FK D" and "FK D-I" indicated that FK posts were cemented with dual cure type resin cement by direct and direct-indirect techniques respectively. Likewise, codes "i-TFC D" and "i-TFC D-I" indicated that i-TFC posts were cemented with resin composite by direct and direct-indirect techniques respectively.

1 . FibreKor® post by direct fabrication technique (FK D)

Root canal walls were etched with 37% phosphoric acid for 15 s and washed with water according to manufacturer's instruction. Excess water was removed with paper points, leaving the root canal moist. A bonding agent (Bond-1, Jeneric/Pentron Inc., USA) was applied to the root canal and left on the surface for 15 s. The same quantity of dual cure type resin cement base and catalyst (Lute-it, Jeneric/Pentron Inc., USA) were mixed on a paper pad and

Table 1 Fabrication technique and prepared reagent for fiber-reinforced composite posts

Code	Technique	Post	Manufacturer	Cement/Luting	Reagent
FK D FK D-I	Direct Direct-indirect	FibreKor	Jeneric/Pentron Inc.	Lute-it	37% phosphoric acid Bond-1
i-TFC D i-TFC D-I	Direct Direct-indirect	Experimental i-TFC	Sun Medical Inc.	Post Resin	Green activator Superbond C&B

delivered into the root canal with a lentulo spiral using a low-speed handpiece. The FK post was then placed in the root canal with finger pressure. Excess resin cement was removed, and cement in root canal was light-cured for 20 s.

2 . FibreKor® post by direct-indirect fabrication technique (FK D-I)

Super Bond Sep as a separating agent (Sun Medical Inc., Shiga, Japan) was applied to the root canal walls and gently air-dried. The same quantity of resin cement base and catalyst (Lute-it) were mixed on a paper pad and delivered into the root canal with a lentulo spiral. The FK post was then placed in the root canal with finger pressure and light-cured for 20 s. Then, the pre-light cured post-and-core was removed from the root canal and light-cured a second time for 20 s. Then, root canal walls were rinsed with water and dried with paper points to remove the residue of Super Bond Sep. Root canal walls were next etched with 37% phosphoric acid for 15 s and washed with water. Bonding agent and resin cement were applied as was done for "FK D". The above prepared post-and-core was then placed in the root canal with finger pressure. Excess resin cement was removed, and cement in root canal was light-cured for 20 s.

3 . i-TFC post by direct fabrication technique (i-TFC D)

Root canal walls were etched with green activator (10% citric acid and 3% ferric chloride) for 5 s, washed with water, air-dried, and then dried with paper points. The monomer, catalyst, and polymethylmethacrylate (PMMA) powder in SuperBond C&B (Sun Medical Inc., Shiga, Japan) were mixed according to manufacturer's instructions. The mixed resin cement was applied to the root canal with a long brush. A resin composite, Post Resin (experimental resin; Sun Medical Inc., Shiga, Japan), was delivered into the root canal with lentulo spiral and the i-TFC post inserted with finger pressure. Excess resin composite was removed, and resin composite was light-cured for 40 s.

4 . i-TFC post by direct-indirect fabrication technique (i-TFC D-I)

Super Bond Sep was applied with a brush to the root canal walls and gently air-dried. Resin composite, Post Resin, was delivered into the root canal with lentulo spiral. The i-TFC post was inserted into the root canal with finger pressure and light-cured for 10 s. The pre-light cured post-and-core was removed from the root canal and light-cured a second time for 30 s. Then, root canal walls were rinsed with water to remove the residue of Super Bond Sep. Green activator was applied to the root canal for 5 s, washed with water, air-dried, and then dried with paper points. Super Bond C&B was applied as for "i-TFC D". The above prepared post-and-core was then placed in the root canal with finger pressure.

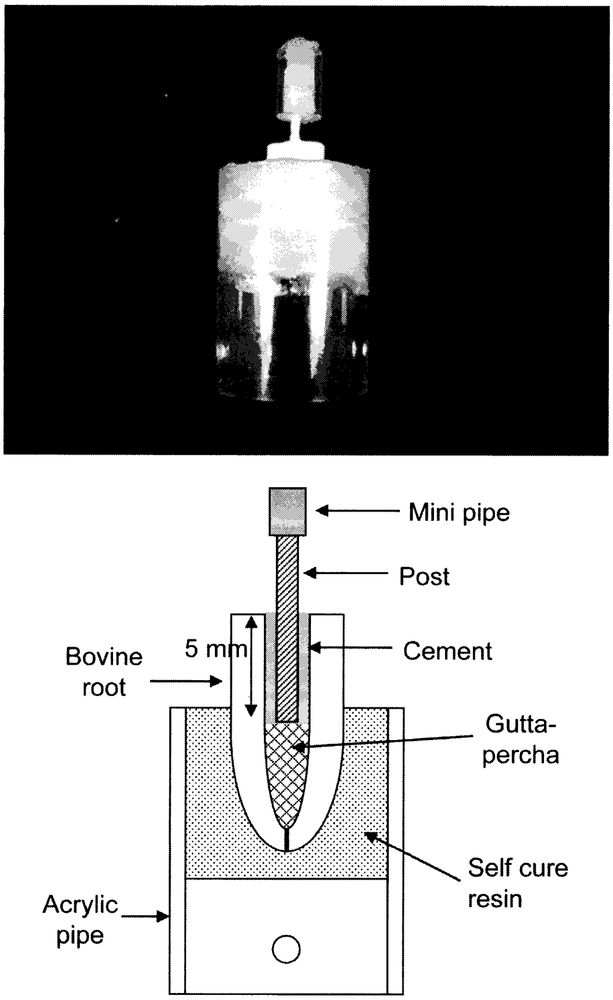

Fig. 3 Photograph and schematic illustration of prepared specimen for retention force test.

After each post-and-core was cemented, a mini acrylic pipe (4 mm in diameter, 10 mm in height) was attached to the top of FRC post with a light-cured composite resin (Core resin, Sun Medical Inc., Shiga, Japan). Fig. 3 shows the photograph and illustration of a test specimen. All specimens were stored for one week at room temperature.

Retention force evaluation

A universal testing machine (Autograph AG-I, Shimadzu, Kyoto, Japan) was used to determine the retention force of each specimen. Fig. 4 shows a photograph of the specimen setup on a testing machine. Crosshead speed was 0.5 mm/min, and the retention force was recorded under tensile mode. After tensile test, fracture sites were observed with a microscope (VH-5000, Keyence Inc., Osaka, Japan).

Statistical analysis

All data were statistically analyzed using analysis of variance (ANOVA) supplemented with Fisher's PLSD

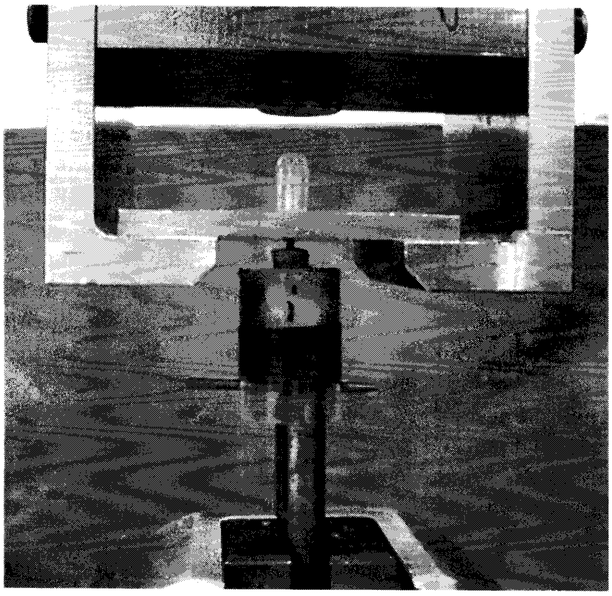

Fig. 4 Test apparatus used for assessing retention force.

at significance level of $p<0.05$.

RESULTS

Table 2 lists the retention forces of post-and-cores fabricated by direct and direct-indirect techniques. In i-TFC D-I group, two specimens were excluded from mean value calculation of retention force due to fracture of acrylic pipe. The i-TFC D-I group had a retention force of 271 N; the highest among the four groups. In contrast, the FK D group had the lowest retention force. The differences in retention force between FK D and FK D-I groups, and between i-TFC D and i-TFC D-I groups, were statistically significant.

Figs. 5(a)-(c) show typical photographs of the fracture sites: (a) Post/Resin indicates the interface between post and resin cement or composite; (b) Resin/Dentin indicates the interface between resin cement or composite and dentin; and (c) Mixture indicates both Resin/Dentin and Post/Resin. Table 3 lists the classifications of fracture sites in each group. Fractures of FK D and FK D-I groups occurred at the Post/Resin interface. In addition, most fractures of FK D group were a Mixture. In contrast, fractures of i-TFC D and i-TFC D-I groups were mainly in Resin/Dentin and Mixture categories.

Table 2 Average and standard deviation of retention force of built-up post-and-core

Code	Average (N)	Standard deviation (N)
FK D*	29^{a}	11
FK D-I*	105^{b}	53
i-TFC D*	167^{b}	59
i-TFC D-I**	271^{c}	126

*n=7.
**n=5 because two specimen were excluded.
Different letters (a, b, c) indicate statistical differences between groups based on ANOVA and Fisher's PLSD ($p<0.05$).

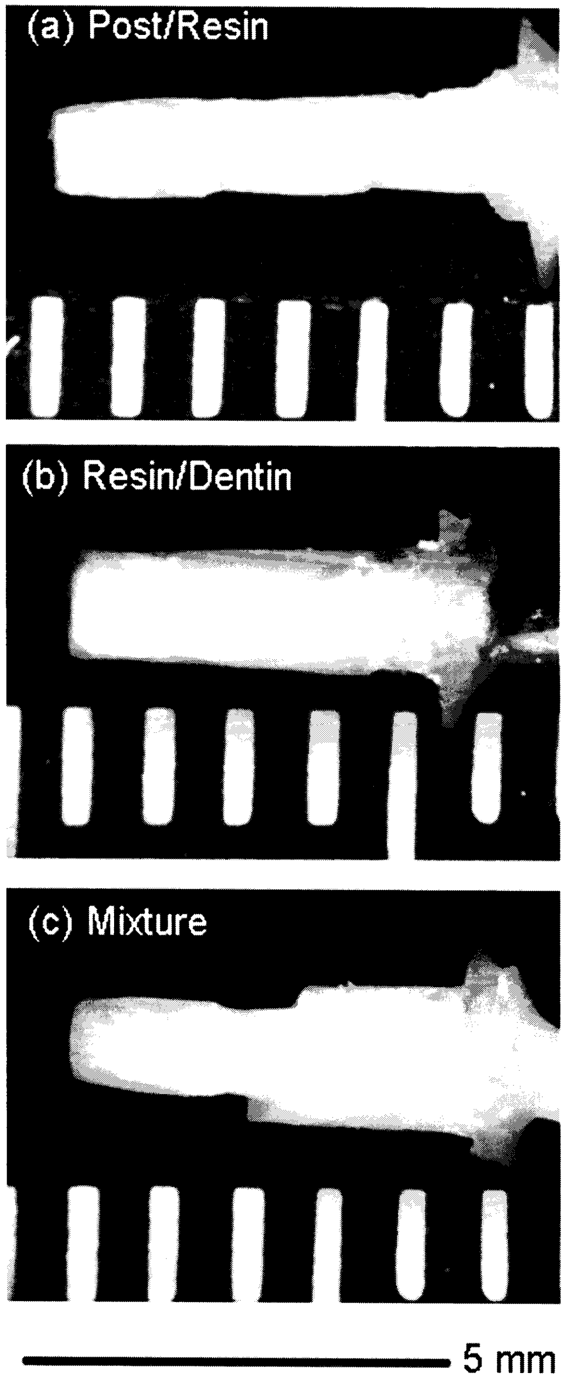

Fig. 5 Typical classification of failure sites after retention force test. (a) Post/Resin: interface between post and resin cement or composite; (b) Resin/Dentin: interface between resin cement or composite and dentin; (c) Mixture: interfaces between post or dentin and resin cement or composite.

Table 3 Classification of fracture modes after retention force test

Code	Post/Resin	Resin/Dentin	Mixture	Others*
FK D	2		5	
FK D-I	2	3	2	
i-TFC D		5	2	
i-TFC D-I		3	2	2

*Two specimens were fractured at acrylic pipe during retention force test

DISCUSSION

Recently, FRC post-and-core systems have been widely used for the restoration of endodontically treated teeth because FRC posts have an elastic modulus close to dentin and a more pleasing esthetic quality than metallic posts[4,5]. Of the available post-and-core fabrication techniques, two are highly recommended as such: direct fabrication technique for FRC posts of Jeneric/Pentron Inc., and direct-indirect fabrication technique for FRC posts of Sun Medical Inc.. However, it is still unclear which fabrication technique is more suitable for these FRC post-and-core systems. In this study, therefore, we examined the influence of fabrication technique on the retention force of post-and-cores.

In the present study, the difference in retention force between FK D and FK D-I was statistically significant. Note that FK D fractures occurred at Post/Resin interface or were a Mixture (*i.e.*, at the interface between post and resin cement or at the interface between resin cement and dentin). The luting agents remained in the root canal as well as on the post surface (Fig. 5(c)). This indicated that the failure mode was a combination of adhesive and cohesive failures at the post and resin cement interface. These results implied that either the bond strength between resin cement and post was weak, or that the cure depth was shallow. Cure depth is related to the light source or power density, light curing time, and resin shade[6,7]. Inadequate curing is known to result in a lower degree of polymerization at the bottom of the root canal, whereby fracture at mid-range of core suggested a low degree of polymerization in the resin cement. In other words, a post-and-core fabricated with direct technique might fracture within resin cement because power density of light source was insufficient to cure the resin cement. In addition, material composition of resin cement and curing mode can affect polymerization shrinkage. Although a low filler content of resin cement decreases viscosity and facilitates clinical procedure, these cements have more volumetric shrinkage than those with high filler content[8]. Consequently, retention force of post-and-core is decreased if luting cement is applied.

In the case of experimental i-TFC post, i-TFC D-I yielded a higher retention force than i-TFC D. However, most fractures for these two groups occurred at the Resin/Dentin interface. These results might be related to the polymerization shrinkage of the resin composite. Polymerization shrinkage caused stress at Resin/Dentin interface, resulting in gap formation at the interface[9]. By taking polymerization shrinkage of resin composite into consideration, the difference in retention force between direct technique and direct-indirect technique can be explained as follows. In direct-indirect technique, most of the polymerization shrinkage occurred during light-curing outside the root canal. When the pre-light cured post-and-core was re-inserted in the root canal, adhesion with resin cement worked only between dentin and the core resin of post-and-core. On the other hand, in direct technique, polymerization shrinkage of resin composite occurred in the root canal. Consequently, the thickness of i-TFC D-I resin cement was thinner than that of i-TFC D. In addition, the technique used for cement filling might lead to voids or bubbles[10,11]. In direct-indirect technique, the fabrication system might serve to reduce operator mistakes. In summary, the difference in retention force between i-TFC D and i-TFC D-I could be attributed to polymerization shrinkage or voids/bubbles in the resin cement or resin composite.

When comparing the two post systems, the i-TFC system exhibited a higher retention force than the FibreKor system. The difference in retention force is influenced not only by the morphology or material of the FRC post, but also by the properties of resin cement and resin composite. Consequently, the retention force of post-and-core influences the adaptation of the restoration[12]. Resin cement and resin composite played the role of the luting agent between FRC post and dentin, and then that of retention of post or restoration. In this study, no fractures occurred in the FRC posts after tensile test, indicating the importance of luting agent's properties. The luting material must adhere to both the dentin and the post, thereby maintaining the post or restoration. According to the manufacturer's instructions for FibreKor system, the post-and-core system is to be fabricated by direct technique using bonding agent, dual-cure resin cement, base, and catalyst. In contrast, the i-TFC post-and-core system is recommended to be fabricated by direct-indirect technique using self-cure adhesive resin cement and resin composite. Therefore, the comparison of FK and i-TFC posts is not as important as the comparison of resin materials that influence the retention force of post-and-cores. Difference in retention force of post-and-core cemented with dual cure type resin or light-cure type resin should be examined further detailed research elsewhere.

In the present study, some specimens exhibited standard deviations that span over a wide range. Other studies on the retention force of post-and-core systems also revealed wide deviations in measurement[13-15]. A possible explanation for this is the unequal sizes and shapes of the root canals, coupled with the inevitable differences in texture and properties of the root canal walls[13]. Furthermore, technique employed by dentists to fabricate post-and-cores could influence retention force too. Since a wide disparity among retention forces exists in clinical applications, dentists should be educated on the various factors that influence retention force of post-and-core, and thereby develop effective fabrication techniques.

CONCLUSIONS

We investigated the hypothesis that fabrication technique influenced the retention force of post-and-cores. The results of two kinds of fiber-reinforced core build-up system showed that post-and-cores fabricated by direct-indirect technique exhibited a higher retention force than those fabricated by direct technique. The difference was statistically significant. In conclusion, the results of this study clearly suggest that direct-indirect technique is an effective chairside technique for fiber-reinforced core build-up systems.

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REFERENCES

1) Christensen G. Posts and core: States of the art. J Am Dent Assoc 1998; 129: 96-97.
2) Mannocci F, Innocenti M, Ferrari M, Watson TF. Confocal and scanning electron microscopic study of teeth restored with fiber post, metal post, and composite resin. J Endodont 1999; 25: 789-794.
3) Perdigao J, Villar A. Use of a tooth-colored post for anterior restorations. Northwest Dentistry 2002; 81: 13-17.
4) Akkayan B, Gulmez T. Resistance to fracture of endodontically treated teeth restored with different post systems. J Prosthet Dent 2002; 87: 431-437.
5) Duret B, Duret F, Reynaud M. Long-life physical property preservation and post endodontic rehabilitation with the Composipost. Compendium of Continuing Education in Dentistry (Supplement) 1996; 20: S50-S56.
6) Tanoue N, Matsumura H, Atsuta M. Curing depth of composite veneering materials polymerized with seven laboratory photo-curing units. J Oral Rehabil 1998; 25: 199-203.
7) Tarle Z, Meniga A, Ristic M, Sutalo J, Pichler G. Polymerization of composites using pulsed laser. Euro J Oral Sci 1995; 103: 394-398.
8) Condon JR, Ferracane JL. Assessing the effect of composite formulation on polymerization stress. J Am Dent Assoc 2000; 131: 497-503.
9) Peutzfeldt A, Asmussen E. Determinants of *in vitro* gap formation of resin composites. J Dent 2004; 32: 109-115.
10) Monticelli F, Goracci C, Ferrrari M. Micromorphology of the fiber post-resin core unit: a scanning electron microscopy evaluation. Dent Mater 2004; 20: 176-183.
11) Vichi A, Grandini S, Davidson CL, Ferrari M. An SEM evaluation of several adhesive systems used for bonding fiber posts under clinical conditions. Dent Mater 2002; 18: 495-502.
12) Furukawa K, Inai N, Tagami J. The effects of luting resin bond to dentin on the strength of dentin supported by indirect resin composite. Dent Mater 2002; 18: 136-142.
13) Hedlund SO, Johansson NG, Sjogren G. Retention of prefabricated and individually cast root canal posts *in vitro*. Brit Dent J 2003; 195: 155-158.
14) Tsai PCL, Meyers IA, Walsh LJ. Depth of cure and surface microhardness of composite resin cured with blue LED curing lights. Dent Mater 2004; 20: 364-369.
15) Purton DG, Love RM, Chandler NP. Rigidity and retention of ceramic root canal posts. Oper Dent 2000; 25: 223-227.