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Study on the Fracture Strength of Root Reconstructed with Post and Core: Alveolar Bone Resorbed Case

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This study evaluated the influence of alveolar bone level on the fracture resistance of root restored with post and core. Forty-eight extracted human mandibular premolars were divided into six groups. Cast posts and cores were cemented (MN8 and MP8) or resin cores were built up with fiber posts and composite resin (FN8, FP8, FN4, and FP4). Post length was 8 mm (MN8, MP8, FN8, and FP8) or 4 mm (FN4 and FP4). Specimens were embedded 2 mm (MN8, FN8 and FN4) or 5 mm (MP8, FP8 and FP4) below cement-enamel junction. All specimens were loaded at 45 degrees to the long axis until fracture. With normal bone model, cast post and core (MN8) showed the highest fracture resistance (2262.4 N). However, in the resorbed bone model, there were no significant differences in fracture resistance between cast post and core and fiber post with composite resin.

Key words: Glass fiber post, Alveolar bone, Fracture strength

INTRODUCTION

Root canal posts are frequently used in the restoration of endodontically treated teeth to aid crown retention. In particular, cast posts and cores are the most popular choice worldwide. Recently, due to marked improvement in the mechanical properties of composite resins, they have been used as a core buildup material with stainless steel post, quartz fiber post, carbon fiber post, or glass fiber post instead of cast post and core. When cast metal posts and cores are used, ions of corroded metal rarely dissolve in the oral cavity and they are believed to be one of the substances that triggers metal allergic reactions[1]. On the other hand, when all-ceramic crowns or resin jacket crowns are chosen as final restorations, the use of composite resin with glass fiber post enhanced the ability to reproduce the shade and translucency of natural teeth[2].

While cast post and core has been regarded as the gold standard in the restoration of endodontically treated teeth, researches on post design are still continuing with unabated ardor and diligence. Some authors suggested that post length should be half to two-third of root length[5,6]. Others proposed that a suitable diameter for the cast post should be one-third of root width. Then, there were also many researchers who studied the form of post tip to avoid stress concentration. Indeed, retention of a cast post and core depends on the depth and shape of dowel space as well as the volume of the remaining tooth structure. This is because after softened carious dentin or undercuts are removed to prepare the dowel space, root canal dentin may be thinned. Since there are great differences in Young's modulus between metal and dentin, excessive stress concentration may cause root fracture, especially in a clasped tooth of removable partial denture or abutment tooth of fixed partial denture. On the contrary, the Young's modulus of composite resin core with glass fiber post is similar to that of natural tooth dentin. As a result, they serve to decrease stress concentration and thereby increase longevity of the restoration.

A lot of papers on the *in vitro* studies of posts and cores have been published[7−13]. In many studies, composite resin cores were reported to have significantly lower fracture strength than cast posts and cores[7,8]. However, most researchers do not pay attention to the level of alveolar bone. It must be highlighted that when the alveolar bone is resorbed, especially with aged people, occlusal relationship with the crown and post and core must also be reconstructed. The purpose of this study, therefore, was to examine the influence of alveolar bone level on the fracture strength and failure mode of the tooth root reconstructed with two different post and core systems − namely, resin core with glass fiber post and cast metal post and core.

MATERIALS AND METHODS

Experimental conditions

Table 1 lists the post and core systems evaluated in this study, and Fig. 1 illustrates the experimental conditions. For the composite resin cores, two post lengths were used (4 mm and 8 mm). Specimens were embedded in acrylic resin either 2 mm below the cement-enamel junction (CEJ) (*i.e.*, normal bone

Table 1 Experimental groups

Group	Model	Post length (mm)	Post and core type
MN8	I	8	Cast metal post and core
MP8	II	8	Cast metal post and core
FN8	I	8	Resin core with glass fiber post
FP8	II	8	Resin core with glass fiber post
FN4	III	4	Resin core with glass fiber post
FP4	IV	4	Resin core with glass fiber post

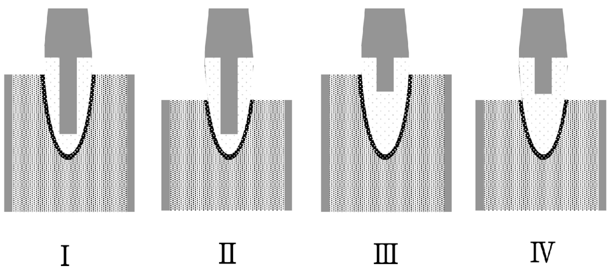

Fig. 1 Schematic illustration of the embedded models. Types I and III were of the normal bone model, and Types II and IV were of the alveolar bone resorption model. Post length was 8 mm in Types I and II, 4 mm in Types III and IV.

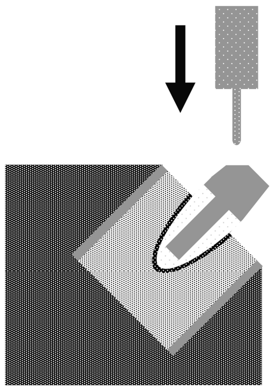

Fig. 2 Schematic illustration of loading test. Specimens were fixed at an exclusive gauge and loaded at 45 degrees to the long axis with a universal testing machine at a cross-head speed of 1.0 mm/min until fracture.

model) or 5 mm below CEJ (*i.e.*, resorbed bone model).

Tooth specimens and endodontic treatment

Forty-eight extracted human mandibular premolars (with single root canal), free of cracks, fractures, and caries were used in this study. Immediately after extraction, they were preserved in a frozen state at −15℃. Before this experiment commenced, tooth specimens were defrosted at room temperature and divided into six groups of eight specimens each. All specimens were sectioned at the cement-enamel junction with a low-speed diamond saw (Isomet, Buehler Ltd., Germany), and the crowns were removed. All canals were shaped with K-files (up to No. 40) and then washed with 6% sodium hypochlorite solution and 2.5-3.5% hydrogen peroxide solution. After they were dried, they were obturated with gutta-percha points (GC Co., Japan) and polymeric calcium hydroxide root canal sealer (Sealapex, Kerr, USA).

Cast post and core

Dowel spaces of 8 mm depth were prepared with #3 post drill (1.5 mm in diameter, taper 1/20 Nikkosha, Japan). Impressions for the post and core cavity were taken using hydrophilic vinyl polysiloxane impression materials (ExamineFine Regular Type and Regular Hard Type, GC Co., Japan). Stone casts from these impressions were fabricated with a modified dental stone (New Fujirock, GC Co., Japan). Wax patterns were fabricated with an inlay wax (Inlay Wax Soft, GC Co., Japan) and a prefabricated plastic post pattern. They were then invested with an investment material (Cristobalite PF, Shofu Inc., Japan) and cast with gold-silver-palladium alloy (Castwell MC 12% Gold, GC Co., Japan).

As shown in Fig. 2, height of core was 5 mm. To apply load, the bucco-coronal edge of the abutment was removed at an angle of 45 degrees. Fitness of cast post and core was checked and adjusted to ensure a passive fit with the white silicone (Fit Checker, GC Co., Japan). Then, specimens were abraded with 50-μm aluminum oxide powder under 5 kg/cm^2 pressure in five seconds and cemented with glass ionomer cement (Ketac Cem, 3M ESPE, Germany). All specimens were stored in purified water at 37℃ for 24 hours in darkness.

Composite resin core with glass fiber post

Dowel spaces of 8 mm (FN8 and FP8) or 4 mm (FN4 and FP4) depth were prepared with an exclusive post drill (FiberKor Post Drill, Pentron, USA; 125 mm in diameter). After etching for 10 seconds with 40% phosphoric acid (K-etchant GEL, Kuraray Medical Inc., Japan), tooth specimens were rinsed with water and air-dried. Then, root canal dentin was applied with a primer (Clearfil Liner Bond II Σ Primer agent, Kuraray Medical Inc., Japan) for 20 seconds. Excessive primer agent was removed with paper points and dried with air. Next, a bonding agent (Clearfil Liner Bond II Σ Bond agent, Kuraray Medical Inc., Japan) was applied, and excess bonding agent was removed with paper points and air-dried. Treated tooth specimens were then cured with a light-curing unit (Optilux 501, Kerr, USA) for 40 seconds.

Length of glass fiber post (FiberKor Post, Pentron, USA) was adjusted to extrude 3 mm above CEJ and coated with a silane coupling agent and primer (Clearfil Liner Bond II Σ Primer A, B and Clearfil Porcelain Bond, Kuraray Medical Inc., Japan). Auto-mixed composite resin (Clearfil DC Core Automix, Kuraray Medical Inc., Japan) was injected into the dowel spaces and the glass fiber posts were inserted. After curing with the same light-curing unit for 40 seconds, the cores were built up with the same composite resin using core forms (Build-It Core Forms, Pentron, USA). All specimens were prepared for abutment teeth. Height of core was 5 mm, and the bucco-coronal edge of the abutment was removed in order to apply load (Fig. 2). All specimens were then stored in purified water at 37℃ for 24 hours in darkness.

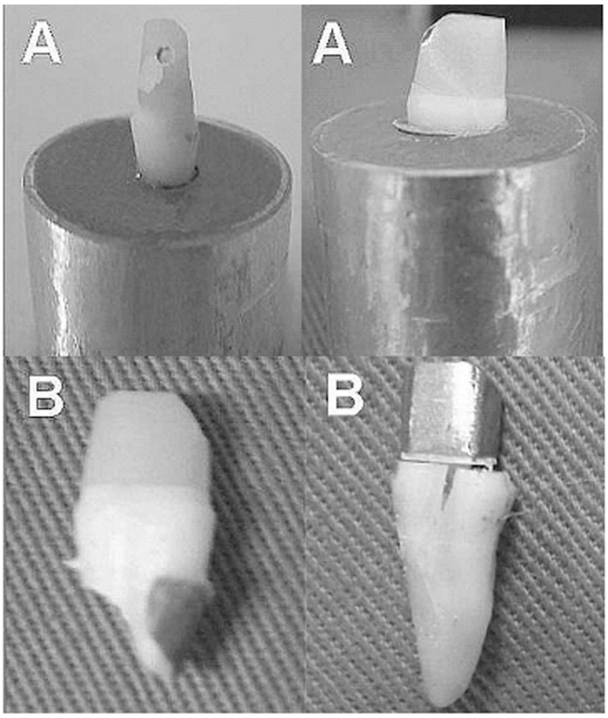

Fig. 3 Photographs showing typical fracture modes (A: restorable fracture; B: non-restorable fracture).

Embedded model

Aluminum rings (20 mm in length and 20 mm in diameter) were filled with acrylic resin (Pala press vario, Heraeus Kulzer, Germany), and specimens were embedded in the prescribed position using a gauge. Upper level of acrylic resin was either 2 mm (MN8, FN8, and FN4) or 5 mm (MP8, FP8, and FP4) below the CEJ. Each specimen's root was surrounded with a layer of silicone (Correct Plus Bite, Pentron, USA) to serve as the artificial periodontal ligament (about 0.25 mm). The four types of embedded model are shown in Fig. 1.

Loading test

All specimens were fixed at the exclusive gauge (Fig. 2) and loaded at 45 degrees to the long axis with a ball end (ϕ2.0mm) using a universal testing machine (Aughtgraph AGS-H, Shimadzu Co. Ltd., Japan) at a cross-head speed of 1.0 mm/min until fracture. The compressive load required to cause fracture was recorded for each specimen. After the loading test, the failure modes of all specimens were classified into two groups by visual inspection — Group A: Core portion failed or lowest point of fracture was above acrylic resin; Group B: Lowest point of fracture was below acrylic resin (Fig. 3).

Statistical analysis

One-way ANOVA and Dunnett's T3 test were used for the statistical analysis of fracture loads with significance level at $\alpha = 0.05$. First, one-way ANOVA was used to detect overall significance. Following which, Dunnett's T3 test was used to identify which pairs of groups demonstrated a significant difference ($\alpha = 0.05$). Additionally, the chi-square test was used for the statistical analysis of fracture modes ($\alpha = 0.05$).

RESULTS

Fracture strength

Arithmetic mean and standard deviation of obtained stress value for each group are presented in Tables 2 and 3. Cast post and core with normal bone level showed the highest fracture strength (2262.4 N). There were statistically no significant differences among these groups except for comparison between MN8 and the others ($P < 0.05$).

Failure mode

Failure mode results for each group are listed in Table 4 and statistical analysis results using chi-square test are presented in Table 5. For both normal and resorbed bone level models, cast post and core showed non-restorable root failure. With the normal bone level model, composite resin core with glass fiber post showed restorable root failure in majority of the specimens. However, with the resorbed bone level model, composite resin core with glass fiber post deeply inserted in the root canal had a tendency to exhibit non-restorable root fracture.

Table 2 Statistical analysis by one-way ANOVA ($P<0.05$)

Group	Sum of squares	df	Mean square	F	Sig.
Between groups	17304936.297	5	3460987.259	25.252	0.000
Within groups	5756409.031	42	137057.358		
Total	23061345.328	47			

Table 3 Fracture strength results (n=8)

Group	Mean ± S.D. (N)
MN8	2262.4 ± 677.0^a
MP8	739.5 ± 344.4^b
FN8	856.2 ± 347.2^b
FP8	514.3 ± 216.2^b
FN4	785.4 ± 220.7^b
FP4	536.8 ± 171.4^b

All values are mean ± SD. Groups with the same superscript letter are not significantly different ($P>0.05$).

Table 4 Fracture mode results (n=8)

Group	A	B
MN8	0	8
MP8	0	8
FN8	6	2
FP8	4	4
FN4	6	2
FP4	7	1

A Core portion failed or lowest point of fracture was above the acrylic resin.
B Lowest point of fracture was below acrylic resin.

Table 5 Results of chi-square test for the fracture modes ($P<0.05$)

	MN8	MP8	FN8	FP8	FN4	FP4
MN8		—	*	—	*	*
MP8	—		*	—	*	*
FN8	*	*		—	—	—
FP8	—	—	—		—	—
FN4	*	*	—	—		—
FP4	*	*	—	—	—	

*: $\alpha=0.05$
—: not significantly different

DISCUSSION

Tooth specimens and root canal treatment

In previous studies that investigated the bonding strength of composite resin luting cement to root canal dentin, bovine teeth were used for the experiments[14−17]. However, Cagidiaco *et al.*[18] reported that tubular density and diameter were important factors that influenced resin bonding to dentin after acid etching, and that these factors were different between bovine teeth and human teeth. Therefore, in the present study, extracted human mandibular premolars were used as the tooth specimens.

If formaldehyde fixative or alcohol were used as the conservation liquid of extracted teeth, it would lead to degeneration of root canal dentin. Therefore, tooth specimens were frozen at −15℃ after dental calculus and periodontal membrane were removed. Likewise, the use of sodium hypochlorite solution for pulp chamber wall would also adversely affect the bonding strength of some adhesives[19]. However, the irrigation of root canals with sodium hypochlorite solution and hydrogen peroxide solution are well known measures for endodontic treatment[20]. Therefore, in this study, chemical cleaning of root canals was performed with 2.5-3.5% sodium hypochlorite solution and hydrogen peroxide solution. This experiment was carried out under conditions that largely simulated clinical conditions.

Setup of experimental conditions

In some studies that investigated the fracture strength of abutment teeth restored with dowel and core, tooth specimens were embedded in either acrylic resin or dental stone[21−25]. In these studies, volume of the alveolar bone was completely out of consideration. However, in many clinical cases, patients do not always have sufficient amount of alveolar bone, especially among aged people. So, in this research, the assumptions were that the initial periodontal treatment was already completed and the movements of teeth settled. However, alveolar bone resorption was also recognized, and thus the alveolar bone resorption model was produced. With both normal and alveolar bone resorption models, we then studied the fracture strength of endodontically treated teeth restored with different post-and-core designs.

To acquire sufficient retention for the cast post and core construction, some authors have suggested that an adequate post length would be half to two-third of root length[5,6]. Average root length of the first human mandibular premolar is said to 12.5 mm while that of the second premolar is 13.0 mm[26]. Therefore, in this study, post length was set at 8 mm and glass ionomer cement was used as the luting agent. For cast post and core, the retention force depends on the mechanical interlocking force. As for resin core with glass fiber post, the retention force depends on the bond strength between resin and root canal dentin. In the latter case, it is not clear yet how long the glass fiber post should be. Therefore, two post lengths were used to find out how long the glass fiber post should be.

Failure strength and failure mode

The principal objective of this study was to evaluate the fracture strengths and failure modes of the assessed posts and cores. Therefore, the final restorations were not cemented on the posts and cores to preclude influences stemming from ferrule effect and the material properties of the final restorations. As a result, cast post and core of the normal bone model showed the highest fracture strength (2262.4 N), which was similar to previous studies[21,22]. As for the cast post and core in resorbed bone model, it showed a lower fracture strength (739.5 N) than that of the normal bone model. However, regardless of alveolar bone level, all cast post and core specimens showed non-restorable root failure. In other words, root fracture reached under the alveolar bone.

Young's modulus of gold-silver-palladium alloy is about 90 GPa, while that of human dentin is 15-20 GPa. The difference in Young's modulus between metal post and human dentin causes stress concentration at the tip of the metal post and the alveolar bone ridge. This phenomenon then induced lateral root fracture. In the alveolar bone resorption model, the distance between the top of the alveolar bone (which acted as the fulcrum) and loading point was longer than that of the normal bone model. Therefore, specimens in the alveolar bone resorption model — even specimens with glass fiber post deeply inserted in the root canal — showed the same non-restorable root fracture, as the metal post sustained only a low load level.

In the normal bone model, composite resin cores with glass fiber posts showed no significant differences in fracture load and mode regardless of post length. Most of the specimens showed restorable root failure. Despite low fracture resistance, most of the fractures remained inside the composite resin core and did not reach under the alveolar bone. Young's modulus of glass fiber post is 29.2 GPa, which is close to that of dentin compared with metal post. Therefore, stress concentration was reduced at post tip. However, fracture strengths of composite resin core with glass fiber post were much lower than that of cast metal post and core. Some researchers suggested that the fracture strength of restored teeth with post and core is related to the ferrule length[25,27]. Therefore, if we restore endodontically treated teeth with fiber post and composite resin, it had better to count on the ferrule effect.

In the alveolar bone resorption model, fracture strength of resin core with fiber post was the same as that of cast metal post and core — regardless of post length. This meant that what mattered most for the fracture resistance of a metal post was not the post length but the post length below the alveolar bone.

In terms of fracture mode, half of FP8 specimens showed non-restorable root failure. This meant that in an alveolar bone resorption case, restoration with 8 mm long glass fiber post did not show any significant improvement in root fracture mode when compared with cast post and core (Table 5). On the other hand, with 4 mm long fiber post and composite resin core, there were statistically significant differences in root fracture mode when compared with cast post and core. Indeed, most of the composite resin restorations with 4 mm long glass fiber post showed restorable root failure. Through the results of this study, it was shown that in an alveolar bone resorption case, composite resin core with glass fiber post did not need a post length equal to cast metal post. The length of 4 mm for glass fiber post was not only adequate, but even more appropriate than the length of 8 mm.

CONCLUSIONS

Within the limitations of the present study, the following conclusions were drawn:

- With the normal alveolar bone model, cast post and core showed the highest fracture strength (2262.4 N).
- With the resorbed alveolar bone model, the fracture strength of cast post and core was comparable to that of composite resin core with glass fiber post.
- With cast post and core, there were no relations between fracture pattern and alveolar born level.
- With composite resin core and glass fiber post in the normal alveolar bone case, fracture strength did not depend on post length and a higher rate of restorable root fractures was indicated.
- In the alveolar bone resorption case, glass fiber post of 4 mm length showed a restorable fracture pattern with no observable differences in fracture strength when compared with 8 mm long fiber post.

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