Effect of a Crown Ferrule on the Fracture Strength of Endodontically Treated Canines Restored with Fiber Posts and Metal-Ceramic or All-Ceramic Crowns

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The aim of this study was to comparatively evaluate the fracture strength of endodontically treated canines restored with glass-fiber posts (GFPs) and either metal-ceramic (MC) or all-ceramic (AC) crowns in the presence or absence of 2 mm of ferrule height. Fifty human maxillary canines were endodontically treated and randomly divided into five groups of 10 specimens each. The first group remained intact (control), while the remainder were restored with GFPs and composite cores with either MC or AC crowns. Each of the AC and MC groups was equally divided between teeth with or without ferrule. Teeth were embedded in acrylic resin and loaded at a 135-degree angle to their long axis until fracture. Fracture strength was not significantly different between ferrule and no ferrule groups ($P = .571$), but was significantly larger for the MC groups compared with the control and AC groups ($P = .009$ and $P = .024$, respectively). A significant effect of the type of restoration was found as teeth restored with MC crowns presented significantly higher fracture strength, independently of ferrule.
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Glass-fiber posts (GFPs) have been introduced as a valid alternative to metal posts in the restoration of endodontically treated teeth (ETT) because of their esthetic advantages, favorable modulus of elasticity that is similar to dentin, and the reduced risk of fractures.[1] The most essential component with respect to fracture resistance of ETT is a remaining circumferential dentin collar of at least 2 mm in height called the "ferrule effect," although findings have been controversial.[2–4] A major factor that can affect the fracture strength of ETT restored with posts is the placement of metal-ceramic (MC) or all-ceramic (AC) crowns, which may provide a reinforcing effect, thereby downgrading the real benefit of the presence of ferrule.[5]

The aim of this study was to evaluate the fracture strength of endodontically treated canines (ETC) restored with GFPs and either MC or AC crowns in the presence or absence of ferrule. Two research hypotheses were investigated: *(1)* the presence of 2-mm ferrule above the cementoenamel junction (CEJ) would significantly increase the fracture strength of ETCs restored with fiber posts and either MC or AC restorations, and *(2)* the type of restoration would affect the fracture strength of ETCs restored with GFPs irrespective of the presence or absence of 2-mm ferrule.

Materials and Methods

Fifty maxillary human canines with similar dimensions were used and divided equally between five groups of 10 specimens each (Fig 1). After root canal instrumentation (ProTaper files, Dentsply) and obturation using lateral compaction of gutta-percha, specimens were embeded in autopolymerizing acrylic resin (Triplex, Ivoclar Vivadent) up to a level set at 2 mm below the CEJ. To simulate the periodontal ligament, the

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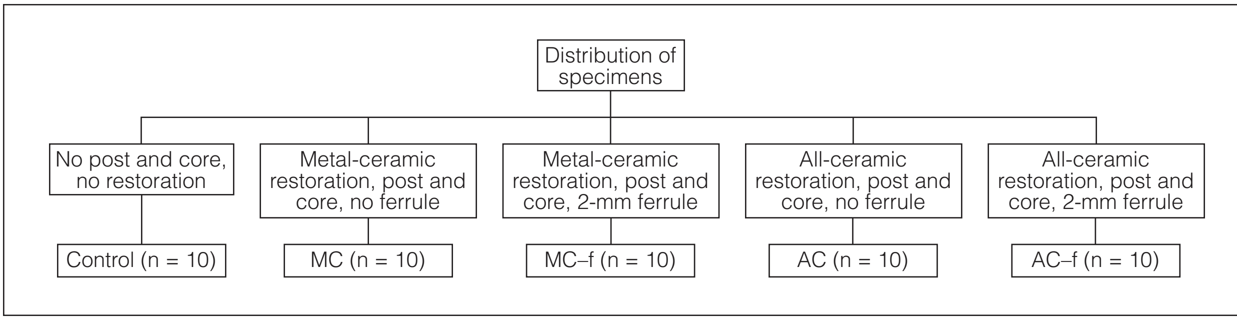

Fig 1 Distribution of specimens.

root surfaces were coated with a layer of polyvinyl siloxane impression material (Virtual, Ivoclar Vivadent) prior to embedding.

The GFPs (Reforpost, Angelus, Odonto-LógiKA) were luted with a dual-polymerizing adhesive resin cement (Panavia F 2.0, Kuraray) that deposited at least 5 mm of apical gutta-percha seal in all specimens. Composite resin core buildups (Beautiful II Giomer, Shofu) were standardized using the same cellulite core-forming matrix (C-95, Kemdent). A silicone index key was fabricated to control preparation depth (MC: chamfer, 1.5 mm buccally and gradually diminishing to 0.5 mm palatally; AC: chamfer, uniform depth of 1.0 mm). MC crowns were fabricated using a nickel-chromium alloy (Verabond 2, Alba Dent) and an appropriate veneer ceramic (VMK95, Vita Zahnfabrik) and were cemented with a glass-ionomer cement (GC Fuji I). The AC crowns were fabricated from lithium discilicate–reinforced glass-ceramic (IPS Empress-2, Ivoclar Vivadent) and cemented with a dual-cure resin cement (Panavia F 2.0). The specimens were subjected to static loading 3 mm below the incisal edge on the palatal aspect of the crowns on a universal testing machine (Instron 3344, Instron) at a 135-degree angle to the long axis of the root with a crosshead speed of 0.5 mm/min until fracture (Fig 2). Fracture was defined as the point at which the loading force reached maximum value.

Analysis of covariance (ANCOVA) was used to adjust the fracture strength relative to the tooth dimensions. The ANCOVA model included the main effect of the five groups and the effects of the three-dimensional measures as covariates. Mean values were statistically compared with the least significant difference (LSD) criterion at a significance level of $P < .05$.

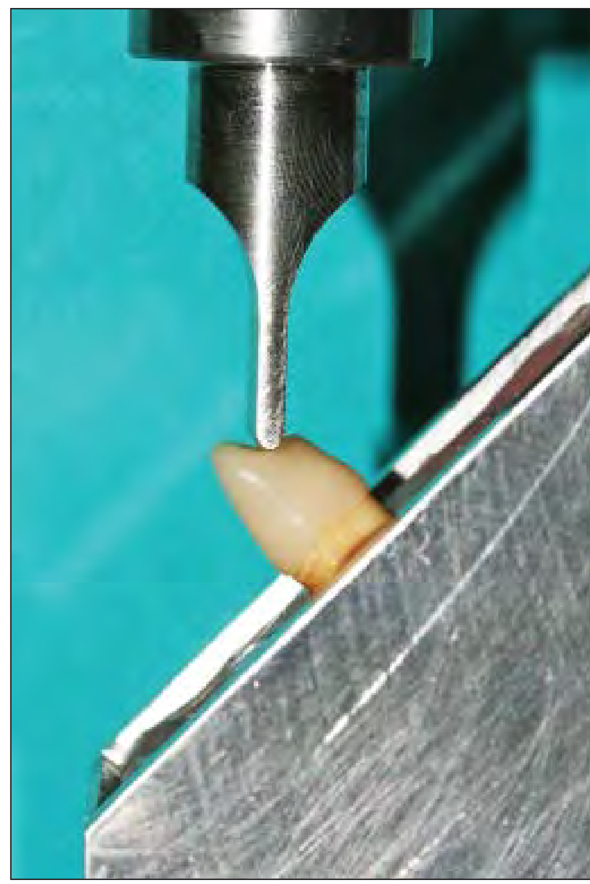

Fig 2 Loading of specimens for the fracture strength test.

Results

The overall mean (± standard deviation [SD]) root dimensions (n = 50) measured from the CEJ are presented in Fig 3 and Table 1. The fracture strength was not statistically significant between the ferrule and no ferrule groups ($P = .571$), independent of the type of restoration, as shown in Tables 2 and 3. The fracture strength for the ferrule MC group was statistically significantly greater than for the control and AC groups.

Fracture strength was statistically significantly greater for both MC groups than for the control and AC groups ($P = .009$ and $P = .024$, respectively). The control and AC groups were not statistically significantly different ($P = .608$).

Fig 3 The mean (± SD) root dimensions (mm) for each group.

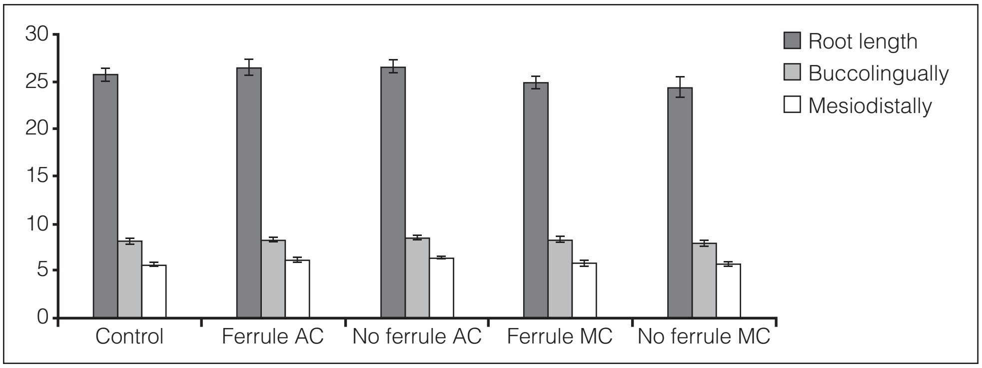

Table 1 Mean Root Dimensions (mm)

		AC		MC	
	Control	Ferrule	No ferrule	Ferrule	No ferrule
Root length	25.76	26.57	26.68	24.92	24.45
Buccolingually	8.17	8.26	8.47	8.33	7.91
Mesiodistally	5.63	6.12	6.4	5.81	5.71

Table 2 Fracture Strength (N) of Each Group

Group	Observed mean	Adjusted mean*	SE
Control	288.20	300.56^{c}	133.79
Ferrule AC	469.10	412.18^{bc}	131.37
No ferrule AC	451.30	357.15^{bc}	140.93
Ferrule MC	753.10	788.45^{a}	131.50
No Ferrule MC	573.80	677.15^{ab}	135.83
	LSD	358.15	

SE = standard error.
*Adjusted means are estimated for the following covariates' values: root length = 25.68, buccolingually = 8.23, mesiodistally = 5.93. Adjusted means followed by different superscripted letter(s) are statistically significantly different at $P < .05$ according to the LSD criterion.

Table 3a Comparison of Fracture Strength (N) Between Control, Ferrule, and No Ferrule Groups

Group	Observed mean	Adjusted mean*	SE
Control	288.20	274.06^{b}	138.28
Ferrule (AC and MC)	611.10	603.25^{a}	92.36
No ferrule (AC and MC)	512.55	527.47^{ab}	95.11

SE = standard error.
*Adjusted means are estimated for the following covariates' values: root length = 25.68, buccolingually = 8.23, mesiodistally = 5.93. Adjusted means followed by different superscripted letter(s) are statistically significantly different at $P < .05$ according to the LSD criterion.

Table 3b Comparison of Fracture Strength (N) Between Control, AC, and MC Groups

Group	Observed mean	Adjusted mean*	SE
Control	288.20	296.48^{b}	131.14
AC (with and without ferrule)	460.20	385.70^{b}	99.46
MC (with and without ferrule)	663.45	733.81^{a}	95.07

SE = standard error.
*Adjusted means are estimated for the following covariates' values: root length = 25.68, buccolingually = 8.23, mesiodistally = 5.93. Adjusted means followed by different superscripted letter(s) are statistically significantly different at $P < .05$ according to the LSD criterion.

Discussion

The first research hypothesis of this study was rejected as the statistically significant differences in fracture strength were not related to the presence of 2 mm of ferrule in either the AC or MC groups or in total, independent of the type of restoration. Similarly, previous studies have failed to demonstrate a difference between ETT with or without ferrule restored with nonmetallic posts and composite cores.[4,6] Furthermore, the GFP-restored teeth presented favorable cervical fracture above the cervical line, as has been advocated in other studies.[3,7] These findings can be explained by the similarity of the Young's moduli of fiber posts and dentin as the forces could be distributed along the length of the post uniformly for all groups, independent of the presence of ferrule. Furthermore, adhesive cementation results in the formation of a monoblock configuration where the tooth, post, core, and luting agent function as a cohesive unit.[8] The lowest strength was recorded for the control ETC probably due to phenomena related to dentin desiccation affecting its mechanical and physical properties.

The second hyposthesis has to be accepted as the fracture strength of teeth restored with MC crowns was statistically significantly higher when compared with the AC-restored and control teeth. This is in accordance with the literature, as a strong correlation between core elastic modulus and fracture strength has been suggested for crown restorations.[9] The Young's modulus of the Empress II core material that was used in this study is around 96 GPa, while the respective value for nonprecious alloys is over 200 GPa, thus resulting in increased fracture strength of the MC-restored teeth.

The results of this study suggest that ETCs restored with GFPs and AC or MC crowns are able to withstand loads of more than 460 N, a value above the mean occlusal forces in the anterior region[10] and even higher (> 750 N) when restored with an MC crown. However, these findings should be evaluated with caution as in different clinical situations oblique lateral or parafunctional forces may be exerted on canines.

Conclusions

The presence of ferrule did not significantly increase the fracture strength of ETCs restored with GFPs and either MC or AC crowns. Secondly, the type of crown significantly affected the fracture strength, especially in the case of 2-mm ferrule, as teeth restored with GFPs and MC crowns were significantly more fracture resistant compared with those with AC crowns.

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Literature Abstract

Prognostic factors for clinical outcomes according to time after direct pulp capping

This study aimed to investigate the treatment outcome of direct pulp capping in permanent teeth with cariously exposed pulps as well as the potential factors contributing to pulpal survival according to time. One-hundred seventy-five patients who had pulp capping done at the Department of Conservative Dentistry, Yonsei University Dental Hospital, Seoul, Korea, from November 2007 to August 2010 satisfied the inclusion criteria. Seven clinical variables (sex, age, maxilla versus mandible, tooth position, capping materials, temporary filling materials, and exposure site) were analyzed. The Kaplan-Meier method showed that age, exposure site, and capping material had significant effects on the pulpal survival rate ($P < .05$). A Cox regression model showed that the capping material, mineral trioxide aggregate, was the only factor affecting the pulpal survival ($P < .05$). In the time-based analyses, no significant variable was found to affect the survival rate before 100 days but after 100 days, the type of pulp capping material was the most important survival influencing variable ($P < .05$). The authors concluded that patient selection and the type of pulp capping material should be taken into consideration when performing a pulp capping treatment.

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