DENTAL MATERIALS 29 (2013) 1280–1286

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journal homepage: www.intl.elsevierhealth.com/journals/dema

# The influence of substance loss and ferrule height on the fracture resistance of endodontically treated premolars. An in vitro study

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ARTICLE INFO

*Article history:*
Received 3 February 2013
Received in revised form
14 August 2013
Accepted 7 October 2013

*Keywords:*
Residual coronal wall
Ferrule height
Glass fiber post
Resin cement

ABSTRACT

*Objective.* This study evaluated the effect of different ferrule heights and varying degrees of substance loss on the fracture resistance of endodontically treated premolars.

*Methods.* Eighty extracted and endodontically treated lower premolars were used and divided into 5 test groups ($n = 16$) depending on the ferrule height: A (0.0 mm), B (0.5 mm), C (1.0 mm), D (1.5 mm) and E (2.0 mm) respectively. Teeth in subgroups were either with 1 or 2 residual coronal dentin walls which were 3 mm in height and 1 mm in thickness. Teeth were restored with glass fiber posts and cast crowns. All specimens were then subjected to dynamic loading in a masticatory simulator for 1,200,000 loading cycles with a nominal load of 5 kg at 1.2 Hz combined with thermal cycling (5–55 °C, dwell time 30 s). Then specimens were quasi-statically loaded at 30° in a universal testing machine until fractured. Data were analyzed with 2-way ANOVA, followed by multiple comparisons using Tukey HSD test ($\alpha = .05$).

*Results.* Mean (SD) failure loads for groups ranged from 679.5 ± 164.9 N to 1084.5 ± 269.9 N. Two-way ANOVA revealed that both the ferrule height and the number of residual coronal walls had a significant influence on the fracture resistance ($P < .001$ and $P = .006$, respectively). Significant increases were produced in the final fracture resistance, when the ferrule height was increased, which was reduced to approximately 37% when teeth with 2 mm ferrule height were compared with teeth without a ferrule.

*Significance.* Under the conditions of this in vitro study, increasing the number of residual coronal walls and ferrule height had a significant effect on the fracture resistance of endodontically treated premolars restored with prefabricated posts.



## 1. Introduction

Endodontically treated teeth (ETT) have been problematic because of coronal destruction from dental caries, fractures, previous restoration, and endodontic therapy. This results in an increase of the likelihood of fracture of the treated tooth during function [1]. The prognosis of ETT is influenced by different parameters such as amount of hard tissue loss [2], presence of a minimum of 1.5–2.0 mm ferrule height

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http://dx.doi.org/10.1016/j.dental.2013.10.003

preparation [3], material and design of post and core material used [4]. The susceptibility to fracture of a restored tooth is increased with the loss of coronal dentin. Therefore, tooth longevity will depend on the amount of remaining tooth structure and the efficiency of the restorative procedures to replace lost structural integrity [5]. A treatment using posts should be used only for retention of a core within the remaining tooth structure but not for aiming to strengthen the tooth [6].

Several post system techniques are available for the restoration of ETT and can be divided into custom-made cast post and core systems and prefabricated post systems. There are many concerns when using custom-made metallic posts due to their inhomogeneous stress distribution, biological side effects due to microleakage and corrosion, and the dark color under all-ceramic restorations [7]. The popularity of the fiber posts is due to their favorable physical properties [8] and their bond strength is equivalent to adhesively or conventionally luted gold posts [9]. They were reported to reduce the risk of tooth fracture and display higher survival rates than teeth restored with rigid zirconia posts [10].

An important element for tooth preparation is the incorporation of a ferrule design. Sorensen and Engelman described the ferrule as the coronal dentinal extension of the tooth structure occlusal to the shoulder preparation [11]. Libman and Nicholls suggested that to achieve the full benefits of ferrule effect, it should be a minimum of 1.5 mm in height with parallel dentin walls, totally encircling the tooth and ending on sound tooth structure [12]. Many studies investigating the ferrule effect have used cast posts and cores [13–15], but there is little information as to whether the ferrule is of additional value in providing reinforcement in teeth restored with prefabricated glass-fiber posts and composite cores [16]. Mangold and Kern [17] described the influence of posts on fracture resistance of ETT with varying substance loss but they did not indicate the effect of the different ferrule height in their study.

Therefore, the aim of this study was to evaluate the fracture resistance of endodontically treated premolars (ETPs) restored with glass-fiber posts when different ferrule heights and varying degrees of substance loss were incorporated. The null hypothesis of the study was that neither ferrule height nor the amount of residual coronal dentin would affect the fracture resistance of crowned premolars.

## 2. Materials and methods

### 2.1. Test groups

Eighty recently extracted caries-free lower premolars, which were removed for orthodontics or periodontal reasons, were selected and then stored in 0.1% thymol solution (Caelo, Hilden, Germany). The teeth were cleaned with a hand scaler and stored then at room temperature during the study.

Endodontic access cavities were prepared using a water cooled air turbine handpiece. During root canal preparation the working length was set at 1 mm short of the apical foramen. The teeth were endodontically prepared using the step-back technique to an ISO size 50 (K-files; Dentsply De Trey, Constance, Germany), irrigated with 3% sodium hypochlorite solution (Hedinger, Stuttgart, Germany) and dried with paper points (Coltene/Whaledent Inc., Langenau, Germany). Each canal was obturated using the lateral condensation method with gutta-percha points (Coltene/Whaledent Inc.) and sealed with an eugenol-free epoxyamine resin sealer (AH Plus; Dentsply De Trey). After 24-h water storage at 37 °C, gutta-percha was removed using no. 2,3,4 Gates-Glidden burs (Maillefer, Ballaigues, Switzerland). The teeth roots were embedded into brass tubes, using an auto-polymerizing resin (Technovit 4000; Heraeus Kulzer, Wehrheim, Germany) up to 2 mm apical to the cemento-enamel junction (CEJ) and oriented their long axes perpendicular to horizontal using a custom-made surveyor. The ETPs received 0.8 mm shoulder finish lines which were mesial and distal 1 mm more coronal than the facial and lingual surfaces and which were cervical to the (CEJ). Burs were replaced after 8 preparations, in order to ensure high cutting efficacy. For teeth preparations, diamond rotary cutting instruments (Brasseler, Lemgo, Germany) under copious air-water cooling were used (with a 2° taper to achieve a 4° convergence angle) in a high-speed handpiece mounted on a custom-made parallelometer to standardize the preparation for all specimens. The teeth were assigned randomly to 5 groups of 16 teeth each according to the ferrule height. The properties of the specimens included in each group were as follows: group A: specimens without circumferential ferrule; group B: circumferential ferrule 0.5 mm above the finish line; group C: circumferential ferrule 1 mm above the finish line; group D: circumferential ferrule 1.5 mm above the finish line; group E: circumferential ferrule 2 mm above the finish line. Teeth in subgroups had either 1 residual facial wall (A1, B1, C1, D1 and E1) or 2 residual facial and lingual walls (A2, B2, C2, D2 and E2). The walls were 3 mm high and 1 mm thick.

Post spaces were accomplished with a tapered drill (ER-post kit; Brasseler) of ISO size 90 to achieve an intraradicular post length of 7.5 mm for all teeth. The coronal opening of the post space was enlarged in a facio-lingual direction to a 3 mm in width and 2 mm in depth to resist rotation and to standardize the coronal openings and the thickness of residual coronal walls. The walls of the post preparation were roughened using a diamond-coated hand instrument 3 times (ER Post Systems; Brasseler) [18].

The glass-fiber posts (Komet ER DentinPost; ISO size 90, Brasseler) were airborne-particle abraded for 5 s at a distance of 30-mm with 50 μm alumina particles (Heraeus Kulzer) at 0.25 MPa and ultrasonically cleaned in 96% isopropanol (German Federal Monopoly Administration for Spirits, Hamburg, Germany) for 3 min. The post spaces were then irrigated with a 3% sodium hypochlorite solution and dried with paper points, followed by irrigating with 70% ethanol (German Federal Monopoly Administration for Spirits) and drying with paper points.

The posts were luted with adhesive composite-resin cement using a microbrush (Panavia 21 TC; Kuraray Medical, Osaka, Japan) after conditioning the dentin with the system's autopolymerizing primer (ED-Primer; Kuraray) for 60 s. The resin cements were mixed and applied according to the manufacturer's instructions. Excess luting resin was used to coat the coronal portion of the post. An auto-polymerizing composite resin (Clearfil Core; Kuraray Medical, Osaka, Japan) was applied as the core material according to the manufacturer's