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ORIGINAL ARTICLE

Influence of remaining coronal structure and of the marginal design on the fracture strength of roots restored with cast post and core

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Abstract

Objective. The purpose of this study was to evaluate the fracture strength of roots that were prosthetically restored with cast post and core with or without any remaining coronal structure and with different finish lines. ***Materials and methods.*** Sixty bovine incisors were sectioned below the cementoenamel junction, endodontically treated and randomly divided into six experimental groups ($n = 10$) containing teeth with or without any remaining coronal structure and with a beveled shoulder, a chanfered or a shoulder finish line design. The cast post and core were luted with dual-cured resin cement. The metal crowns were cemented with zinc phosphate cement. The specimens were subjected to a tangential compressive load (135° angle) at a crosshead speed of 0.5 mm/min until failure, using a universal testing machine. The fracture strength data were analyzed using the ANOVA and LSMeans (least square means) tests ($\alpha = 0.05$). ***Results.*** The data indicated that the teeth with 2 mm of remaining coronal structure showed the highest fracture strength values when compared with the teeth without any remaining structure ($p < 0.05$). As to the different finish line designs, the highest fracture strength values were obtained for the beveled shoulder, followed by the chanfered and then by the shoulder designs ($p < 0.05$). ***Conclusions.*** It may be concluded that, to increase fracture strength, a beveled shoulder and 2 mm of remaining coronal structure are the ideal conditions.

Key Words: *tooth root, post and core technique, compressive strength*

Introduction

Endodontically-treated teeth frequently require indirect restorations because of extensive loss of healthy tooth structure as a result of carious lesion or fracture [1]. In these cases, the use of posts is recommended to promote retention of the final restoration [2,3].

The preservation of tooth structure is an important factor in the successful restoration of endodontically-treated teeth. Some authors [4,5] have suggested that a tooth should have a minimum amount (2 mm) of coronal structure above the cementoenamel junction (CEJ) to ensure a proper shape of strength for a tooth. This coronal structure will provide a ferrule effect with the artificial crown that should prevent root fracture, post fracture and dislodgement.

The strength of a prosthetic restoration depends not only on the post and remaining coronal structure, but also on a suitable preparation and finish line design [4]. In studies designed to investigate the fracture strength of metal and glass ceramic crowns, it was observed that tooth preparation with a 1.2-mm shoulder finish line and a sharp axiogingival line angle produced the strongest crowns, whereas crowns fabricated for preparations with a chamfer finish line produced the weakest restoration [6,7]. In contrast, some authors reported that the fracture strength of crowns luted with a resin luting agent was unaffected by the type of finish line used [8,9]. Rosen [10] and Rosner [11] reported that the beveled preparation design promoted a reduction in casting errors, a seal against tooth fracture, appropriate adaptation

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of the prosthesis and the establishment of the ferrule effect.

Thus, the purpose of this study was to evaluate the fracture strength of anterior tooth roots that were prosthetically restored with cast post and core with or without 2 mm of remaining coronal structure, and with a beveled shoulder, a chanfered or a shoulder finish line design. The hypothesis tested was that the fracture strength of roots might be affected by the remaining coronal structure and by the finish line design.

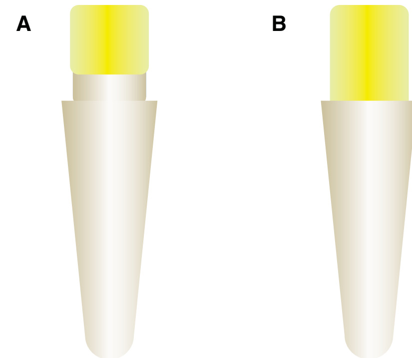

Figure 1. Two millimeters of coronal dentin structure associated to a composite core is viewed in A, representing groups WIBS, WICH and WISH; while in B the core was built with composite resin, without coronal dentin structure, representing groups WOBS, WOCH and WOSH.

Materials and methods

Sixty recently extracted bovine lower central incisors stored in 0.9% thymol solution at 4°C were selected for use in this study. The teeth were transversally sectioned at their cervical portion, using a diamond double-faced disk (Extec, São Paulo, Brazil) fitted to a low-speed handpiece and cooled with air/water spray. Thirty roots were standardized at a length of 17 mm, whereas the other 30 were standardized at 19 mm. This difference was used to generate the 2-mm remaining coronal structure in half of the specimens.

The roots were embedded in polystyrene resin (Cromex, Piracicaba, Brazil) using a circular metal matrix (25 mm in diameter by 20 mm in height). Adhesive material and elastic-based urethane (Nexus, Nucleus Duplex, Sweden) were used to simulate the periodontal ligament. All roots were embedded to a depth of 15 mm, to maintain 2 mm of root length extending beyond the top of the acrylic resin in 30 roots and 4 mm in the other 30 roots.

The root canals were prepared 1 mm short of the apex and filled with gutta-percha points (Dentsply Maillefer, Ballaigues, Switzerland) and Endomethasone root canal sealer (Septodont, Saint-Maur-Dês-Fossés, France). After root canal filling, the gutta-percha points were all cut with size 3 Gates-Glidden burs (Dentsply Maillefer, Ballaigues, Switzerland), with a low-speed handpiece, maintaining 5 mm of filling material in the apical third of all specimens.

The roots without any remaining coronal structure and with 2 mm of remaining coronal structure (Figure 1) were randomly divided into six groups (n = 10) according to different finish line designs: beveled shoulder, chanfered or shoulder (Figure 2). The groups are described in Table I.

The post spaces were prepared to a depth of 12 mm in the roots without any remaining coronal structure and to a depth of 14 mm in the roots with 2 mm of remaining coronal structure, using a drill supplied by the post manufacturer, fitted to a low-speed handpiece. Air/water spray cooling was used during preparation and dentin thickness was standardized.

The root dentin was etched with 37% phosphoric acid (FGM, Joinville, Brazil). Scotchbond MP Plus adhesive system (3M ESPE, St. Paul, MN) was then applied according to the manufacturer's recommendations and light-polymerized for 40 s with a curing unit (3M, Sumaré, Brazil) using a light intensity of 500 mv/cm^2. Cast post and core were cemented with dual-cured resin cement (Enforce, Dentsply Maillefer, Ballaigues, Switzerland). The cement was mixed and introduced into the post spaces with a lentulo-spiral drill using a low-speed handpiece [12]. Cement was also applied on the posts before they were gently seated by finger pressure and held in place for 60 s. The cement was light polymerized for 30 s on each surface (buccal, palatal, mesial and distal), for a total 2-min light polymerization cycle.

The finish line was prepared according to three different designs: beveled shoulder, chanfered or shoulder. The finish line was located at the limit between the tooth and the core for the teeth with no coronal remainder and 2 mm below this limit for the specimens with remaining dental structure (Figure 2). The finish line axial depth was 1 mm in all groups. All specimens were finished with a no. 3216 diamond bur (KG Sorensen, Barueri, Brazil) at high speed and water spray cooling. Specimens were prepared to receive complete crowns with a reduction of 1.5 mm and ferrule of 2.0 mm.

The crown was replicated with silicone impression material (Aquasil Ultra, Dentsply Maillefer, Ballaigus, Switzerland) and poured in acrylic resin to make the other patterns. Rectangular-shaped stops with a central concavity were made on the palatine aspect of the patterns to locate and stabilize the metal tip during the fracture strength test. Standardized acrylic resin crowns were obtained for all teeth. All crowns were cemented with zinc phosphate cement (Zinc Cement, SS White, Rio de Janeiro, Brazil). The specimens were then stored in 100% relative humidity, at a constant temperature of 37 (± 2)°C for a period of 48 h to ensure totally cured cement.

Next, the specimens were subjected to a compressive test in a universal testing machine (Emic DL

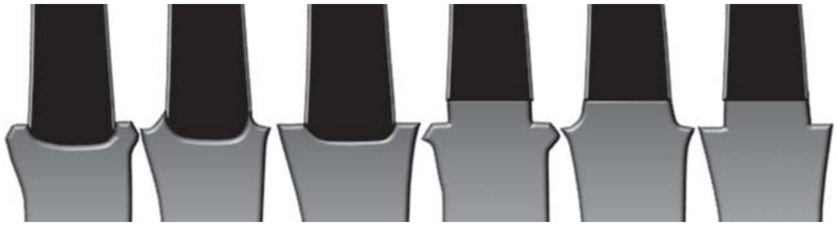

Figure 2. Schematic illustration of the groups under study. WOBS, WOCH and WOSH stand for the groups without any remaining coronal structure and, respectively, with a beveled shoulder, a chanfered or a shoulder design. WIBS, WICH and WISH stand for the groups with 2 mm of remaining coronal structure and, respectively, with a beveled shoulder, a chanfered or a shoulder design.

2000, Sao José dos Pinhais, Brazil). The position of the specimens was standardized using a device on the base of the apparatus and load was applied at an angle of 135° in relation to the long axis of the roots [13,14]. An increasing oblique compressive load was applied on the cingulum of the tooth's palatal aspect (3 mm from the incisor edge), using a cylindrical-shaped device with a round tip (2.7 mm in diameter). A - cross-head speed of 0.5 mm/min was applied until fracture. The root-post fragments set was removed from the acrylic resin after fracture and observed under a stereoscopic magnifying glass at 4× magnification for fracture analysis. The fractures were classified according to location as follows: horizontal fracture (HF) at the cementation line; transverse fracture in the cervical third of the root canal (CTF); transverse fracture in the middle third of the root canal (MTF); transverse fracture in the apical third of the root canal (ATF); longitudinal fracture of the root (LF) (Figure 3).

The data were analyzed by ANOVA and by LSMeans. The significance level was set at 5%.

Results

The compressive loads required to fracture the roots in each of the six groups are displayed in Table II.

The groups with 2 mm of remaining coronal structure (WIBS, WICH and WISH) showed higher fracture strength values than those without any remaining coronal structure (WOBS, WOCH and WOSH) ($p < 0.05$), except for Groups WOBS and WISH, which did not differ statistically ($p < 0.05$). Regarding the preparation design, the highest fracture strength values were found for the beveled shoulder with or without any remaining structure ($p < 0.05$). However, the beveled shoulder and the chanfered designs did not differ statistically ($p > 0.05$). Similar results were also observed when the chanfered and the shoulder designs were compared within the groups with 2 mm of remaining coronal structure. The beveled shoulder design showed a fracture behavior similar to that of the chanfered and the shoulder designs ($p > 0.05$). The preparation designs affected the fracture strength values in the groups without any remaining structure, considering that a statistically significant difference was found ($p < 0.05$).

Groups without any remaining coronal structure (WOBS, WOCH and WOSH) typically showed an LF, whereas most fractures in the other groups were MTF and CTF (Table III).

Table I. Groups, remaining coronal structure and finish line designs of the roots.

Groups	Remaining coronal structure	Finish line
WOBS	Without	Beveled shoulder
WOCH	Without	Chanfered
WOSH	Without	Shoulder
WIBS	With	Beveled shoulder
WICH	With	Chanfered
WISH	With	Shoulder

Discussion

This study evaluated whether the remaining coronal dentinal structure and finish line design could interfere with the fracture behavior of an endodontically-restored tooth. In general, the groups with remaining dental structure required higher values of compressive

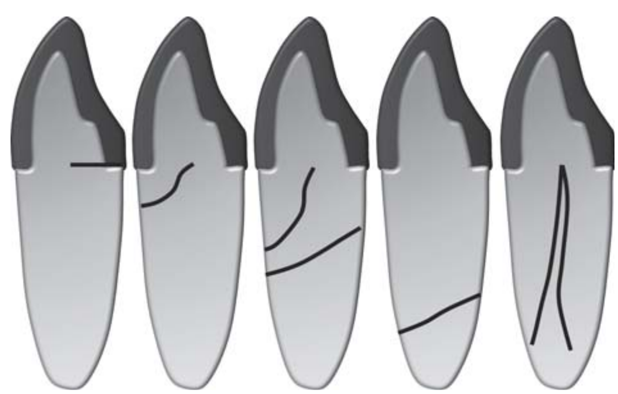

Figure 3. The fracture locations observed for the experimental groups were as follows: HF, horizontal fracture; CTF, transverse fracture in the cervical third of the root canal; MTF, transverse fracture in the middle third of the root canal; ATF, transverse fracture in the apical third of the root canal; LF, longitudinal fracture of the root.

Table II. Mean, SD, minimum and maximum stress (Kgf) for each group of compressive force required for root fracture.

Group	n	Mean ± SD	Minimum	Maximum
WOBS	10	83.96 ± 11.34[c]	63.28	101.70
WOCH	10	66.60 ± 16.48[d]	42.35	92.38
WOSH	10	44.57 ± 9.06[e]	36.75	64.34
WIBS	10	121.67 ± 19.98[a]	87.08	142.10
WICH	10	121.24 ± 12.97[a,b]	104.20	146.80
WISH	10	95.57 ± 23.57[b,c]	59.54	121.30

Mean values followed by the same letters are not statistically different.

load to promote root fracture. These results are in agreement with those of the studies by Varvara et al. [15] and Ma et al. [16]. After prosthetic preparation, the remaining coronal structure becomes part of the axial wall of the core and subsequent cementation of the crown will lead to a ferrule effect that increases the fracture resistance of the root. The increase in resistance is explained by the greater preservation of dental structure and by a reduction of the lever effect of the post on the root canal walls [4]. According to Sorensen and Engelman [4], 1 mm of coronal tooth structure above the crown margin substantially increased the fracture resistance of endodontically-treated teeth, whereas a contrabevel at either the tooth–core junction or the crown margin was ineffective.

For the groups without any remaining dental structure, the beveled shoulder design presented the highest fracture resistance values, which were similar to those obtained by the group with remaining structure and a shoulder design. This could be explained by the fact that the chanfered extended 1 mm beyond the limit between the root and the prosthetic core and, when embraced by a metal band, this type of finish line is capable of increasing the fracture resistance of the root/core/prosthetic crown set [4]. Hence, these results demonstrated that, even in the presence of remaining coronal dentin, the type of finish line design still influences fracture resistance values.

The lowest fracture strength values were found for the shoulder design without any remaining structure, a preparation configuration which lacks a wall in dentin for the prosthetic crown to embrace. As a result, all the oblique force exerted on the crown is supported directly by the prosthetic core and transmitted successively to the post and root canal, generating a lever effect on the root wall. The chanfered design was extended beyond the limit between the root and the prosthetic crown, involving ~ 0.5 mm of root dentinal structure. This feature allowed embracing only a small quantity of dental structure by the prosthetic crown, providing a less ferrule effect than that achieved with the beveled shoulder and leading to lower resistance values.

In the groups with remaining coronal dental structure, the beveled shoulder and the chanfered designs showed similar behavior, a fact which could be attributed to the prosthetic crown having involved part of the root dentinal structure. The groups without any remaining coronal structure and with a beveled shoulder design behaved similarly to the group with remaining coronal dental structure and a shoulder design, which allows us to conclude that the ferrule effect is achieved in a similar manner by using the cervical chanfered or involving the coronal structure on the axial wall of the core. Moreover, there is an indication of synergism, considering that the highest fracture resistance values were achieved when there was remaining coronal structure at the gingival chanfered. This combination of a remaining dental structure and the construction of a metal band can be used in cases of teeth with a short clinical crown, in which esthetics is not a preponderant factor and when the oblique forces on the prosthetic crown exceed the normal mastication forces, as is the case of teeth with fixed partial or removable dentures, adjacent to distal extensions or large prosthetic spaces.

Analysis of the fracture pattern demonstrated a greater trend towards longitudinal fractures (LF) for the groups without any remaining coronal structure, whereas there was predominance of fractures in the middle and gingival thirds of the root for the groups with remaining coronal structure, evidencing the protection exerted by the ferrule effect against longitudinal fractures [16,17]. Similarly, there was a trend towards longitudinal fractures for the shoulder design, contrasting with the beveled shoulder and chanfered designs, which presented a trend towards transverse fractures in the middle third. The results of

Table III. Types of failure for the experimental groups.

Groups	FH	CTF	MTF	ATF	FL	Total
WOBS	1 (10%)	3 (30%)	3 (30%)	—	3 (30%)	10 (100%)
WOCH	1 (10%)	4 (40%)	2 (20%)	—	3 (30%)	10 (100%)
WOSH	1 (10%)	2 (20%)	3 (30%)	—	4 (40%)	10 (100%)
WIBS	1 (10%)	3 (30%)	6 (60%)	—	—	10 (100%)
WICH	1 (10%)	4 (40%)	4 (40%)	—	1 (10%)	10 (100%)
WISH	3 (30%)	1 (10%)	5 (50%)	—	—	10 (100%)

this analysis highlight the importance of preserving the coronal dental structure and involving it in the preparation, as well as that of the ferrule effect achieved by constructing a metal band. The beveled design showed a behavior similar to that of the beveled shoulder design with regard to the predominant fracture pattern.

The fracture pattern has great clinical relevance, since it dictates the possibility of reconstructing the remaining dental structure. In this study, preservation of healthy tooth structure and its later involvement in the prosthetic preparation contributed to the occurrence of less catastrophic fractures, in comparison with those observed in teeth without any remaining coronal structure or without a chanfered to be embraced by the metal belt provided by the metal prosthetic crown. The strength of the prosthetic restoration appears to be primarily related to the quantity of remaining coronal structure involved in the preparation [16] and secondly to the finish line design. Furthermore, in this study was used cast metal posts and core systems. This material has traditionally been used for intra-radicular retention. However, these materials have a high elastic modulus and, therefore, are more likely to cause fracture of the remaining dental structure [18].

In the case of teeth without any remaining dental structure, the possibility of augmenting the clinical crown or of performing root traction should be evaluated, in order to involve healthy dental structure in the prosthetic preparation [12]. In the the event that these procedures are not possible, it is suggested that a beveled finish line be chosen so that a metal belt can embrace the root. The adhesive technique with resin composite and pre-fabricated fiber posts is recommended because it forms a single block between the root and the filling core. Nevertheless, further studies should be conducted to confirm these recommendations.

Based on the results of the present study, a beveled shoulder design should be adopted with a 2-mm minimum remaining coronal structure to achieve higher values of resistance to fracture.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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