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Fracture Resistance of Cast Metal and Zirconia Posts on Endodontically Treated Teeth: An in Vitro Study

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Abstract

Background: Endodontically treated teeth are widely considered to be more susceptible to fracture than vital teeth and require specialized restorative treatment. The aim of this study was to estimate and compare the fracture resistance (FR) of endodontically treated teeth (ETT) restored with cast metal posts (CMP) and zirconia posts (ZP) with Universal Testing Machine (UTM).

Methods and Results: A total of 60 intact canines extracted for periodontal reasons were selected for the present study. The tooth samples were randomly divided into 2 groups based on the post type used for restoration. Group 1 tooth samples (n=30) were restored with CMP. Group 2 tooth samples (n-30) were restored with ZP. All the samples were subjected to compressive load using a UTM at a cross-head speed of 0.5 mm/min on the palatal slope at an angle of 135° to the long axis of the tooth. The maximum load necessary to fracture for each specimen was measured in Newtons (N). The results obtained showed that the difference in FR means between CMP and ZP was statistically significant ($P<0.0001$).

Conclusion: The FR of ZP was found to be significantly higher than those of CMP. The FR analysis with UTM is the only method that enables us to estimate the differences between the ETT restored with CMP and ZP.(**International Journal of Biomedicine. 2022;12(4):606-610.**).

Keywords: fracture resistance • endodontically treated teeth • zirconia posts • cast metal posts

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Abbreviations

CMP, cast metal posts; **ETT**, endodontically treated teeth; **FR**, fracture resistance; **UTM**, Universal Testing Machine, **ZP**, zirconia posts.

Introduction

Endodontically treated teeth (ETT) are more susceptible to biomechanical failure than vital teeth against masticatory forces and may fracture more easily.[1] Additional factors attributed to the increased fracture risk are substantial loss of tooth structure with endodontic root access, bacteria-dentin interaction, and endodontic therapy itself.[2] In treating these teeth, posts are recommended to reinforce the teeth with extensive loss of coronal structure, which also supports the teeth under the action of occlusal forces along the roots and creates retention before placing a crown.[3,4]

In daily dental practice, adequate crown restoration is required to resume the function of the teeth, prevent the penetration of microorganisms through the end of the root canal, restore aesthetics and serve as an abutment in the fixed or removable prostheses.[5] The compatible modulus of elasticity of the post with radicular dentin has a significant role in avoiding root fracture.[6] The success of endodontic posts is based on biocompatibility, high tensile strength, good fitting accuracy, and adequate fatigue strength for favorable distribution of masticatory force.[7] Different types of posts have been proposed, from cast metal posts (CMP) to aesthetic ones.

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CMP have been accepted for their favorable physical properties, superior success rate, long-term prognosis, easy manipulation, and low cost.[8] These posts reproduce the morphology of the root canal with good accuracy.[9] However, reports of low biocompatibility, chances of corrosion, and root fracture, along with the failure to accomplish the desired aesthetics of the teeth, have prompted clinicians to look for another type of post for restoring the ETT.[10-13]

The use of dental posts with identical tooth color has directed attention toward the appearance of ETT.[14] Zirconia posts (ZP) are the foundation of many modern post concepts.[15] Zirconia, a ceramic biomaterial, is widely used because of its mechanical strength, chemical stability, esthetic outcomes, and high toughness. Apart from these favorable properties, there is a risk of root fracture due to a high modulus of elasticity.[16] The quality of cement is fundamental for post-resistance and retention on ETT, so the adhesive resin cement is indicated only when post-retention is severely impaired.[17,18] Adhesive resin cements have been preferred because they have been shown to increase the retention of the post [19] and the overall resistance against fracture of ETT.[20] Due to the low elastic modulus of the adhesive resin cement, it may act as a shock absorber, thus decreasing the risk of fracture of ETT. The types of posts have been explored by many authors. Therefore, this in vitro study aimed to estimate and compare the fracture resistance (FR) of ETT restored with CMP and ZP.

Materials and Methods

This study was conducted in the Prosthodontics Department at the University Dentistry Clinical Center of Kosovo with prior approval from the Ethical Committee (Protocol #4068/5.13.2021) of this institution. A total of 60 canines extracted for periodontal reasons, with a root length of 15-18 mm, were selected for the present study. The freshly extracted teeth were immediately placed in 5.25% NaOCl for 5 min and stored in 0.9% saline solution at room temperature (20-23° C). Teeth were used within 6 months after extraction.

The inclusion criteria were as follows: teeth with almost straight roots, completely formed apices and intact clinical crowns. The exclusion criteria were as follows: the presence of caries in the root, previous endodontic treatments, dental anomalies, and the presence of visible fracture lines in the root. Buccolingual and mesiodistal radiographs of all teeth were taken and examined to evaluate root integrity.

Any calculus or residual debris from the surface of the teeth was removed by ultrasonic scaling. Thereafter, teeth were stored in 0.9% normal saline for the rest of the study. All the tooth samples were sectioned 3mm above the cementoenamel junction. An adequate access cavity was prepared on all the teeth. The root canals were prepared and shaped up to the X3 file using a Protaper Next rotary file (ProTaper, Dentsply Maillefer, USA) and were irrigated with 2ml of 0.5% NaOCl solution between each file size. The remaining dentin layer was removed with 17% EDTA for 1 minute. The root canals were dried with absorbent paper points and obturated with ProTaper gutta-percha cones using a sealer (AH Plus, Dentsply Maillefer, USA) with cold lateral condensation. The access cavity was filled with a temporary restorative material (3M ESPE Cavit, Seefeld, Germany).

Post-space for all teeth was prepared after 7 days from obturation by the sequential use of Gates-Glidden and Pesso reamer size 1 up to size 4, keeping 4mm of gutta-percha as an apical seal. Then the finalized root canals were irrigated with 2.5% NaOCl, followed by normal saline, and dried with paper points. The tooth samples were randomly divided into 2 groups based on the post type used for restoration. A root canal impression for 2 groups was made by using a patterned resin (Duralay, Reliance Dental Manufacturing LLC, Alsip, USA).

Group1 tooth samples were restored with Co-Cr CMP (Ivoclar, Vivadent, Lichtenstein). Group 2 samples were restored with ZP using a monolithic block of Zirconium Oxide (2N99%) with CAD-CAM technology (Sirona Dental Systems, Germany). The posts were then sandblasted for 3-4 seconds with 50µm aluminum oxide powder and then cleaned with distilled water to improve the adhesion.

The post-space was thoroughly dried with absorbent paper points, and CMP and ZP were cemented with Adhesive Rezin Cement, Speed CEM Plus (Ivoclar, Vivadent, Lichtenstein). The cement was spun into the canals using a lentulo spiral (Lentulo; Dentsply Maillefer, Ballaigues, Switzerland). The posts were placed within the canal and held in position with moderate finger pressure. Excess cement was removed using a sable brush (Fig.1, Fig 2).

Fig. 1. *CMP and ZP.*

Fig. 2. *Resin cement injection.*

Final impressions were made for all the samples with polyvinylsiloxane impression material (Elite, Zhermarck). All teeth were restored with a full-coverage metal crown using type IV nickel-chromium (Wiron®99, BEGO Bremer Gold, Bremen, Germany). The crowns were cleaned with ethanol, dried, and cemented using type-1 glass-ionomer cement (GC Fuji I, GC America). The crowns were kept on the prepared samples under finger pressure for 30 sec, and excess cement was removed with a sharp instrument after 10 min.

Finally, each root was thinly covered with a silicone impression material to simulate the thickness of the periodontal ligament (Speedex, Light body, Coltène/Whaledent AG, Altstätten/ Switzerland).

Fracture resistance test

In order to receive the loads, samples were embedded parallel to their vertical axis in acrylic blocks. Loads were then applied using a UTM (H001B:1000kN, Matest, Italy) at a cross-head speed of 0.5mm/min on the palatal slope at an angle of 135° to the long axis of the tooth. The maximum

load necessary to fracture for each specimen was measured in Newtons (N) (Fig.3, Fig.4).

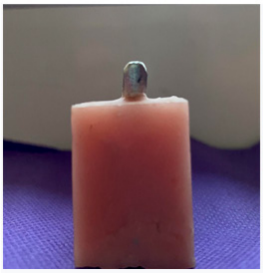

Fig. 3. *Teeth samples in acrylic block.*

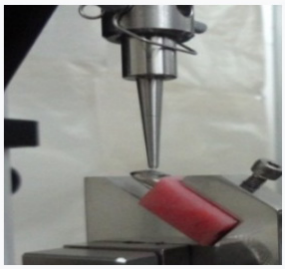

Fig. 4. *Static load application in the UTM.*

Statistical analysis was performed using statistical software package SPSS version 21.0 (SPSS Inc, Armonk, NY: IBM Corp). Data were analyzed with One-way ANOVA & Tukey's (HSD) post-hoc test. The One Sample t-Test was also applied. A probability value of $P<0.05$ was considered statistically significant.

Results

Table 1 presents descriptive statistics for CMP and ZP. In CMP and ZP, the mean FR was 141.87±13.620N and 1041.03±16.497N, respectively. A comparative analysis of the FR values between CMP and ZP groups showed that the influence of post's type on FR was significant (P=0.000) (Table 2). We have done a univariate general linear model test to which we have added Tukey's Honest Significant Difference (HSD) test to assess the significance of differences between CMP and ZP groups (Table 3). The P-value for each group comparison was less than 0.05, showing high significance (Table 3). Table 4 presents the One Sample t-Test. Thus, the difference in FR means between CMP and ZP was statistically significant (P=0.001).

Table 1.

Descriptive statistics of FR values.

Valiable	Mean	n	SD	SEM
CMP	141.87	30	13.620	2.486
ZP	1041.03	30	16.497	3.011

Table 2.

A One-Way Analysis of Variance of FR between the study groups.

	df	SS	MS	F	*P*
Between Groups	1	12127330.584	12127330.58	52997.65	0.000
Within Groups	58	13272.007	228.8277		
Total	59	12140602.59			

df- degree of freedom; SS - sum of squares; MS - mean square

Table 3.

Tukey's HSD comparison of the significance levels between the groups.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	12127330.58400[a]	1	12127330.58400	5299554.774	0.000
Intercept	20989022.73067	1	20989022.73067	9172049.433	0.000
Group#	12127330.58400	1	12127330.58400	5299554.774	0.000
Error	13272.007	58	228.837		
Total	33116486.4000	60			
Corrected Total	12127463.30933	59			

a. R Squared = 1.000 (Adjusted R Squared = 1.000)

Table 4.

The One Sample t-Test.

t	df	Sig. (2-tailed)	Mean difference	95% CI for the difference	
				Lower	Upper
10.105	59	0.001	5914.5333	4743.3377	7085.7290

Discussion

The present study presented 2 posts extensively used to restore ETT and assessed their capacity to resist fracture. This study used UTM to estimate the FR of ETT restored with CMP and ZP. When analyzing the data, we focused on a significant difference between them. In this study, canines were selected as they are vulnerable to trauma because of their position.

The loading angle of 135° applied on the palatal slope was selected in order to simulate a contact angle found in Class 1 occlusion between maxillary and mandibular anterior teeth, consistent with reports of Guzy and Nikolls.[24] In our study, adhesive resin cement was used because its modulus of elasticity is comparable to dentin. A study done by Borer et al.[25] has demonstrated the successful use of adhesive resin cement, allowing for the significant chemical bonds between the dentin and the post. All samples were restored and tested with a full-coverage, cast metal crown to ensure standardization and make it more similar to the clinical situation. The crown coverage leads to an even greater distribution of masticatory forces.

In order to closely simulate the clinical situation, many studies discuss the importance of a simulated periodontal ligament.[26] Our study supports the conclusions of these studies. In our present study, each root was thinly covered with a silicone impression material to simulate the thickness of the periodontal ligament. Marchionatti et al.[27] reported that the artificial periodontal ligament had no effect on the FR of ETT when the roots were surrounded with polyvinyl siloxane. Furthermore, posts are recommended to increase the FR of ETT, and the results of our study are consistent with Kantor and

Pines,[28] and Robbins.[29] It has been reported that more rigid posts are unable to absorb stress and are, therefore, susceptible to fracture.[30,31] The present study showed a significant difference. ETT with CMP showed lower FR than ETT with ZP. The higher modulus of elasticity of CMP compared with dentin would have led to the stress concentrations and might be responsible for the fracture of ETT.[32] The result of our study contradicted the findings of Kivanç et al.,[33] in which they reported higher FR on ETT restored with CMP. Likewise, in the study by Mentik et al.,[34] the success rate of CMP was 82%. However, our results are consistent with data obtained in a study by Abduljabbar et al.,[35] which concluded that FR of ETT restored with ZP was significantly higher than ETT restored with CMP.

The observation in this study may be attributed to the fact that ZP had a higher modulus of elasticity than CMP. On the other hand, in a study by Heydecke et al.,[36] the high elastic modulus of ZP was responsible for catastrophic fractures in teeth restored with these posts. These results are supported by other studies. Rosentrit et al.[37] reported that ZP could even reinforce the tooth structure of ETT and offer better stress distribution of loads along the roots. In our present study, the ZP were custom milled, unlike in other studies, which used prefabricated ZP.[38,39] UTM is considered a valuable method to estimate the FR of ETT restored with CMP and ZP. Nevertheless, it is difficult to compare the results of this study with those of prior studies since previous studies had differences in methodology, testing procedures, and research design. The limitations of our study included the following: the static load was applied for testing samples, unlike masticatory forces. Moreover, dynamic loading, the oral environment, and temperature effects were excluded but may also be considered limitations of the study.

Finally, CMP and ZP evaluated in our study have several advantages and disadvantages. The ultimate clinical decision-making should consider the patient-related variables, such as the amount of remaining tooth structure, tooth anatomy, position, occlusion, masticatory forces, and parafunctional habits to maximize the long-term prognosis of ETT.

In conclusion, within the limitations of this study, the FR of ETT was significantly influenced by the post type. The FR of ZP was found to be significantly higher than those of CMP. The FR analysis with UTM is the only method that enables us to estimate the differences between the ETT restored with CMP and ZP. Therefore, until further studies with long-term follow-ups on CMP are available, the use of ZP with a similar elastic modulus to the dentin might provide more acceptable results in ETT.

Competing Interests

The authors declare that they have no competing interests.

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