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OPEN

10.1515/bjdm-2017-0006

BALKAN JOURNAL OF DENTAL MEDICINE ISSN 2335-0245

The Influence of Crown Ferrule on Fracture Resistance of Endodontically Treated Maxillary Central Incisors

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SUMMARY

Background: *Prefabricated zirconia posts can contribute to increasing the fracture resistance of the endodontically treated teeth. Purpose. This in vitro study compared the fracture resistance of endodontically treated central maxillary incisors prepared with 2mm ferrule length to the ones without ferrule.* ***Material and methods:*** *Twenty-four caries-free maxillary central incisors were divided into 2 groups of 12. In group A circumferential external dentin shoulders were prepared for 2mm external dentin ferrule length. There was no ferrule preparation in Group B. Zirconia VALLPOST BO-S (Ø 1,6mm), Ljubljana, Slovenia were used with retention forms in the coronary part. Core build-up was made of pressed ceramics (IPS e.max Press, Ivoclar, Liechtenstein). Crowns were manufactured from the same ceramic material (IPS e.max Press, Ivoclar). After root canal treatment and post space preparation, all posts were cemented with an adhesive resin cement (Multilink Automix, Ivoclar). The specimens were embedded in acrylic resin blocks (ProBase Polymer/Monomer, Ivoclar) and loaded at an angle of 45º to the long axis in an Instron Testing Machine 4301 (Instron Corp., USA) at a crosshead speed of 1mm/min until fracture. Fracture patterns and loads were recorded. A significance level of $p<0.05$ was used for all comparisons. Two-way analysis of variance was used for statistical analysis. Failure patterns were analyzed with the optical microscope Stereo Discovery V.8 (Carl Zeiss, Germany) and compared using the chi-square nonparametric test.* ***Results:*** *The mean values (±SD) of fracture loads (N) for the Groups A and B were 664.63N (±49.14) and 519.36N (±71.65) recpectively. Significantly lower failure loads were recorded for the specimens in the group B. Failure patterns within the groups revealed non-catastrophic failure in 70% of the specimens for group A and 85% for group B.* ***Conclusions:*** *Within the limitations of this in vitro study, it can be concluded that zirconia VALLPOST BO-S (Ø 1,6mm) with press-ceramic cores and crowns, can be used for restoration of endodontically treated teeth. The teeth prepared with 2mm external dentin ferrule length were found to be more fracture resistant than teeth without ferrule.*

Key words: Endodontically Treated Teeth, Zirconia Post, Press Core, Press Crown, Ferrule

ORIGINAL PAPER (OP)
Balk J Dent Med, 2017; 21:44-49

Introduction

Numerous post and core systems are used to strengthen weakened endodontically treated teeth (ETT)[1,2]. There are various individualized or prefabricated metal, fiber reinforced composite or ceramic posts, which are used for the restoration in the frontal region[3]. There is no agreement in the literature regarding the most suitable choice of material and post placement method, that will result in the highest probability of successful treatment.

Metal post systems might compromise the aesthetics and biocompatibility of the restorations due to corrosion and gingival discoloration. Regarding the strength, zirconia ceramics is superior compared to other ceramic and composite post materials. Therefore, the application of the high-strength all-ceramic zirconia posts are preferred for esthetic restoration of the ETT with zirconia crown and bridges[4,5].

It has been demonstrated, however, that placement of endodontic post can create stresses that lead to root fracture[6,7]. Moreover, the strength of ETT was directly related to the remaining tooth structure[2,3]. In order to protect the root from vertical fractures it is necessary to adequately prepare dentin shoulder in the remaining coronal dentin for most favorable stress-distribution[8,9]. The shoulder preparation of the external part of the coronal dentin was a step to obtaining a ferrule effect from dentin and crown[10,11]. Several authors[5,12,13] have suggested that the tooth should have a minimum amount of 2mm external coronal structure above the cement-enamel junction (CEJ) to ensure proper strength. However, studies concerning the effects of ferrule length on the fracture resistance of ETT, remain controversial[2,14].

Therefore, the purpose of this study was to investigate the influence of the ferrule length on the fracture resistance of the endodontically treated maxillary central incisors.

Material and methods

A total of 24 extracted caries free maxillary central incisors were stored in 0.1% thymol solution immediately after extraction. The root canals were endodontically treated and prepared for the post placement. The anatomic crowns of the teeth were sectioned horizontal to the long axis, 2mm above the CEJ. The sectioned teeth were divided into 2 groups of 12. Group A was prepared with 2mm external dentin shoulder, and the control group B was without external dentin shoulder. The restoration was made using the Y-TZP VALLPOST BO-S (Ø 1,6mm), Ljubljana, Slovenia with length 15/8.5mm[15]. The coronary design of the posts included retention forms[16] (Figure 1).

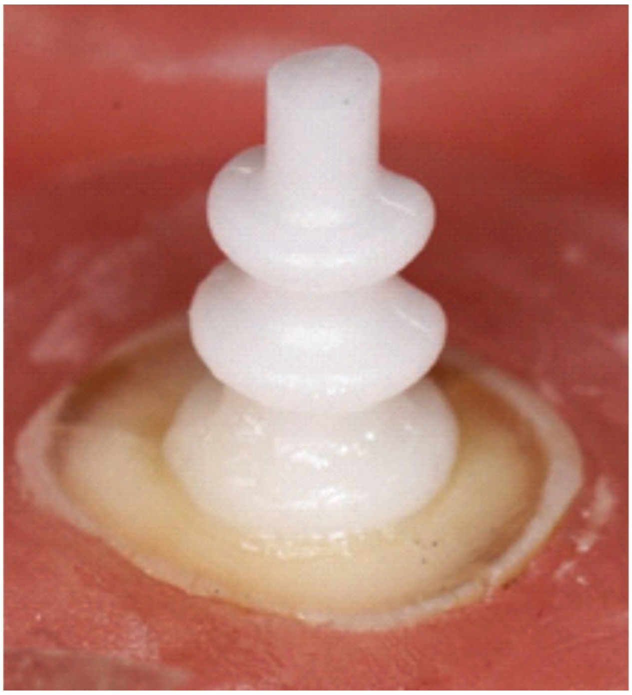

Figure 1. Y-TZP VALLPOST BO-S (Ø 1,6mm) with 3 retentive rings

The first retention element was a full ring, and the remaining two were half-rings, which provided sufficient space for core build-up material. The posts were built-up with the press ceramic cores (IPS e.max Press, Ivoclar). The crowns were made of the same press material with two different dimensions (2mm longer in group A). The zirconia posts and crowns were cemented using resin cement (Multilink Automix, Ivoclar, Vivadent) following the manufacturers guidelines (Figure 2).

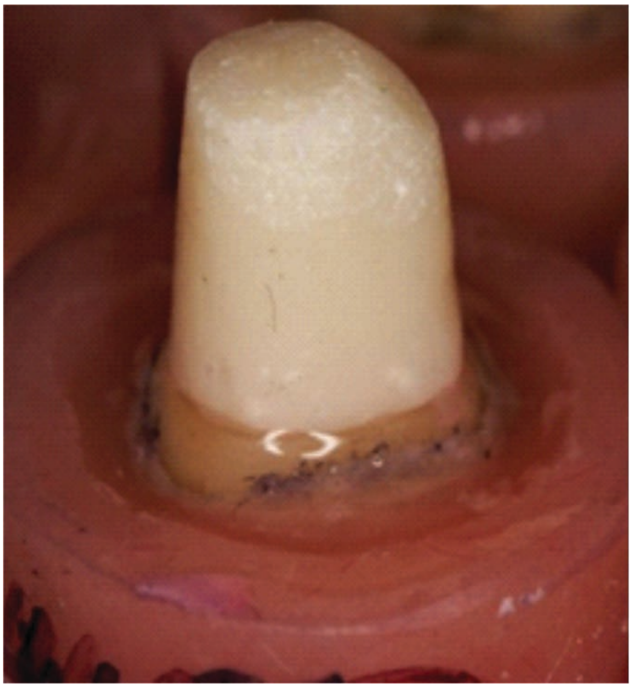

Figure 2. *IPS e.max Press crown cemented over Y-TZP VALLPOST BO-S (Ø 1,6mm) with press core*

The specimens were stabilized in a paralleling device (Bego, Germany) and embedded in acrylic resin blocks (ProBase Cold, Ivoclar, Liechtenstein). Standardized silicone 0.1-0.2mm thin layers simulated periodontal ligament. The specimens were stored for 24h in a thermostatically controlled destilled water bath

(TWB 14, Julabo, Seelbach, Germany) at 37°C. The test specimens were then placed into a special jig and loaded at an angle of 45° to the long axis in Instron Testing Machine 4301 (Instron Corp., USA) with a crosshead speed of 1mm/min until fracture. Load was applied in the middle of the lingual surface, 2mm below the incisal margin. Test specimens were considered to have failed when the crowns or cores separated from the posts, posts failures occurred or tooth fractured (Figure 3).

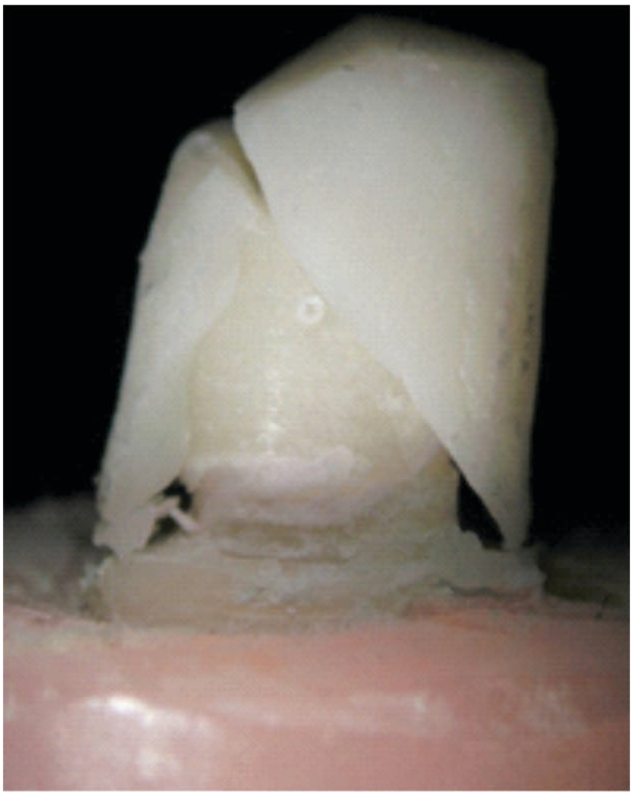

Figure 3. IPS e.max Press fractured crown over Y-TZP VALLPOST BO-S (Ø 1,6mm) with press core

Fracture loads (N) and the type of fractures were recorded. Fractures that could be restored were denominated as reparable and catastrophic fractures as non-reparable[5,6,7,8,17-19]. Two-way analysis of variance (ANOVA) was used for statistical analysis ($p<0.05$). Failure patterns were analyzed with the optical microscope Stereo Discovery V.8 (Carl Zeiss, Germany) and compared using the chi-square nonparametric test.

Results

The mean values of failure loads (N) and standard deviations are shown in Table 1. Average values and standard deviation of fracture force on ETT with and without 2mm ferrule are presented in Figure 4.

Table 1. Average values and standard deviation of fracture forces on ETT with and without 2mm ferrule

ETT/Y-TZP VALLPOST BO-S (Ø 1,6mm) / Press Core-Crown		
Ferrule (mm)	0 mm	2 mm
F (N)	519.36	664.63
±SD	± 71.65	± 49.14

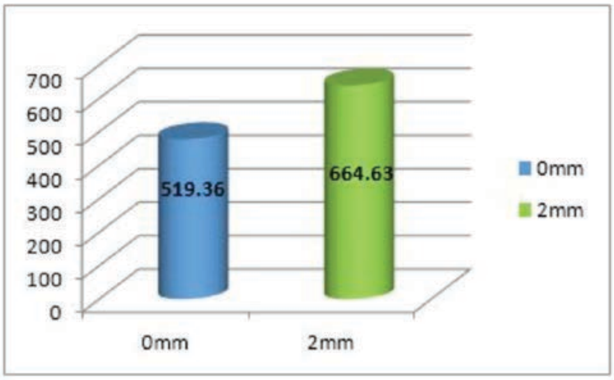

Figure 4. Average values of fracture forces on ETT/Y-TZP VALLPOST BO-S (Ø 1,6mm) / Press Core-Crown with and without 2mm ferrule

Two-way ANOVA revealed a significant difference ($p<0.05$) in fracture resistance between the groups A and B. With respect to the cervical third of the root, fracture patterns were classified according to the root fracture site. Failure patterns within the groups (Table 2) revealed non-catastrophic failure in 70.7% (0mm B group) and 85.3% (2mm A group).

Table 2. Modes of Fractures (number and %)

ETT/Y-TZP VALLPOST BO-S (Ø 1,6mm) / Press Core-Crown			
Fractures	Ø (mm)	FERRULE	
		0 mm	2 mm
Reparable	1.6	8 (70.7%)	10 (85.3%)
Nonreparable	1.6	4 (29.3%)	2 (15.7%)

Discussion

This in vitro study compared the fracture resistance of endodontically treated anterior central maxillary incisors prepared with two different ferrule length. Human teeth were used for the preparation of the specimens. All roots received endodontic treatment and were restored with zirconia WALLPOST with 3 retentive rings, press core build-ups and press crowns.

The prepared dentin shoulder is primary factor that affects the durability of the restored ETT[4,16,20-24]. In this study the contribution of the remaining coronal dentin to the achievement of »ferrule effect« (FE) was examined. The external surface of the circular shoulder preparation on the peripheral, cervical part of the tooth, forms a dentin ring, which allows a better fit for the internal surface of the cervical part of the crown. Only the interaction between these two different structures (dentin and crown), creates a protective ferrule effect[13,15].

In this study, the compressive load was applied directly to the inclined surfaces of the crowns, which is similar as reported in previous studies[8,14,23]. The results showed that, the teeth prepared with 2mm ferrule length showed significantly increased fracture resistance. This corresponds with the results from the other studies[18,22].

According to the results of this study, it can be concluded that it is important to use the external surface of prepared dentin in order to improve the fracture resistance of the tooth and restoration. It is generally accepted that for a restoration extending at least 2mm apical to the junction of the core and the remaining tooth structure, encirclement of the root with external ferrule length will protect the ETT against fracture by counteracting and distributing the stresses better which are generated by the post[8,25,26]. Sorensen and Engelman[27] stated that ferrule with 1mm of vertical height has been shown to double the fracture resistance versus teeth restored without ferrule. On the other hand, Nothdurft and Pospiech[20] stated noticeably lower values for the fracture resistance which were not significantly different for 1mm and for 2mm ferrule. Meng at al.[28] concluded that the provision of a long, heavy ferrule decreased the volume of sound root dentin and increased the clinical crown length relative to the embedded root length.

It should be emphasized that zirconia posts with retention rings were used in this study. In contrast, there are many reports on the fracture resistance using posts with no retention elements[1,2,26,30-32]. In their studies, Ottl at al.[33] reported lower fracture strengths of zirconia posts in artificial root canals compared to the results from this study. Similarly, Asmussen at al.[34] found lower fracture strengths for BioPost and CeraPost. In both of these studies, zirconia posts without retention forms were used, because of the use of artificial roots, lower fracture strength values were obtained. They reduced the effect of structural differences between natural teeth and the posts[14,26,35,36]. In our study, the results primarily depend on the prepared remaining dentin.

Similar to our study, Hazaimeh and Gutteridge[37] concluded that the fracture patterns were more favorable when a ferrule length was present. On the other hand, same authors found that the majority of the fractures in the teeth without ferrule were non-restorable[29,30]. In our study, the results showed increased percentage of reparable fractures in all groups. Namely, in the present study, the teeth prepared with and without EF showed similar fracture modes, all in favor of the reparable fractures. However, we should not forget the fact that the same zirconia posts with retentive coronal elements were used for restoration of the teeth in all the groups. Therefore, it is evident that the retentive coronal form of the zirconia posts contributes to the more favorable outcome of fractures. In addition, it should be noted that the fractures in the different groups occurred under different loads. The difference in fracture loads among the groups shows that the ferrule effect combined with the retentive coronal form of the posts lead to more favorable fracture modes under increased loading.

A study conducted by Akkayan and Guelmez[8] stated catastrophic fractures of zirconia posts. However, this study was performed with zirconia posts without retentive coronal forms. Similar to this study, Ozkurt and Kazazoglu[36] stated that the high rigidity of the zirconia posts is a predisposing factor for vertical root fractures.

Dilmener at al.[9] assumed that the use of a zirconia post with an elastic modulus closer to that of dentin would be mechanically more advantageous for the preservation of recipient roots. Other studies[38-45] have shown maximum beneficial effects from a ferrule length with 1.5 to 2mm. The fracture patterns were more favorable when a ferrule length was present. The results from the mentioned studies, compared with ours, confirm that preparation dentin length and posts design with retentive coronal elements additionally increase the fracture resistance and contribute to more favorable modes of fracture. The present study shows that in order to achieve better survival rates of the post and core restorations, it is of great importance to pay more attention to the preparation design of the tooth using dentin and crown ferrule.

Conclusion

The dentin and crown ferrule influences the fracture resistance of root treated maxillary central incisors. Within the limitations of this in vitro study, the following conclusions were drawn:

1. Teeth without (dentin and crown) ferrule effect were fractured at a significantly lower load than teeth restored with an apical extended 2 mm long ferrule,

2. The fracture patterns of the post-core restored teeth were restorable in 70% to 85% of the cases in both groups.

Therefore, the presented hypothesis that the (dentin and crown) ferrule increases the fracture resistance of the maxillary central incisors was confirmed. The higher percentage of restorable fractures, confirm the second hypothesis that the zirconia posts with retentive forms in the coronal part result in reparable fractures when subjected to fracture loads.

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Received on September 28, 2016.
Revised on December 27, 2016.
Accepted on January 5, 2017.

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