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THE EFFECT OF NEW INTERNAL FERRULE DESIGN PREPARATION ON THE FRACTURE RESISTANCE OF ENDODONTICALLY TREATED CENTRAL INCISORS

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THE EFFECT OF NEW INTERNAL FERRULE DESIGN PREPARATION ON THE FRACTURE RESISTANCE OF ENDODONTICALLY TREATED CENTRAL INCISORS

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Statement of problem. Many studies concerning that the amount of remaining coronal tooth structure may have a significant effect on fracture resistance of endodontically treated teeth.
Purpose. This study investigated the fracture resistance of endodontically treated anterior central incisors prepared with internal ferrule preparation design.
Material and methods. A total of 120 extracted human maxillary central incisor were endodontically treated and divided into 10 groups of 12. From Group A1 to E1 and A2 to E2 represented teeth were prepared without (0mm), 0.5mm, 1mm, 1.5mm, and 2mm internal ferrule preparation. As material for our experiments, we used Ø1.4 - 1.6mm Y-TZP ceramics posts with retention forms in the coronary part of the post, upgraded with IPS E-MAX, Ivoclar, Vivadent. The experimental samples were cemented (Multilink Automix, Ivoclar), embedded in acrylic resin blocks (ProBase Polymer/Monomer, Ivoclar) and loaded at an angle of 45° degrees in an Instron Testing Machine 4301 (Instron Corp., USA) at a crosshead speed of 1mm/min until fracture. Fracture loads (N) and modes (repairable or catastrophic) were recorded. Two-way analysis of variance was used for statistical analysis with the level of significance seat $p<0.05$. Failure patterns were analyzed in the optical microscope Stereo Discovery V.8 (Carl Zeiss, Germany).
Results. The mean values (±SD) for fracture loads were measured (Newtons) for the first two groups without internal ferrule (0mm) = A1: 1.4mm - 405,04N (±100.04); and A2: 1.6 mm - 503,09N (±109.01); for next two groups with 0.5mm = B1: 1.4mm - 401.07N (±75.02) and B2: 1.6mm - 507.13N (±101.08), for next two groups with 1mm = C1: 1.4mm - 479.01N (±109.12) and C2: 1.6mm - 567.06N (±134.37), for next two grups with 1.5mm = D1: 1.4mm - 601.73N (±103.52) and D2: 1.6mm - 675.79N (±171.09), and for last two groups with 2mm = E1: 1.4mm - 719.99N (±220.02) and E2: 1.6mm - 861.06N (±237.15).
Failure patterns within those 1.4 – 1.6mm Y-TZP posts - E-MAX cores groups revealed non catastrophic failure in groups (0mm) A1-A2 = 100% - 100%, groups (0.5mm) B1-B2 = 100% - 100%; groups (1mm) C1-C2 = 91.7% - 91.7%, groups (1.5mm) D1-D2 = 91.7% - 75%; and for 2mm (internal ferrule preparation design) were 66.7% -58.3% in both of groups E1-E2.
Conclusion. With the limitations of this study, the teeth prepared without (0mm), with 0.5mm and 1mm internal ferrule preparation design demonstrated significantly lower failure loads then those with 1.5 and 2mm IF. The results showed that zirconium posts with retentive coronal part and 1.5mm - 2mm internal ferrule preparation which contribute to increasing the fracture resistance of the restored root-coronary dental complex, show significance higher fracture resistance. No-significant results were determined in all of experimental groups restored with different diameter (Ø 1.4 - 1.6mm) of zirconia posts.

Keywords: endodontically treated teeth, zirconia post, ferrule

Introduction

Many studies concerning that the amount of remaining coronal tooth structure may have an effect on the fracture resistance of endodontically treated teeth to provide ferrule effect.[1,2,3,4,5]

Several authors,[6,7,16,17,19,21] have suggested that it is very important to provide ferrule effect from the post, the core and the crown, but they extend their researches only on the effect of the dentin and crown ferrule. Only few studies investigate the effect of internal ferrule preparation on fracture resistance of endodontically treated teeth restored with different post and core. Jovanovski[8]

Faria at al[9] tested different designs of tooth preparation. They researched the influence of the remaining coronal tooth structure location on the fracture resistance and concluded that palatal walls were more resistant to fractures than labial.

In most of the studies[10,11,12,13,14,15,16,19,23] only external ferrule effect between external prepared dentin and crown was researched, not taking into account the influence of internal ferrule effect. Therefore, we decided to investigate the effect of post-core design and internal ferrule preparation design on the fracture resistance of endodontically treated teeth restored with zirconia posts. [8,17,18,20,21,24,25,26,27]

Material and methods

A total of 120 extracted human maxillary central incisors without fractures and with similar dimensions were stored in 0.1% thymol solution after extraction. The root canals were endodontically treated, prepared with K3™XF, Dentsply (Starter kit), obturated with AH plus®and gutta-percha points (Dentsply,DeTrey, Germany). The anatomic crowns of all teeth were sectioned horizontal to the long axis (2 mm incisal to the cement-enamel junction) with water cooled diamond-coated disc, IsoMet® 1000 Precision Saw BUEHLER.

All experimental teeth were divided into 10 groups of 12. Group A1 to E1 (A1 / B1 / C1 / D1 / E1) and E2 to E2 (A2 / B2 / C2 / D2 / E2) represented teeth prepared without (0mm), 0.5mm, 1mm, 1.5mm, and 2mm internal ferrule preparation. As material for our experiments, we used Ø 1.4 - 1.6mm Y-TZP ceramics posts (IJS-MF) Slovenia with retention forms in the coronary part of the post, upgraded with IPS E-MAX, Ivoclar, Vivadent.

Circumferential shoulder preparation of the cervical part of the root canal were prepared (excluding the first two groups) with an apical extended 0.5mm/1mm/1.5mm and 2mm long internal dentin ferrule preparation. 360° parallel internal dentin wall was extended coronal from the preparation shoulder of the root canal. The vertical length of the internal surface of the dentin wall was defined as the length of internal ferrule preparation. (Fig. 1.)

Post spaces were prepared in all groups with the special preparation drills (IJS-MF, Slovenia) leaving at least 4 mm gutta-percha apical seal.

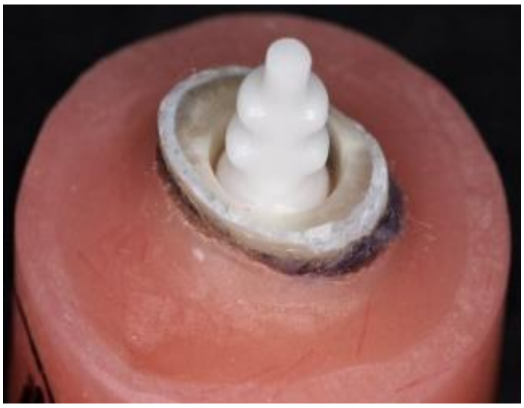


Fig. 1. Internal Dentin Ferrule Preparation and
Y-TZP Post with retentive rings in the coronal part (IJS-MF), Slovenia

Groups A1 / B1 / C1 / D1 / E1, were restored with Ø 1.4mm, length 17.5/11mm, and groups A2 / B2 / C2 / D2 / E2 with Ø 1.6mm, length 15/8.5mm, Y-TZP Post (IJS-MF), Slovenia. The root part of the zirconia experimental post had a cylindric-conical line. The coronary design of the zirconia posts included retention forms with three retentive rings. The first (apical) retention element is a full ring, and upper two half-rings providing sufficient space for core build up material. The experimental posts were build-up with e-max core material (E-MAX, Ivoclar, Vivadent, Liechtenstein) and cemented with resin cement (Multilink Automix, Ivoclar). All simples with uniform core buildup were with dimensions 6 x 5 x 5 mm (base diameter x height x upper surface) and with 45° degrees on the palato-incisal surface made with indirect press method.

Fig 2. Instron Testing Machine 4301.

Root surfaces of the experimental teeth were marked at the CEJ and covered with Durapore adhesive tape. That cemented post/teeth experimental samples were embedded in acrylic resin blocks (ProBase Polymer/Monomer, Ivoclar) with fixator (Bego). (Fig. 1.)
In the next steps Durapore spacers were removed from the root surfaces and impression material (Xantopren plus, HeraeusKulzer, GmbHGermany) was injected into acrylic resin

modle. The experimental teeth were reinserted into acrylic cylinders with standardized silicone 0.1-0.2mm thin layers (simulated periodontal ligament).

Test specimens (unloaded) were then placed at an angle of 45° to the long axis into a special jig and retention tests were performed by Instron Testing Machine 4301 (Instron Corp., USA) with crosshead speed of 1mm/min until fracture. The load was applied in the middle of the lingual surface, 2 mm below the incisal margin. (Fig. 2)

Fracture loads (N) and modes (favorable/repair or catastrophic/non restorable) were recorded, thereby considering that reparable fractures are those that occur above the level of the alveolar bone, and catastrophic are those that occur below the level of the alveolar bone. Two-way analysis of variance (ANOVA) was used for statistical analysis with the level of significance seat $p<0.05$. Failure patterns were analyzed in the optical microscope (Fig. 3.).

Fig. 3. Optical microscope Stereo Discovery V.8 (Carl Zeiss, Germany).

Results

The mean and standard deviations for failure loads are shown in Table 6.1 and 6.2. The mean values for fracture loads measured in Newton's were for the following groups:

Table 1. 1 Fracture loads (N)

POST / CORE	Y-TZP POSTS / E-MAX CORES					
GROUP A(1-2) / B(1-2) / C(1-2)	INTERNAL FERRULE PREPARATION					
	A(1-2) = 0 mm CONTROL GROUP		B(1-2) = O,5mm		C(1-2) = 1 mm	
Ø (mm)	1.4	1.6	1.4	1.6	1.4	1.6
Mean (N)	405.04	503.09	401.07	507.13	479.01	567.06
Stand. Deviation	± 100.04	± 109.01	± 75.02	± 101.08	± 109.12	± 134.37

Table 1. 2 Fracture loads (N)

POST / CORE	Y-TZP POSTS / E-MAX CORES					
GROUP A(1-2) / D(1-2) / E(1-2)	INTERNAL FERRULE PREPARATION					
	A(1-2) = 0 mm CONTROL GROUP		D(1-2) = 1,5mm		E(1-2) = 2 mm	
Ø (mm)	1.4	1.6	1.4	1.6	1.4	1.6
Mean (N)	405.04	503.09	601.73	675.79	719.99	861.06
Stand. Deviation	± 100.04	± 109.61	± 103.52	± 171.08	± 220.02	± 237.15

For fracture resistance, two-way ANOVA revealed a significant difference ($p<0.05$) in groups with 1.5 mm and 2 mm, compared to groups without (0mm), with 0.5mm and 1 mm internal ferrule. No significant difference ($p>0.05$) was evaluated between the teeth in groups without (0mm), with 0.5mm and 1 mm and between the teeth with 1.5 and 2mm internal ferrule preparation.

Table 2. 1. No-Significant Difference ($p>0.05$)

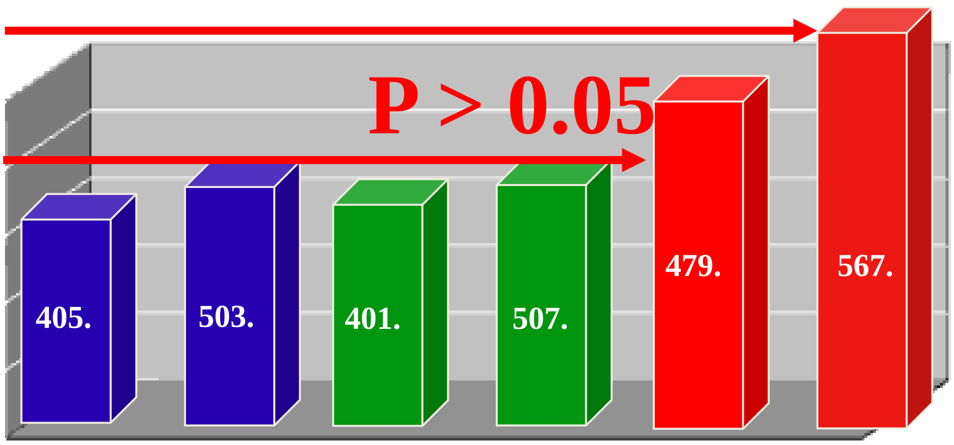
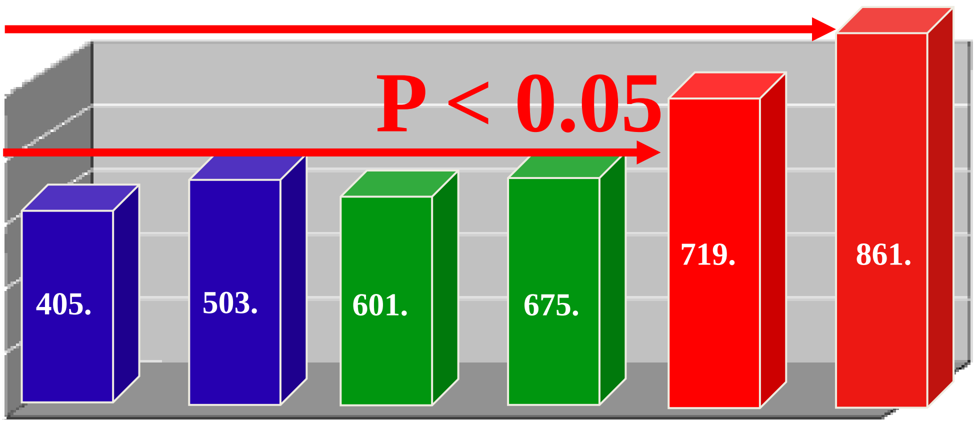


Table 2. 2. Significant Difference ($p<0.05$)



There were no significant differences among the groups with Ø 1.4 mm / 1.6 mm posts, regardless to the prepared internal ferrule (Table 2. 1/2).
Failure patterns within those groups revealed non-catastrophic failure in group A = 100% - 100% for 0mm; group B = 100% - 100% for 0.5mm; group C – 91.7% - 91.7% for 1mm; group D = 91.7% - 75% for 1.5mm; and 66.7% -58.3% for 2mm (internal ferrule preparation design) in both of groups E (Table. 3. 1/2)

Table. 3.1. Types of Failure / Number / (%) of Teeth.

TABLE A: FRACTURES

Y-TZP POST/ E-MAX CORE FRACTURES	%	INTERNAL FERRUlE PREPARATION (IF)		
	Ø	**Control A** (0mm) %	**B** (0.5mm) %	**C** (1mm) %
REPARABLE	1.4	12 (100)	12 (100)	11 (91.7)
	1.6	12 (100)	12 (100)	11 (91.7)
NON-REPARABLE	1.4	0 (0,0)	0(0,0)	1 (8,3)
	1.6	0 (0,0)	0(0,0)	1 (8,3)

Table. 3.2. Types of Failure / Number / (%) of Teeth.

TABLE B: FRACTURES

Y-TZP POST/ E-MAX CORE FRACTURES	%	INTERNAL FERRUlE PREPARATION (IF)		
	Ø	**Control A** (0mm) %	**D** (1.5mm) %	**E** (2mm) %
REPARABLE	1.4	12 (100)	11 (91.7)	8 (66.7)
	1.6	12 (100)	9 (75)	7 (58.3)
NON-REPARABLE	1.4	0 (0,0)	1 (8.3)	4 (33,3)
	1.6	0 (0,0)	3 (25,0)	5 (41,7)

Discussion

In this in vitro experimental study natural teeth were used for preparation and all roots received endodontic treatment and were subjected to a post and core build up. The autors[8] of the present study investigated and described the new design preparation. They concluded that different preparation length has different influence on the fracture resistance. However, adequately prepared dentin for zirconia posts with retentive rings in the coronal part result in reparable fractures when subjected to compressive loads directly applied to the inclined surfaces of the cores. As in similar previous studies[28,29,30,31,32,33,34,35] in this study, the post and cores did not restore with crowns. We used fracture testing as a method for evaluation of the fracture resistance. The testing apparatus did not differentiate between the different modes of failure (Fig 3. Instron Testing Machine 4301).

The results showed that the fracture resistance of the post-core restorations with 0.5mm and 1mm prepared internal part of the dentin was not significantly different from the fracture resistance of the restored teeth without (0mm). On the other hand, the teeth prepared with 1.5mm and 2mm prepared internal part of coronal dentin showed significantly increased fracture resistance. Therefore, it is not only important to use the remaining internal part of dentine in order to improve the fracture resistance of the tooth, but it is crucial to provide the sufficient length of internal preparation.

From many authors[21,23,24,25,26,27,36,37] it is generally accepted that for a restoration extending at least 2mm apical to the junction of the external core surface will protect the endodontically treated tooth. On the other hand, Nothdurft[22] stated noticeably lower values for the fracture resistance which were not significantly different for 1mm and for 2mm ferrule. Stankiewicz and Wilson (2008)[23], and numerous other authors[24,25,26,27,28,39], concluded that a ferrule with 1mm of vertical height has been shown to double the resistance to fracture versus teeth restored without a ferrule preparation design. The results from our study confirm that not only the external ferrule, but also the internal ferrule should be at least 1.5 and 2mm long in order to provide the desired protective effect.[8]

In ours present study cylindric-conical posts with retentive coronal part were used for restaration of experimentally endodontically treated teeth. It is known that cylindrical posts exibit better retention than conical posts. However, the cylindrical shape does not correspond to root anatomy and excessive preparation in the apical portion of the tooth might weaken the root.[21]

Fracture strength values from others rewivers[23,25,26,27,28] is not comparable with the results of the present study because of differences in research design. Namely, in present study the ferrule lengths are presented from the internal part of dentin, unlike other studies which analyze only core-crown ferrule.[2,3,4,5,6,10,11,13,30,31,32,36,37,39.] The internal preparation part of dentin circumferentally provides a cylindrical space for the first retentive ring of the zirconia post in the coronal part of the root. Therefore, it provides fisiological stress distribution throw the dentin walls.

Other than that, in most of the studies on this matter, the composite core was build up on experimental posts that had no retention elements in their coronal part,[15,28,36] while in our study we used posts with retention elements and press core build up.

Ottl at al[33] in artificial root canals stated lower fracture strength of zirconia posts in respect to results from our study. Similarly, Asmussen at al [34] found lower fracture strength for Biopost and CeraPost. In both of these studies, zirconia posts without retention forms were used. With artificial roots lower fracture strength values were obtained because they reduced the effect of structural differences between natural teeth and the posts.[19,30.]

Oblak at al [19] used zirconia posts with retention elements, and stated values for load to fracture similar to ours (without internal ferrule), but their experiments were also conducted on posts mounted in artificial root canals, instead of natural teeth.

They concluded that load to fracture of zirconia posts depends primarily on post diameter but they had not taken into account the effect of dentin preparation. From our results, it is evident that the post diameter is less influential than the internal dentin preparation length for the improvement of the fracture resistance.

Akkayan and Guelmez[28] stated catastrophic fractures of zirconia posts. However, this study was performed with zirconia posts without retentive coronal forms. Similar to this study, Ozkurt at al[35] stated that the high rigidity of the zirconia posts is a predisposing factor for vertical root fractures. Dilmener[31] and Asmussen[34] 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. Many other studies[24,25,26.] have shown maximum beneficial effects from a ferrule with 1.5 to 2mm of vertical tooth structure. The fracture patterns were more favorable when a ferrule was present. The majority of the fractures in the teeth without a ferrule were nonrestorable.[27,28] Hazaimeh and Gutteridge[36] concluded that the fracture patterns were more favorable when an external ferrule was present.

In our experimental study we excluded the external ferrule in order to research only the influence of the internal ferule preparation length on the fracture resistance of endodontically treated teeth. The results showed increased percentage of reparable fractures in all groups. In the present study, the teeth prepared with and without internal preparation dentin 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 post contributes to the more favorable outcome of fractures.

The results from the all mentioned studies, compared with ours, confirm that preparation ferrule design and posts design with retentive coronal elements additionally increase the fracture resistance and produced more favorable modes of fracture.

Conclusion

Within the limitations of this in vitro study, the following conclusions were drawn:

1. The teeth without and with 0.5 and 1 mm internal ferrule preparation design were fractured at significantly lower loading then teeth restored with an apical extended 1.5 and 2mm long internal ferrule preparation.
2. The minimum internal ferrule length that provides increased fracture resistance is 1.5 to 2mm.
3. Load to fracture of the post-core restored endodontically treated teeth depends primarily on the length of the internal ferrule preparation, regardless to the post diameter.
4. The fracture patterns of the post-core restored teeth were restorable in 60 to 100% in all of the groups and significantly higher % of reparable fractures was determined in all of experimental groups.

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