
INFLUENCE OF INNER CORONAL DENTIN ON THE FRACTURE STRENGTH OF POST-ENDODONTIC RESTORED UPPER LATERAL INCISORS

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Abstract: Purpose. This in vitro research studied the influence of the amount of inner ferrule (IF) on fracture strength of restored endodontically treated teeth (ETT).

Material and methods. 72 upper lateral incisors (ULI) were extracted, treated endodontically, and divided into the following groups: A 1/2, without IF (0mm); B 1/2, 1mm of IF, and C 1/2, 2mm of IF, respectively. For our experiments Y-TZP VALL-POST (WALL-CER, Slovenia) with 3 retentive rings, coronally upgraded with direct composite MultiCore (Ivoclar) were used. The experimental posts were cemented with composite cement Multi-link (Ivoclar), embedded in blocks (Pro-Base acrylic resin), and loaded (45 degrees) on Testing Machine (Instron 4301 USA) until fracture (1mm/min crosshead speed). Fracture loads and modes were analyzed. Two-way of variance analysis was used (significance $p < 0.05$).

Results. For fracture loads, mean values (\pm SD) were measured in Newton's (N). For groups A1 / B1 / C1 ($\varnothing = 1.4\text{mm}$) and A2 / B2 / C2 ($\varnothing = 1.6\text{mm}$), we obtained the following results: A1 = 305.04N (± 74.04); B1 = 351.07N (± 77.17); C1 = 579.11N (± 112.21) and groups A2 = 373,17N (± 49.04); B2 = 393.03N (± 73.11); C2 = 618.79N (± 130.02). There occurred repairable failure patterns in different percentages concerning the IF: A1 = 100% / A2 = 91.5% (0mm IF); groups B1 = 84.3% / B2 = 66.6% (1mm IF), and groups C1 = 75.0% / C2 = 57.4% (2mm IF).

Conclusion. Within the confines of this research the ETT with 1mm IF and without IF demonstrated considerably lower failure loads than those with 2mm IF, with repairable failure patterns in all groups ULI.

Keywords: Endodontic treated teeth, Y-TZP post, inner ferrule

1. INTRODUCTION

A few separate articles describe the main concept of the restoration of ETT. Cheung W. (2004, 2005) and almost all of the authors of those articles state that the ferrule effect is one of the important concepts for prosthetic restorations of ETT. Adequately prepared coronal tooth structure provides a ferrule effect that will enable the most favorable stress distribution from the crown, core, and post to dentin. Clarisse C. (2006); Friedel W. and Kern M. (2006) in their studies researched only the outer dentin-crown ferrule. On the other hand, the influence of the inner ferrule effect between dentin and post was not researched. Only a few studies Pereira JR (2009), Faria A. et al., (2011), Jovanovski S. (2012, 2018, 2021) investigate the effect of IF preparation around the root canal on fracture strength of ETT. Consequently, in this in vitro research, the effect of IF and retentive rings on the fracture strength of ETT restored with Y-TZP VALL-POST was investigated.

2. MATERIAL AND METHODS

72 extracted ULI with similar dimensions after extraction were stored in a 0.1% solution of thymol. The ULI root canals were treated (Starter kit - K3™XF, DENTSPLY), obturated with AH plus® and gutta-percha points (DENTSPLY). The crowns of experimental ULI were sectioned horizontally 2mm above the cement-enamel junction with a diamond-coated disc (1000 IsoMet® BUEHLER). Circumferential shoulders were prepared around ULI root canals (excluding the first two control groups) with a 1mm & 2mm length of IF. The vertical length of the IF dentin walls (internal surface) was prepared with special drills (VALL-CER, Slovenia).

Fig. 1. Y-TZP WALLPOST



Source: author

Groups A1/A2, B1/B2, and C1/C2 were configured without (0mm), with 1mm, and 2mm IF, respectively. Groups A1/B1/C1, were reconstructed with \varnothing 1.4mm Y-TZP VALLPOST, RO-L (lengths 17.5/11mm), and groups A2/B2/C2 with \varnothing 1.6mm Y-TZP VALLPOST, BO-S, (lengths 15/8.5mm). The full ring is the first retention element, and half-rings are the upper two rings that provide more space for the core restoration (Fig. 1.). The Y-TZP VALLPOST was built-up using a direct method with composite MultiCore (Ivoclar) and cemented with composite Multilink cement (Ivoclar). All samples were upgraded with uniform cores and have a base diameter of 6mm, 5mm height, and 5mm upper surface length. The palatal-incisal surface of the samples was positioned 45° degrees relative to the horizontal axis (Fig. 2.). The cemented experimental samples (post/teeth) were embedded in acrylic Pro-Base resin (Ivoclar) with a dental Bego fixator (USA) and reinserted with standardized 0.1-0.2 mm thin silicone layers (simulated periodontal ligament).

Fig 2. Testing Machine (Instron 4301 USA)



Source: author

Experimental loading was carried out on the testing machine (Instron 4301, USA) at an angle of 45° to the long axis until fracture with 1mm/min crosshead speed. In the middle of the palatal surface, 2 mm underneath the incisal margin, the load was exerted (Fig 2.). The type of fracture loads and modes were documented. The ANOVA test was used for statistical analysis ($p < 0.05$). The Carl Zeiss Optical Microscope V.8 was used for failure pattern analysis.

3. RESULTS

The mean values and standard deviations for fracture loads were measured in newtons (N) and presented in Table 1. and Figure 4. The mean values of fracture loads for $\varnothing = 1.4$ mm groups were:
A1 = 305,04N (± 74.04); B1 = 351.07N (± 77.17) and C1 = 579.11N (± 112.21).
For the other $\varnothing = 1.6$ mm groups, the following measurements were made:
A2 = 373,17N (± 49.04); B2 = 393.03N (± 73.11) and C2 = 618.79N (± 130.02).

Table 1. Fracture loads (N)

POST / CORE	Y-TZP VALLPOST / MULTICORE					
	INNER FERRULE (IF)					
	A _{1/2} 0 mm		B _{1/2} 1mm		C _{1/2} 2mm	
Ø (mm)	1.4	1.6	1.4	1.6	1.4	1.6
Mean (N)	305.04	373.17	351.07	393.03	579.11	618.79
Stand. Deviation	± 74.04	± 49.04	± 77.17	± 73.11	± 112.21	± 130.02

Source: author

The ANOVA test for fracture strength results, detected a significant difference ($p < 0.05$) between groups with 2mm IF preparations, and groups without (0mm) and with 1mm IF. There was no significant difference ($p > 0.05$) among fracture load values in specimens without (0mm) and with 1mm IF. No difference of high significance was found in fracture loads between groups of Y-TZP VALLPOST with Ø 1.4mm and Ø 1.6mm, irrespective of IF depth (Fig. 4).

Figure 4. Mean values for fracture strength of upper lateral incisors - ULI without (0mm), 1mm and 2mm inner ferrule - IF



Source: author

For all ULI groups, repairable failure patterns were recorded. They occurred in different percentages concerning the inner coronal ferrule preparation: A1 = 100% / A2 = 91.7% (0mm IF), groups B1 = 83.3% / B2 = 66.6% (1mm IF), and groups C1 = 75.0% / C2 = 58.4% (2mm IF), (Tab. 2.).

TABLE 2. Fractures - Failure, Number of Teeth, (%).

Y-TZP VALLPOST/ MULTICORE FRACTURES	Ø	INNER FERRULE (IF)					
		0mm		1mm		2mm	
		N ₀	%	N ₀	%	N ₀	%
REPARABLE	1.4	12	(100)	10	(83.3)	9	(75.0)
	1.6	11	(91.7)	8	(66.6)	7	(58.4)
NON-REPARABLE	1.4	0	(0.0)	2	(16.7)	3	(25.0)
	1.6	1	(8.3)	4	(33.4)	5	(41.6)

Source: author

4. DISCUSSIONS

In our in vitro research, we used natural teeth as specimens for endodontic and post-endodontic treatment. We restored them (ULI) with a post and core build-up. As in similar previous studies Akkayan B. (2002, 2004), Ng CC et al. (2004), and Jovanovski S. et al. (2015, 2017, 2018, 2021), in this study, we used affirmed methods of testing

the specimens and their loading endurance. Such methods include application of directly applied compressive load on the surface of the 45° inclined cores in order to simulate occlusal stress in the oral environment. In addition, the author of the present study, Jovanovski (2012), in his doctoral dissertation described, for the first time in literature, a completely new type of preparation design around the root canal. Preparing the inner portion of the dentine around the root canal is important for achieving the inner ferrule effect which in turn increases the fracture resistance of the tooth. Only a few authors, among them Pereira et al. (2009), and Badami V. (2022) similar to our research, concluded that preparing the inner dentine part additionally increases the fracture strength of the ETT.

The results from our study confirmed that prepared dentin seating for Y-TZP posts with 3 coronal rings when subjected to fracture loads, resulted in repairable fractures. Also, our results did not present an important difference from the fracture strength of the ETT restored without and with 1mm inner dentine preparations length around the cervical part of the canal. In contrast to this finding, a 2mm IF showed a significant increase in fracture resistance. Therefore, it is very important to provide an adequate length of IF. To sum up, strengthening of the ETT largely depends on the length of the IF.

From our group of authors and many others Stankiewicz N. and Wilson P. (2008), Ozkurt Z et al. (2010), it is evident and accepted that at least 2mm of apical extending length of an outer ring will make the ETT more resistant to fracture. Nothdurft P. and Pospiech R. (2006) on the contrary, stated lower values for fracture strength without a significant difference between 1mm and 2mm outer ferrule preparations. Different from previous authors, Kramer E. et. al. (2019) and a few other authors, Batista V. et al. (2020), Kharboutly N. et al. (2023), Tulbah H. (2019) stated that only 1mm vertical height IF length doubles the increase in fracture strength in relation to teeth without IF. However, this experimental research and our previous results confirm that the IF should be at least 2 mm long to provide a very high protective IF effect (against longitudinal fracture) by an enhanced distribution of stresses to dentin generated by the 3 retentive coronal rings & post. Our newly designed inner part of dentin provides a circumferential space in the cervical part of the root exclusively only for the first retentive ring. Also, regarding the same inner dentin preparation, the appropriate length is achieved in the root canal by preparing a cylindrical-conical space for the root part of the post.

According to the results from the literature, it is seen that our research group, for the first time, exclusively published the original IF results for ULI. In this study, a new type of inner prepared surface on the ULI is presented. This new type of preparation ensures an IF effect between the inner part of the dentin and the outer surface of the post (dentin-post). Many other studies analyze only the outer ferrule (dentin-crown) effect. Different from us, in most of the studies on this matter, experimental research on zirconium posts was conducted without providing retention elements (post-retentive rings). During the in vitro study at our research center, we used posts with 3 retentive rings in their coronal part and MultiCore for core material.

Our results showed that there was no significant difference between the different diameters of the used experimental posts. According to the significance of the two different research subjects in our study (inner ferrule and diameter), it can be seen that IF is crucial for an increase of the fracture strength. Opposite to this conclusion, the post diameter is less influential than the inner dentin preparation length.

The author of this in vitro study referred to the IADR conference in 2015, that the fracture modes were more favorable when an inner and outer ferrule effect was present. In previous studies, a few other authors, Gegauf AG. (2000), Hezaimeh N., Gutteridge D. (2001), Zhi-Yue L., Yu-Xing Z. (2003), and Meng QF. (2007) also concluded that most of the fractures in ETT without ferrule effect could not be restored. In contrast, the results from our study showed a more than 50% increase of non-catastrophic fractures with the possibility of repairation. This contrast is owed to the fact that our teeth had an external and an internal ferrule effect. In addition, the retentive rings of the post contributed to having more desirable fractures after test loading. Similar fracture modes were recorded in all experimental ETT with and without IF preparation, all in favor of repairable fractures because the same Y-TZP posts with 3 retentive rings (coronal elements) were used to restore ETT in all groups. However, from the statements above, we can declare that the first full retentive coronal ring of the post contributes to a more physiological occlusal stress distribution, and it is evident that the function of the first full ring of the post contributes to fractures that are more favorable.

5. CONCLUSIONS

Within the confines of this in vitro study, we have concluded that:

1. The ETT without and with 1mm new IF fractured under a significantly lower load compared to ETT restored with a 2mm IF.
2. The new 2mm IF contributes to a significant increase in the fracture strength of ETT.
3. The fracture strength of the IF-restored ETT is largely dependent on the depth of the IF preparation, irrespective of the diameter of the zirconia post.

4. A significantly higher percentage of restorable fractures was determined in all IF experimental groups.

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