



Full Length Research Paper

Effect of ferrule location on fracture resistance and failure pattern of endodontically treated maxillary incisors restored with quartz fiber posts

^{*1}Wala Majid Amin, ²Naser S. Al-Huniti, ³Noor I. Hasan, ⁴Dina W. Al-Nimri, ⁵Saba A. Al-Najdawi, ⁶Ushtar W Amin, ⁷Sheyar W. Amin

^{*1}Department of Prosthodontics, Faculty of Dentistry, the University of Jordan

²Dept. of Mechanical Engineering, Faculty of Engineering and Technology, the University of Jordan

^{3,4,5}Research Fellow, Faculty of Dentistry, the University of Jordan

^{6,7}Research Fellow, Faculty of Medicine, the University of Jordan

*Corresponding Author's E-mail: wami@ju.edu.jo; walaamin@gmail.com; Tel: 00962 6 5353666 Ext: 24601

Abstract

The contribution to fracture resistance of fiber post restored endodontically treated maxillary incisors of 2 mm high coronal dentin retained at different aspects of the preparation was evaluated. 60 extracted maxillary incisors were endodontically treated, divided to six equal groups, 5 groups received quartz fiber posts. A 2 mm high coronal dentin ring was prepared in one group; half a ring of dentin was left either palatally, labially or proximally in three groups; and removed from another group. The sixth group, neither had posts nor coronal dentin. All teeth were restored with metal crowns and their fracture resistance was measured in compression at 135 degrees to its long axis until failure. Data were analyzed by two-way-ANOVA, Tukey and *Chi-square* tests. Coronal structures had a significantly more influence on the fracture resistance than the root posts ($p < 0.05$). Fiber post restored teeth showed predominantly reparable failure patterns. Coronal dentin was more efficacious in restoring endodontically treated teeth than placing root posts, because fracture resistance of the teeth is made up mainly by the ferrule effect afforded by the bracing of full crown against the retained coronal structures.

Keywords: Ferrule, coronal dentin, fiber post, catastrophic root fracture, crown-core-post complex, debonding.

INTRODUCTION

Provision of an adequate fixed prosthodontic treatment to endodontically treated teeth is often present a challenge to clinicians. This is so because the majority of failures appeared to be due to biomechanical, restorative and to a lesser extent biological reasons (Naumann et al., 2005 a, b). The challenge of post-endodontic restoration more intensifies when the tooth presents a substantial structural damage and tissue loss at both the root and crown levels (Ferrari et al., 2007). The role of the amount of remaining tooth structure on fracture resistance of endodontically treated teeth has been emphasized in previous studies (Ferrari et al., 2007; Libman and Nicholls 1995). When the remaining tooth structure is less than 5

mm in height, it may be increased either surgically through a crown lengthening procedure or orthodontically through forced extrusion of the tooth. Both procedures result in a satisfactory and predictable increase in coronal tooth structure but may be contraindicated in situations in which the crown-to-root ratio is compromised (Shillingburg et al., 1997; Clarisse et al., 2006). A 1:1 crown-to-root ratio has been advocated as the minimum ratio necessary for resisting lateral forces that may occur during function whereby the resistance to fracture caused by lateral forces is best afforded by what is termed to be the "ferrule effect" (Shillingburg et al., 1997). The cervical zone of a complete crown restoration functions like a

ferrule when encircling axial tooth structure between the core and the preparation finish line (Clarisse et al., 2006). This ferrule effect has been shown to provide positive reinforcement to endodontically treated teeth by resisting leveraged functional forces, the wedging effect of tapered posts, and lateral forces exerted during post insertion (Sorensen and Engelman, 1990). In particular a "ferrule effect" of at least 1.5 mm has been recommended for a long term success of post-endodontic restorations (Lima et al., 2010). Some past studies reported that a 2 mm of axial wall height beneficially increased fracture resistance of endodontically treated teeth that were restored with prefabricated posts, composite resin cores and complete crowns (Akkayan, 2004; Naumann et al., 2006 a,b). Other studies have also demonstrated that the presence of remaining coronal tooth structure between the core and preparation finish line was more important for fracture resistance of endodontically treated teeth than post length or type (Milot and Stein, 1992; Isidor et al., 1999). It has been shown that posts do not strengthen the tooth (Morgano and Milot, 1993; Fokkinga et al., 2004). Moreover, post space preparation procedures remove remaining tooth structure thus weakening the tooth and increasing the risk of root fracture (Manning et al., 1995; Bolhuis et al., 2001). Restoration with fiber posts have been shown to fail mostly because of less tooth-threatening failures such as loss of post retention and fracture of the post, as compared to the traditional cast-post-and-cores and metallic posts, that frequently yielded unfavorable failure by root fracture (Malferrari et al., 2003; Goodcare, 2010).

The present investigation evaluated whether or not the presence of 2 mm high half ring of axial coronal dentin retained at different aspects of tooth circumference, and the placement of fiber root post can influence the fracture resistance of endodontically treated maxillary incisors. The hypotheses tested were, (1) the retained axial coronal dentin of 2 mm height, and (2) the placement of prefabricated quartz fiber root post do not affect fracture resistance or failure pattern of restored endodontically treated maxillary incisors.

MATERIALS AND METHODS

A total of sixty extracted maxillary incisors were collected from the oral surgery clinics of the Jordan University Hospital. The teeth were thoroughly brushed clean from blood and attached soft tissues using "ASEPTI-ZYME" presoak cleaner (Ecolab Inc. MN USA). The teeth were immersed in 5% sodium hypochlorite disinfectant for 24 hours, and then stored in distilled water. The collected teeth were inspected for uniformity of root shape and those with unacceptably curved roots at the middle or the coronal third were replaced by teeth of more uniform roots. The teeth were cross-sectioned at an 18 mm distance from the root tip using a high speed rotary

diamond separating disc (SS White Burs, Inc. Lakewood, NJ USA) so that the flat and smooth sectioned root face was normal to the long axis of the root.

Root canal filling of all teeth was carried out by one operator using rotary PROTAPER® system (Quality Endodontic Distributors Ltd, Peterborough – U.K.) and 2.5% sodium hypochlorite solution for irrigation. In order to standardize the shape of the root canals of all employed teeth, all canals were shaped up to F3 size file and were, consequently, obturated using system based Gutta percha points and ZX sealer (DENTSPLY Ltd., Addlestone; Surrey, United Kingdom). Post space was prepared in 50 roots to the length of 13mm and standard dimensions using the same size drills (provided in the system kit of D.T Light posts Illusion, RTD. Manufacturing Co. Ltd., Saint Egreve, France). The thickness of the dentine between the root perimeter and the prepared post space was measured for all roots using a Computerized Digital Caliper (CDC) and custom-made software (Amin et al. 2008), the average dentin thickness for all prepared teeth ($n=50$) was 1.23 mm (± 0.26 Stdev).

For the remaining 10 teeth, of the control group, the coronal opening of the obturated root canal was enlarged in a labio-palatal direction to provide a composite resin well of a width of 3 mm and depth of 2 mm for retention of the composite resin core. The external surfaces of the roots were mechanically scored using a diamond separating disc (SS White Burs, Inc. Lakewood, NJ USA); the roughened root surface was indented to help fix the root and stabilize it within its mount during testing. The roots were coated with a thin film (approximately 0.5mm thick) of silicon-based impression material (SPEDEX, Coltene, Switzerland). This artificial layer was used to mimic the periodontal ligament during fracture test and to isolate the root from its mount and allow its removal for inspection and detection for cracks following fracture test. The teeth were, then, mounted into copper rings filled with self-polymerized acrylic resin (PALAPRESS, HERAEUS KULZER, Newbury, Berkshire, U.K.). A dental surveyor (FERRARO ENG. Hereford, Arizona USA) was used to ensure that the long axes of the mounted teeth were perpendicular to the horizontal plane. A distance of 5mm of the tooth height in the coronal direction was left unmounted but emerged out of the acrylic resin surface in the copper ring. Of the unmounted 5mm length, 2mm of the tooth structure represented a ferrule, and the remaining 3mm represented the height of the simulated bone level. The 50 teeth that were prepared for post space were restored by fiber post (D.T LIGHT POSTS ILLUSION, RTD. Manufacturing Co. Ltd., Saint Egreve, France), then divided into five groups of ten teeth each. In the first group, coded "full ring ferrule" group, the 2 mm high axial coronal tooth structure covered the entire tooth circumference. In each tooth specimen of the second, the third and the fourth groups, half of the remaining axial ring of coronal tooth structure was eliminated and the

remaining half ring was placed labially, lingually and proximally, respectively, and the three groups were coded accordingly. Whereas, in the fifth group (the “no ferrule” group), the remaining coronal tooth structure was entirely eliminated. Likewise, the teeth of sixth group (the control group) were flattened coronally by eliminating the remaining tooth structure incisal to the finish line.

The remaining natural crown structure of each tooth in each group was prepared for full metal crown restoration. A shoulder of 1 mm depth, measured by the computerized digital calipers (Amin et al., 2008) was prepared around the full circumference of the tooth with a diamond drill (Nos. 68, 69 and 70 stump preparation diamond burs, DENTSPLY MAILLEFER, Ballaigues-Switzerland). The uniformity of canal orifices among teeth and the near comparability of mean tooth diameters among the different groups helped standardize axial wall width of a minimum of 1 mm in the entire sample. In the “no ferrule group” however, no axial walls were present since teeth of this group had a flat core incisal to the finish line. Axial walls of the “full ring ferrule group” were prepared parallel to each other and to the long axis of the tooth. Likewise, parallelism between the long axis of the tooth and the labial, lingual and proximal walls was achieved in teeth of the second, third and fourth groups, respectively.

The prepared composite core of each specimen was lubricated using petroleum jelly (NRS GLOBAL Partners, Kuala Lumpur-Malaysia) and on which a blue inlay wax (RICHTER & HOFFMANN Harvard Dental GmbH, Berlin-Germany) pattern for a full metal crown restoration was formed using the appropriate size readymade polycarbonate resin incisor crown form (SDI, SVENSKA DENTAL INSTRUMENT AB, Soha-Sweden). A transverse groove, 1mm deep, was scored across the palatal surface 3 mm away from the incisal edge of the wax pattern. The scored groove confined to the chisel like blade of the loading device simulating the incisal edge of a lower central incisor. The wax patterns were invested in high expansion phosphate-bonded investment material (GC FUJIVEST II; GC America Inc., Alsip, Ill) and cast using a high-palladium alloy (ULTIMA LITE; DENTSPLY CERAMCO, Burlington, NJ). The cast crowns were cemented (NEXUS 2; KERR DENTAL).

A custom designed and manufactured holding rig was used to insure that the tooth specimen was housed firmly at the point of load application by the universal testing machine (*WP 310 HYDRAULIC UNIVERSAL TESTER equipped with a PC-aided data-recording system, G.U.N.T. Gerätebau GmbH, Barsbüttel-Germany*), which was used to apply a quasi-static compressive load to tooth specimens with a crosshead speed of 0.5 cm/min (Sidoli et al 1997; Padmanabhan, 2010) at an angle of 135 degrees to the long axis of teeth until failure occurred (Figure 1). The inclined compressive force was applied to the notch on the palatal surface of the crowns. Force data applied over time were

recorded using the universal testing machine's computer software. The failure of the specimen was determined when the force-versus-time graph showed an abrupt change in load, indicating a sudden decrease in the specimen's resistance to compressive loading.

The collected data sets were treated statistically using two-way analysis of variance (ANOVA) to compare fracture resistance means among the various test groups. The two-way ANOVA helped evaluate the influence on specimens' fracture resistance of the presence and location of a crown ferrule, and that of root posts as well as the interaction between these two variables. Multiple comparisons among the investigated test groups of various crown ferrule orientations were carried out using Tukey's test whereby the groups that were statistically different from the others were identified.

The metal crowns of the test specimens were split opened and all specimens were visually and radiographically examined for the type and location of failure, as well as the direction of cracks when occurred. Fractures above the embedded resin, i.e., the simulated bone level were considered repairable and fractures below the resin level were considered irreparable. The influence of root post and the presence and location of crown ferrule on the type of failure was analyzed statistically using “Chi-square” test and Fisher's Exact Probability test. The statistical analyses of data were conducted at 99% confidence level.

Clinical Significance: Residual coronal structures retained either as a full circumferential ring or a half ring on the palatal or proximal aspect of tooth preparation, positively contribute to fracture resistance of the post-endodontic crown restorations of maxillary incisors.

RESULTS

The mean force to fracture and standard deviations of the test specimens were presented in Table 1 and Figure 2. The fracture resistance of tooth specimens to quasi-static compressive loading varied with the presence and location of the residual crown ferrule. Two-way ANOVA revealed a specific contribution to tooth fracture strength was demonstrated by each crown ferrule orientation- full, palatal, proximal and labial. ANOVA showed that at least two of the four crown ferrule orientation groups differed statistically from the others. Tukey-HSD for post hoc multiple comparisons (Table 2) indicated that the ferrule effect in the full, palatal and proximal orientations, significantly affected the fracture resistance of endodontically treated maxillary incisors ($f=79.92$, $p<0.001$). On the other hand, a pair-wise comparison of fracture resistance between the group of teeth that had crown ferrules prepared on the labial aspect of the teeth and the control group which had no crown ferrules showed no significant difference existed ($p>0.01$).



Figure 1. A mounted specimen positioned at 135⁰ angle in a custom made holding grip used in the Universal testing machine (MTS 858; MTS Systems Corp, Eden Prairie, Minn) employed for fracture resistance testing.

Table 1. Force to failure of endodontically treated root-post restored maxillary incisors (Values in the table represent means $\pm$ Stdev, measured in Newton).

Root post restoration	Mean Force to failure (Mean $\pm$ Stdev. for $n=10$) (Newton)				
	Crown ferrule orientation				
	Circumferential ring ferrule	Palatal half ring ferrule	Labial half ring ferrule	Proximal half ring ferrule	No ferrule (control)
Quartz fiber post	310 ($\pm$ 49) ^A	290 ($\pm$ 63) ^A	102 ($\pm$ 62) ^B	222 ($\pm$ 59) ^A	110 ($\pm$ 43) ^B
No post (control)	257.5 ($\pm$ 96) ^A	238 ($\pm$ 56) ^A	60 ($\pm$ 32) ^B	156 ($\pm$ 28) ^A	54 ($\pm$ 57) ^B

Different alphabets denote significant differences at 99% confidence level.

The effect of root posts on the fracture resistance of the endodontically treated maxillary incisors proved to be not significant (Table 1 and Figure 2). The comparisons of the fracture resistance of teeth that shared the same crown ferrule orientation, circumferential, palatal, proximal, labial, made between the groups that were restored with quartz fiber posts and those without, showed that the differences were insignificant ($p>0.01$). The comparison between the labial ferrule orientation groups demonstrated no significant differences in fracture resistance between the fiber post-restored group and the group in which the teeth did not receive fiber post

restorations. Likewise, no significant difference was found between the labial ferrule groups and the control group ($p>0.01$) (Table 1 and Figure 2).

The prevalence of the reparable failure pattern was significantly higher in both the fiber post restored and the control groups than the irreparable mode of failure (Figure 3), the obtained *chi*-square value was 30.1, which indicated a very highly significant difference ($p<0.001$).

The fracture behavior in the fiber post restored group of teeth differed from that of the control group, in the former the type of failure was influenced by the presence

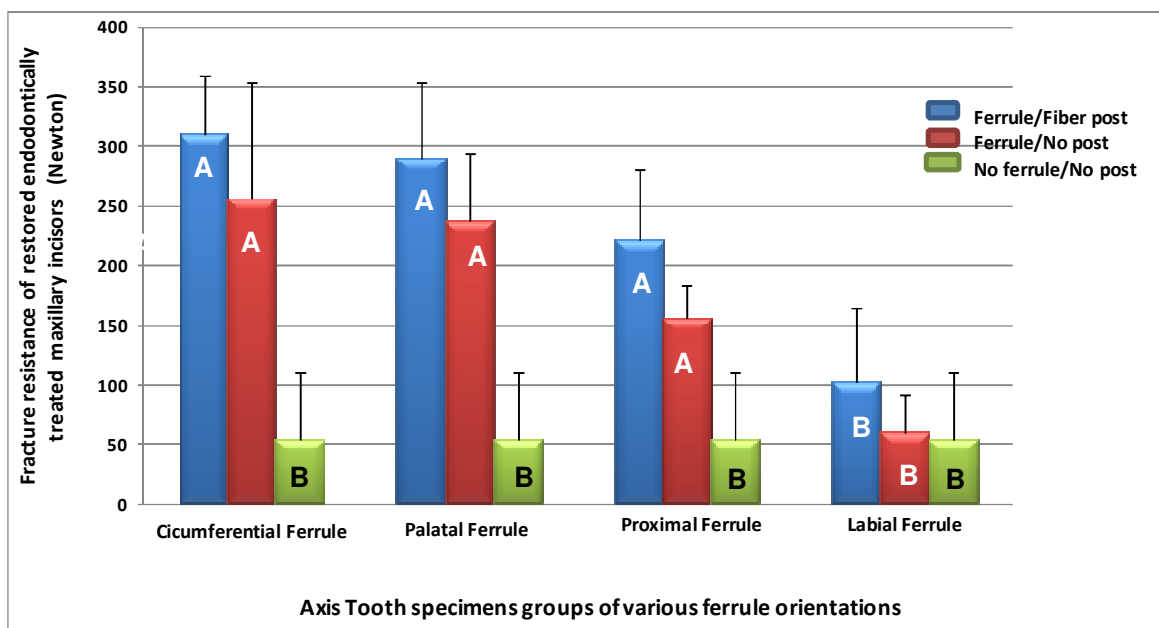


Figure 2. Force (Newton) for failure of endodontically treated quartz fiber post restored maxillary incisors. Error bars represent values of standard deviation. Different alphabets (inserts) denote statistically significant difference at 99% confidence level.

Table 2. Group Mean Differences. The obtained Tukey's "T" value=176; if this was smaller than the difference between two means, the means are significantly different.

(** denote significant mean difference $p < 0.01$. NS indicates not significant mean difference).

Type of ferrule/post complex	Mean fracture resistance (Newton)	Comparison Means (Newton)			
		M2	M3	M4	M5
Full ferrule/ Fiber post	M1= 310	M1-M2= 200**	M1-M3= 20 ^{NS} M3-M2= 180**	M1-M4= 88 ^{NS} M4-M2= 112 ^{NS} M3-M4= 68 ^{NS}	M1-M5= 208** M2-M5= 8 ^{NS} M3-M5= 188** M4-M5= 120 ^{NS}
No ferrule/ Fiber post	M2= 110				
Palatal ferrule/ Fiber post	M3= 290	M6-M7= 203.5**	M6-M8= 19.5 ^{NS} M8-M7= 184**	M6-M9= 101.5 ^{NS} M9-M7= 102 ^{NS} M8-M9= 82 ^{NS}	M6-M10= 197.5** M10-M7= 6 ^{NS} M8-M10= 178** M9-M10= 96 ^{NS}
Proximal ferrule/ Fiber post	M4= 222				
Labial ferrule/ Fiber post	M5= 102				
Full ferrule/ No post	M6= 257.5				
No ferrule/ No post	M7= 54				
Palatal ferrule/ No post	M8= 238				
Proximal ferrule/ No post	M9= 156				
Labial ferrule/ No post	M10= 60				

and orientation of crown ferrule (Figure 4). Albeit, teeth of both groups showed a predominantly reparable failure (Figure 3), the teeth in the control group did not demonstrate an initial tooth fracture but, instead, the majority (19 out of 25) of specimens failed by a complete debonding of the entire crown-core complex off the root (Figure 5-A) and in two instances the core was completely fragmented. Whereas, in the fiber post restored group, 18 out of 25 specimens (9 teeth of the full circumferential ring ferrule and 6 teeth of the proximal half ring ferrule) showed a primary crown core complex fracture with a crack above the simulated bone level

(Figure 5-B). In three specimens, the fiber post failed adhesively and detached from the root (Figure 5-C). The teeth restored with fiber post and had a palatal crown ferrule, showed an initial core fracture that ran on an oblique line in a labial to palatal direction along the crown margin but above the simulated bone level (Figure 5-D). Irreparable fractures were shown by the fiber post restored teeth of a labial half ring ferrule. All those teeth demonstrated a catastrophic crown-core-post complex failure with an oblique palatal to labial root fracture (Figure 5-E).

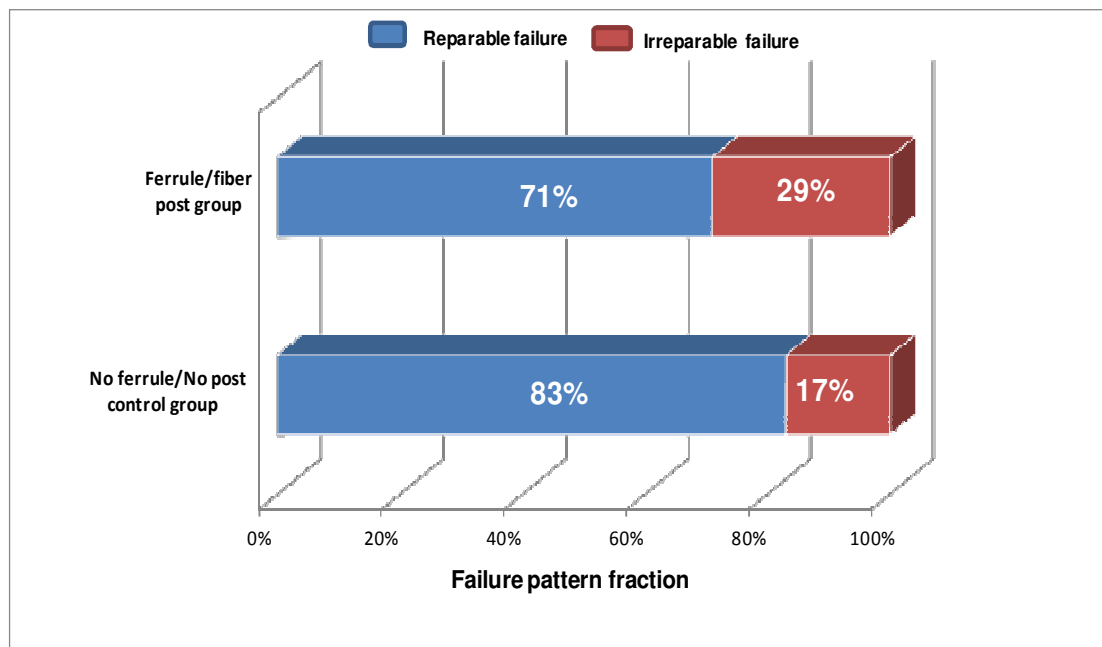


Figure 3. The reparable/irreparable failure mode fraction of the endodontically treated maxillary incisors.

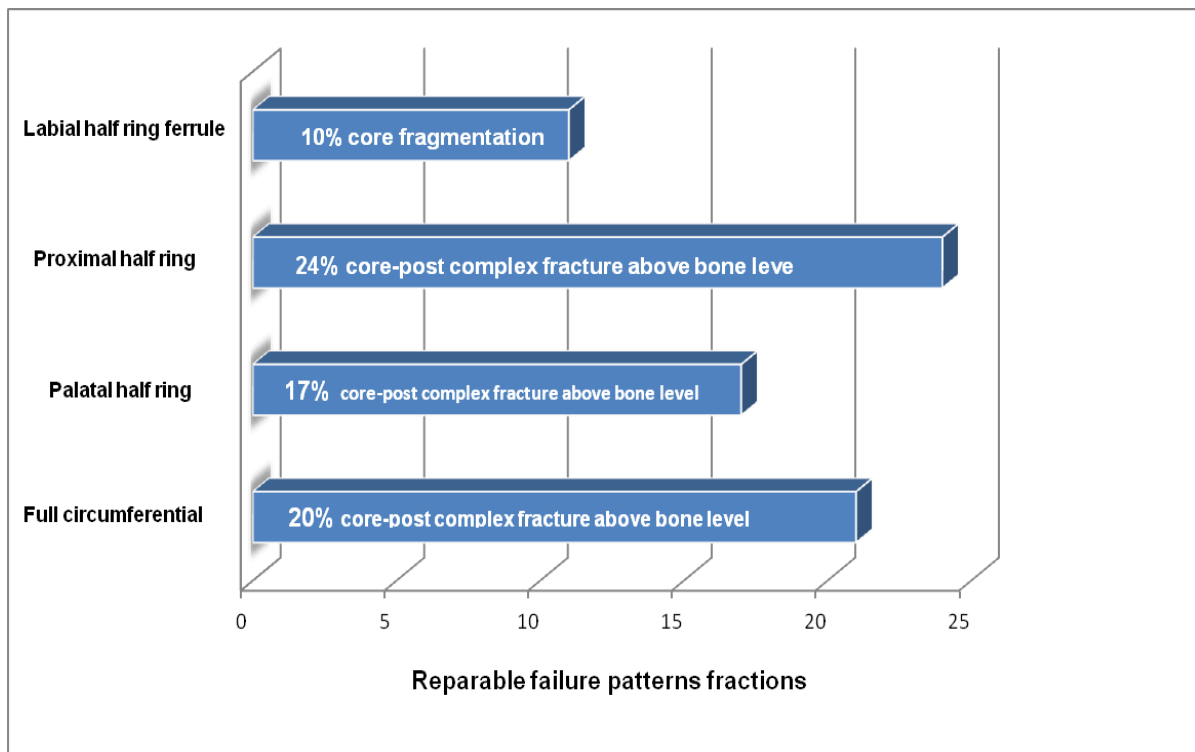


Figure 4. Types of reparable failure patterns exhibited by fiber post restored teeth of various ferrule orientation

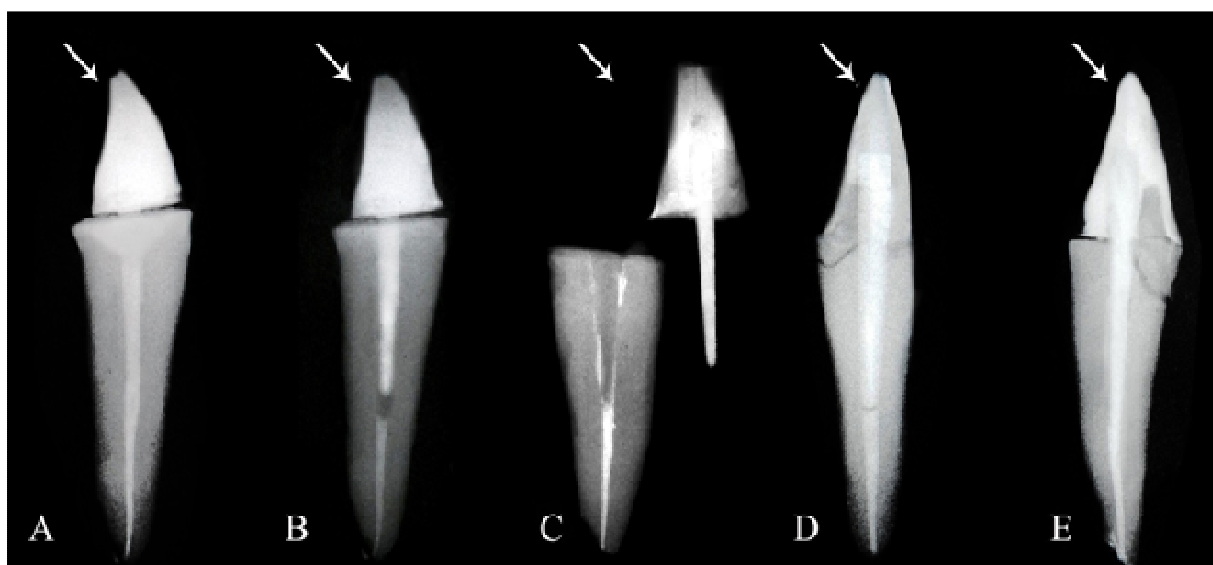


Figure 5. A sample of restored endodontically treated teeth showing various modes of failure after they were subjected to fracture resistance test. (A) a *control group* specimen, with a composite core but without a ferrule or a post displaying crown debonding due to core adhesive failure; (B) a fiber post restored tooth with a full-ring ferrule preparation exhibiting a reparable crown-core-post complex fracture; (C) a fiber post restored tooth displaying root/post adhesive failure; (D) a fiber post- restored tooth with a palatal half-ring ferrule orientation demonstrating a reparable core fracture along an oblique crack running above the simulated bone level; (E) a fiber post restored tooth with a labial half-ring ferrule orientation revealing an irreparable core fracture along a palato-labial oblique crack running below the simulated bone level.

DISCUSSION

Patients often present to dental clinics with destructed teeth and damaged coronal structures due to caries, trauma or removal of decayed enamel and dentin in preparation of access cavity for endodontic treatment. Regardless the reason of tooth tissue destruction, it is essential that the remaining coronal structure must have an adequate bulk and dimensions as required for provision of the resistance form of crown preparations. This is imperative to prevent the complications of tooth/root fracture. It must be emphasized that the resistance form of a crown is made up by the bracing effect provided by the crown when it is placed over tooth structure or core foundation incisal to the finish line. This bracing effect is known as the “ferrule effect”. Ever since the first mention of the term “ferrule effect” by Shillingburg (1997), there has been quite a large number of published reports that evaluated the worth of “crown ferrules” and appraised their role. It must be emphasized that the remaining coronal structure or core foundation per se does not constitute the ferrule but rather it is the bracing of the complete crown over the tooth structure or core material that constitutes the ferrule effect (Clarisse et al., 2006).

The present study focused on the effect on the survival of restored endodontically treated teeth of

retained axial coronal dentin of 2 mm height when it covered the tooth circumference both completely, circumferential ring around the preparations, and partially in a form of a half ring, in a palatal, proximal or labial locations. The first hypothesis that presence of a 2 mm high coronal dentin that constituted a ferrule effect does not affect the fracture resistance of endodontically treated teeth was rejected. The results of the present study showed that preserving a coronal structure, particularly a full circumferential ring, or a half ring of either palatal or proximal orientation had significantly enhanced the final fracture resistance of restored endodontically treated teeth ($P=0.001$). Our findings indicated that the fracture resistance of restored endodontically treated teeth was dependent on the presence and location, relative to the circumference of the preparations, of retained residual coronal dentin. This outcome supported those of previous studies, in which a ferrule of the same features has been reported to be effectual for the survival of restorations of endodontically treated teeth (Sorensen and Engelman, 1990; Akkayan, 2004). On the other hand, our results threw doubts on the findings of one previous publication (Jefferson et al., 2005) which reported that the remaining coronal structure, up to 3 mm high, did not influence the fracture strength of endodontically treated post-restored teeth. This is surprising because our results indicated that with no coronal tooth structure remaining, the fracture

resistance of the restored tooth was reduced down to approximately 30% of its magnitude when teeth with full circumferential ferrule were compared with those without ferrules.

Other reports indicated that the higher the number of remaining cavity walls, the better the biomechanical performance of endodontically treated teeth (Soares et al., 2008; Mangold and Kern, 2011; Zicari et al., 2012; Cagidiaco et al., 2008). The findings of the present investigation shed light on the location of a ferrule as more crucial to tooth survival than the number of ferrules. When the retained coronal structure which could, effectively, incorporate the principle of a ferrule was located at the palatal aspect of the preparation, i. e., where the load was applied, it would afford the most effective resistance to fracture. Thus, the magnitude of the occlusal load at which tooth resistance is overwhelmed, would be the true measure of the fracture strength of the restored endodontically treated tooth. On the other hand, when the retained residual coronal structure was located labially, it would constitute a fulcrum for a curvilinear displacement of the entire crown-core-post complex, palatal to the fulcrum, in response to palatal applied loading. Such a dislodging palatal load would be a measure of the interfacial adhesive bond strength between the crown-core-post complex and the root, rather than the fracture resistance of the restored tooth.

The results of the present study showed that the magnitudes of this interfacial adhesive bond strength were far inferior to the fracture resistance attained by the restored teeth of other ferrule configurations. This explains the significantly lower force to failure shown by teeth of a labial ferrule orientation compared to the significantly much higher fracture resistance ($p < 0.01$) demonstrated by restored teeth of, full, palatal and proximal ferrule orientations. This finding contradicts that of a previous report (Clarisse et al., 2006) which considered a labially located ferrule, among others, as a promoter of the resistance to fracture of restored endodontically treated teeth.

The force for failure attained by the teeth that had no retained residual coronal structure severed the crowns in more than 80% of the specimens tested in the present investigation. This force represented a measure of the interfacial adhesive bond strength between the crown-core-post complex and the roots of those teeth. This explained the comparable results attained by the teeth that had no ferrules and those of the teeth with labial ferrule orientation. In both of these groups the magnitude of the force for failure did not differ significantly ($p > 0.01$), since it measured the bond strength at the crown-core-post/root interface of those teeth rather than their resistance to fracture.

Placement of a prefabricated quartz fiber post, did not significantly improve the resistance to fracture of maxillary incisors whether a ferrule was present or not

and regardless the location of the ferrule when present. Thus, the hypothesis that placing a prefabricated fiber posts does not affect the fracture resistance of restored endodontically treated teeth has been accepted. This was in agreement with the findings of previously published reports (Heydecke et al., 2001; Zicari et al., 2012) which showed that insertion of a post does not add any beneficial effect to teeth, even in the anterior region where higher tension stress due to more horizontal forces develops during function.

In addition to tooth fracture resistance property, success of a restoration has to be regarded as the chance of re-intervention and preservation of the restored tooth when failure has happened (Zicari et al., 2012). It may be more favorable that failure occurs at a lower load but in a way that it maintains the tooth reparable. This entails that the ideal post system selected for restoring an endodontically treated tooth should exhibit fracture resistance more than the average physiologic masticatory force, but should not be too high to inflict a catastrophic root fracture. Fracture resistance is of greater importance than retention because post can be recemented if dislodged from the tooth. However, if the root fractures, the tooth is invariably lost. It is essential, therefore, that a post should not be evaluated on its size or rigidity but its ability to respect the root structure. In the present investigation, the level of embedding of the tooth specimen in the autopolymerizing resin was 3 mm below the cemento-enamel junction, which simulated the level of the alveolar bone. The mode of failure was considered reparable or irreparable depending on whether the fracture of the tooth specimen was above or below the embedding resin, respectively. Fractures above the resin level were considered reparable as retreatment could be initiated due to accessibility and the adequate amount of remaining tooth structure present to provide restorative treatment. The fracture of the specimen below the embedded resin was considered irreparable as treatment would be difficult (Raygot et al., 2001). In this study, more than 70% of the fiber post-restored teeth of the full, palatal, and proximal ferrule configurations exhibited reparable failures whereby their crown-core-post complex fractured above simulated bone level. The results of this study were consistent with those of previous studies (Clarisse et al., 2006; Padmanabhan, 2010; Jefferson et al., 2005; Cagidiaco et al., 2008; Naumann et al., 2006 b; Makade et al., 2001; Wadhvani et al., 2003; Fraga et al., 1998; Torbjørner and Fransson, 2004; Asmussen et al., 2005; Dean and Gail, 1988; Sirimai et al., 1999) which reported that teeth restored with prefabricated fiber post systems predominantly failed by post or core fracture without damaging the root. This finding pointed to the correlation that existed between post material and fracture of roots. It has been postulated that ideally, the post material should have the same modulus of elasticity as the root dentin in order to distribute the applied force evenly along the length of the post and the root. When a

system with components of different rigidity is loaded, the more rigid component is capable of resisting forces without distortion. The less rigid component fails and relieves stresses (King and Setchell, 1990). In the case of a metal post restored endodontically treated tooth the released stresses initiate cracks, within the root, that would propagate resulting in root fracture.

According to the manufacturers of the materials employed in the present investigation, the fiber posts' elastic modulus is approximately 23-29 GPa; that is very similar to the modulus of elasticity of dentin which is approximately 18-22 GPa (Makade et al. 2011), such a close similarity in elasticity would allow post flexion mimicking that of the tooth. It is very likely that the fiber post had absorbed and distributed the stresses and thus, transmitted only reduced stresses to the root. The longitudinal arrangement of fibers in the post and its elastic modulus that is nearly equal to that of the dentin would help redistribute the stresses into the tooth in a fashion that would increase the likelihood of failure of the post-core/root interface instead of root fracture.

CONCLUSION

Within the limits of this *in vitro* study, it was concluded that the fracture resistance of endodontically treated maxillary incisors is dependent on the presence of retained coronal dentin located where opposing tooth contacts generate occlusal loads. Placement of root posts seemed not to be necessary to improve the fracture resistance of the teeth.

ACKNOWLEDGMENTS

The authors express their sincere gratitude to Mr. Mazin Alborini of the dental lab at the Jordan University Hospital for his help in fabricating the metal crowns of the test specimens. Special thanks go to Mrs. Sana'a Karazoun of the "Materials' lab" at the faculty of Engineering and Technology for her invaluable help and assistance in conducting the quasi-static compressive tests.

REFERENCES

- Akkayan B (2004). An *in vitro* study evaluating the effect of ferrule length on the fracture resistance of endodontically treated teeth restored with fiber-reinforced and zirconia dwell systems. J. Prosthet. Dent. 92:155-62.
- Amin WM, Al-Tarawneh SK, Saleh M, Ghzawi A (2008). The Relationships of the Maxillary Central Incisors and Canines to the Incisive Papilla in Jordanians. J. Contemp. Dent. Pract. July; 9(5):042-051.
- Asmussen E, Peutzfeldt A, Sahafi A (2005). Finite element analysis of stresses in endodontically treated, dwell restored teeth. J. Prosthet. Dent. 94:321-9.
- Bolhuis HPB, De Gee AJ, Feilzer AJ, Davidson CL (2005). Fracture strength of different core build-up designs. Am. J. Dent. 14:286-90.
- Cagidiaco MC, Garcia-Godoy F, Vichi A, Grandini S, Giracci C, Ferrari M (2008). placement of fiber prefabricate or custom made posts affects the 3-year survival of endodontically treated premolars. Am. J. Dent. 21:179-84.
- Clarisse CH, Ng, Herman B, Dumbrigue, Manal I, AL-bayat, Jason A, Griggs, Charles W (2006). Wakefield. Influence of remaining coronal tooth structure location on the fracture resistance of restored endodontically treated anterior teeth. J. Prosthet. Dent. 95(4):290-296.
- Dean P, Gail B (1988). *In vitro* evaluation of carbon fiber post. J. Endod. 24:807-10.
- Ferrari M, Cagidiaco MC, Grandini S, De Sanctis M, Goracci C (2007). Post placement affects survival of endodontically treated premolars. J. Dent. R 86:729-34.
- Fokkinga WA, Kreuen GM, Vallittu PK, Greugers NH (2004). A structured analysis of in vitro failure loads and failure modes of fiber, metal and ceramic post-and-core systems. Int. J. Prosthodontics 17:476-82.
- Fraga RC, Chaves BT, Mello GS, Siqueira JF Jr (1998). Fracture resistance of endodontically treated roots after restoration. J. Oral. Rehabil. 25:809-813.
- Goodcare GJ (2010). Carbon fiber posts may have fewer failures than metal posts, J. Evidence Based Dental Practice 10:32-4
- Heydecke G, Butz F, Strub JR (2001). fracture strength and survival rate of endodontically treated maxillary incisors with approximal cavities after restoration with different post and core systems: an *in vitro* study. J. Dent. 29:427-33.
- Isidor F, Brøndum K, Ravnholt G (1999). The influence of post length and crown ferrule length on the resistance to cyclic loading of bovine teeth with prefabricated titanium posts. Int. J. Prosthodont. 12(1):78-82.
- Jefferson Ricardo Pereira, Fabio de Ornelas, Paulo Cesar Rodrigues Conti, Accacio Lins do Valle (2005). Effect of a crown ferrule on the fracture resistance of endodontically treated teeth restored with prefabricated posts. Braz. Dent. J. 16(3):197-201.
- King PA, Setchell DJ (1990). An *in vitro* evaluation of a prototype carbon fiber reinforced prefabricated post developed for the restoration of pulpless teeth. J. Oral Rehabil. 17:599-609.
- Libman WJ, Nicholls JI (1995). Load fatigue of teeth restored with cast posts and cores and complete crowns Int. J. Prosthodont. 8:155-61.
- Lima AF, Spazzin AO, Galafassi D, Correr-Sobrinho L, Garlini-Junior B (2010). Influence of ferrule preparation with or without glass fiber post on fracture resistance of endodontically treated teeth. J. Appl. Oral Sci. 18:360-73.
- Makade CS, Meshram GK, Warhadpande M, Patil PG (2011). A comparative evaluation of the fracture resistance of endodontically treated teeth restored with different post core systems- an *in vitro* study. J. Adv. Prosthodont. 3(2):90-5.
- Malferrari S, Monaco C, Scotti R (2003). Clinical evaluation of teeth restored with quartz fiber-reinforced epoxy resin posts. Int. J. Prosthodont. 16:39-44.
- Mangold JT, Kern M (2011). Influence of glass-fiber posts on the fracture resistance and failure pattern of endodontically treated premolars with varying substance loss: an *in vitro* study. J. Prosthet. Dent. 105(6):387-93.
- Manning KE, Yu DC, Kwan EW (1995). Factors to consider for predictable post and core build-ups of endodontically treated teeth. Part II: Clinical application of basic concepts. J. Can. Dental Association. 61:696-701.
- Milot P, Stein RS (1992). Root fracture in endodontically treated teeth related to post selection and crown design. J. Prosthet. Dent. 68:428-35.
- Morgano SM, Milot P (1993). Clinical success of cast metal posts and cores. J. Prosthet. Dent. 70:11-6.
- Naumann M, Blankenstein F, Kiessling S, Dietrich T (2005). Risk factors for failure of glass fiber-reinforced composite post restorations: a prospective observational clinical study. Eur. J. Oral Sci. a;113:519-24.
- Naumann M, Blankenstein F, Dietrich T (2005). Survival of glass fiber reinforced composite post restorations after 2 years – an observational clinical study. J. Dent. b; 33:305-12.

- Naumann M, Preuss A, Frankenberger R (2006). load capability of excessively flared teeth restored with fiber-reinforced composite posts and all-ceramic crowns. *Operative Dentistry* a; 31:699-704.
- Naumann M, Preuss A, Rosentritt M (2006). Effect of incomplete crown ferrules on load capacity of endodontically treated maxillary incisors restored with fiber posts, composite build-ups, and all ceramic crowns: an *in vitro* evaluation after chewing simulation. *Acta Odontol Scand* b; 64:31-6.
- Padmanabhan P (2010). A comparative evaluation of the fracture resistance of three different pre-fabricated posts in endodontically treated teeth: An *in vitro* study. *J. Conserv. Dent.* 13 (3): 124-8.
- Raygot CG, Chai J, Jameson DL (2001). Fracture resistance and primary failure mode of endodontically treated teeth with a carbon fiber reinforced resin post system *in vitro*. *Int J Prosthodont.* 14:141-5.
- Shillingburg HT, Hobo S, Whitsett LD, Jacobi R, Brackett SE (1997). *Fundamentals of fixed prosthodontics.* 3rd ed. Chicago. Quintessence Publishing Co; p. 89.
- Sidoli GE, King PA, Setchell DJ (1997). An *in vitro* evaluation of a carbon fiber-based post and core system. *J. Prosthet. Dent.* 78(1): 5-9.
- Sirimai S, Riis DN, Morgano SM. An *in vitro* study of the fracture resistance and incidence of vertical root fracture of pulpless teeth restored with six post-and-core systems. *J Prosthet Dent* 1999; 81:262-269.
- Soares PV, Santos-Filho PC, Martins LR, Soares CJ (2008). Influence of restorative technique on the biomechanical behavior of endodontically treated maxillary premolars. Part I: fracture resistance and fracture mode. *J. Prosthet. Dent.* 99(1):30-7.
- Sorensen JA, Engelman MJ (1990). Ferrule design and fracture resistance of endodontically treated teeth. *J. Prosthet. Dent.* 63:529-36.
- Torbjorner A, Fransson B (2004). Biomechanical aspects of prosthetic treatment of structurally compromised teeth. *Int. J. Prosthodont.* 17:135-41.
- Wadhvani KK, Shrivastava S, Nigam P (2003). Comparative evaluation of fracture resistance of various post systems: An *in vitro* study. *J. Conserv. Dent.* 6:56-61.
- Zicari F, Van Meerbeek B, Scotti R, Naert I (2012). Effect of ferrule and post placement on fracture resistance of endodontically treated teeth after fatigue loading. *J Dent.*; <http://dx.doi.org/10.1016/j.jdent.2012.10.004>

How to cite this article: Amin WM, Al-Huniti NS, Hasan NI, Al-Nimri DW, Al-Najdawi SA, Amin UW, Amin SW (2013). Effect of ferrule location on fracture resistance and failure pattern of endodontically treated maxillary incisors restored with quartz fiber posts. *J. Med. Med. Sci.* 4(9):343-352