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THE EFFECT OF REMAINING CORONAL DENTIN WALL THICKNESS ON FRACTURE RESISTANCE OF ENDODONTICALLY TREATED TEETH RESTORED WITH POST AND CORE

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ABSTRACT

Objectives. The aim of this study was to evaluate the effect of the remaining coronal wall thickness of dentin on fracture resistance of endodontically treated anterior tooth restored by cast post and glass fiber post and core.

Materials & Methods. A total number of 100 human maxillary central incisors were collected and stored in an isotonic saline solution at room temperature until used. Teeth were randomly divided into 3 main groups control group (CG), group A and B. Control group 20 endodontically treated teeth (ETT) without post and core fabrication restored with full metal crown.

Group A, 40 ETT restored by custom made casted metal post and core.

Group A, subdivided into subgroup A1, subgroup A2 of 20 ETT and restored with metal crown of 0.5mm and 1.0mm finish line width respectively.

Group B, 40 ETT restored by glass fiber post and composite core. Group B, subdivided into subgroup B1, subgroup B2 of 20 ETT and restored with metal crown of 0.5mm and 1.0mm finish line width respectively. The prepared specimens were subjected to load testing using a universal testing machine. The fracture pattern was observed and fracture load results were then statistically analyzed using One-way analysis of variance (ANOVA) in SPSS software.

Results. The highest mean fracture load of 991.5±54.1 N for The control group CG followed by group A1 with a mean of 780.2±67.8 N and group A2with a mean of 521.5± 96.8 N then group B1 with a mean of 489.24 ±30.61 N and the lowest mean fracture load of 388.32± 29.45 N was for group B2.

Conclusion. The thickness of remaining coronal dentin affects the fracture resistance of endodontically treated teeth received both casted metal and fiber post and core significantly.

KEYWORDS. Endodontically treated teeth, Cast post, Fiber posts, Ferrule effect

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INTRODUCTION

Endodontically treated teeth (ETT) are generally more susceptible to fracture as a consequence of moisture loss and considerable destruction of tooth structure. [1,2]

ETT that suffer large destruction require a post placement to provide retention to the core and the restoration but there was a lot of debates about whether a high or low elastic modulus of post materials can help the distribution of occlusal forces to the remaining dentin and improve the clinical outcome. [3]

Posts are supposed to strengthen weakened ETT against intraoral forces by distributing the forces within the radicular dentin.[4]

However the post at the same time may create stresses and may lead to root fracture during post placement or function as a result of a mismatch between post stiffness and the residual dental structure.

The mismatch in stiffness leads to concentration of higher stresses within the root consequently affect the strength of the ETT.[5-7]

Most recent studies agree that the ferrule effect is the most important success factor when restoring ETT with post and core through distribution of stress within the restored tooth under functional stress.[8]

It was proved that cervical area of ETT restored by post is exposed to a high stress level and the ferrule reduces this stress level, moreover the preservation of sound coronal tooth structure is an important factor for resistance of ETT to the functional stresses.[9-12]

The ferrule is cast metal band around the coronal surface of the tooth that may resist functional stresses, wedging effect of posts, and the lateral forces exerted. [13-16]

Fiber-reinforced posts are widely used as alternative to metallic post and core due to its elastic modulus which is similar to that of dentin, which may produce a favorable stress distribution and high success rates without root fracture compared to metallic post, however fiber-reinforced posts may concentrate stress at the post cement interface that may result in loss of adhesion. [17,18]

The failure pattern of bonded fiber posts differs from that of metal posts, the fiber posts often fail due to debonding, but metal posts often cause root fracture.[19]

Remaining tooth structure that enhances the incorporation of a ferrule design is an important element. Many studies investigated the ferrule effect with cast metal post and core but there is little information about whether the ferrule has additional value in providing reinforcement in teeth restored with glass-fiber posts and composite core or not.

Although the dental literature supports 2 mm height of axial sound dentin to support the ferrule, but there is a little data about the significance of the remaining coronal wall thickness of dentin and its role in preventing tooth fracture. [20]

Esthetic anterior restorations require significant reduction of tooth structure at least1.5mm at the margin, this type of preparations reduce the thickness of the remaining dentin. [18]

Clinical studies could not confirm the significant influence of the ferrule as a factor that affect the survival rate of endodontically treated teeth because a similar failure risk was found in teeth with complete absence of ferrule and those with 2 mm ferrule nevertheless, when adequate 2-mm ferrule was included in the preparation design a successful treatment outcome was recorded over several years of observation period, irrespective of the post type. [21]

The purpose of this study is to evaluate the effect of the remaining axial wall thickness of dentin of anterior tooth restored by cast post and fiber posts and core on tooth fracture.

The hypothesis was that the presence of enough cervical dentin thickness of ETT restored by post has a positive effect on reduction of the stress levels regardless post material which consequently decrease the liability of root fracture.

MATERIALS AND METHODS

Materials

A total number of 100 Human maxillary central incisors were used in this study collected from outpatient clinic, Department of Oral Surgery, Faculty of Dentistry-Alexandria University, and stored in an isotonic saline solution at room temperature until used.

All selected teeth have inclusion criteria of being intact with no previous restorations or endodontic treatment, cracks, root caries and have similar dimensions with average length of (25±2mm), confirmed by a digital caliper.

Materials used in the study. Table1

Methods

Specimens Preparation

All teeth were endodontically treated and hand instrumented by k-files (Mani) to file size (60) using step back technique and the prepared canals were obturated with gutta-percha points by lateral condensation technique. Teeth were sectioned horizontally 3 mm coronal to the cemento-enamel junction with a diamond stone in a high-speed hand piece with water spray. To simulate the periodontal ligament, the roots were covered by immersing in melted wax to a depth of 2 mm below the cemento-enamel junction. Teeth then were embedded in an auto polymerizing acrylic resin block using customized copper mold of dimensions (15X20mm), to a depth 2 mm apical to their cemento-enamel junction. [21]

After polymerization the resin block was immersed in water at 75°C for 1 min to remove the wax layer and for the subsequent application of Vinylpolysiloxane impression material (Ivoclar

TABLE (1)

Material	Composition	Manufacturer
Fiber post	RelyX post (Size # 2; Glass fiber reinforced composite, methacrylate resin) Silanization Ceramic Bond (3methacryloxypropyltrimethoxysilane in an ethanol/ water solution, isopropanol)	3M ESPE, St. Paul, MN, USA
Core build-up material	Filtek P60 (Matrix: Bis-GMA, UDMA, Bis-EMA resins. Filler: zirconia/silica (61%, vol., 83%, wt). Particle size range of 0.01–3.5 _m. Initiators, Inorganic pigments)	3M ESPE, St. Paul, MN, USA
Rely-X UniCem, self-adhesive resin cement Maxicap	Organic matrix of multifunctional phosphoric acid (meth) acrylates. Inorganic Silica filler of approximately 72% (by weight) Particle size is <9.5µm. Initiators, Inorganic pigments, Stabiliser	3M ESPE, St. Paul, MN, USA
Metal post 4all Nickel-Chrome alloy	Composition in % weight Ni 61. 4, Cr 25.7, Mo 11.0, Si 1.5, Mn< 1.0, Al< 1.0 , C < 1.0	Ivoclar Vivadent AG, Bendererstrasse 2, FL-94 94 Schaan, Liechtenstein

Vivadent AG, FL-9494 Schaan/Liechtenstein) around the root surface which was injected into the acrylic resin. [23]

The tooth was then reinserted into the resin block, and the excess impression material was removed with a surgical blade.

Grouping of the specimens

Teeth (N=100) were randomly divided into 3 main groups Control group, group A and B.

Control group (CG) 20 Endodontically treated teeth without post and core fabrication.

Group A, 40 Endodontically treated teeth restored by custom made casted metal post and core and metal crown

Group B 40 Endodontically treated teeth restored by glass fiber post and composite core and metal crown

Groups A is subdivided into two subgroups A1, and A2 of 20 teeth each.

Subgroup A 2mm ferrule height, and 0.5mm finish line width. Subgroup A 2mm ferrule height, and 1.0mm finish line width.

Groups B is subdivided into two subgroups of 20 teeth each

Subgroup B1 2mm ferrule height, and 0.5mm finish line width.

Subgroup B2 2mm ferrule height, and 1.0 mm finish line width.

Coronal Preparation

A parallelometer (CRUISE®) (Silfradent via G Divittorio 35/37-470185 Sofia FORLI- Italy) with speed of (270 rpm), used to prepare the axial wall of group CG with 1mm finish line thickness, (Control groups).

Subgroups A1, and A2 with 0.5, and 1 mm thickness respectively and Subgroups B1, and B2, with 0.5 and 1 mm thickness respectively.

Post Space Preparation for custom made metal post

24 Hours after root canal treatment, post space preparation started by removing gutta percha with gates glidden drills (size 1, 2). The rubber stopper was adjusted to length (13 mm) while maintaining (4-5 mm) of gutta percha for apical seal. Shaping of post space was done by peaso reamer size 1, 2 and 3 in a sequential order for shaping the canal and eliminate any undercut inside it. An anti-rotational groove was made at the thickest part in dentin using 171 bur with length of 4mm and depth of 0.5 mm. A contra bevel was placed around the cavo-surface margin of the preparation by flame shape stone.

The amount of dentin around the canal was measured with digital caliper to ensure a 2-mm thickness on all aspects.

Post and Core Fabrication

A serrated plastic post was checked to be loose inside the canal. A Duralay separating medium (DuraLay Reliance Dental Mfg Co) was used to prevent adherence of duralay inside the canal. The duralay pattern of post and core was done using the brush bead technique until the pattern was passively fit inside the canal. The inciso-gingival dimension measured from the labial aspect of the core was 4 mm for all specimens. The patterns were invested and casted in Ni-Cr alloy.

A vent was prepared in the post to avoid incomplete seating of posts for all specimens then the post-core was cemented to their corresponding teeth using Rely X Unicem Self-Adhesive Universal Resin Cement according to manufacturer's instruction.

Post Space Preparation and cementation of Glass fiber post

24 Hours after root canal treatment, post space preparation started by removing gutta percha with gates glidden drills (no. 1, 2). The rubber stopper was adjusted to length (13 mm) while maintaining

(4-5 mm) of gutta percha for apical seal then a tapered drill of 1.4mm diameter was used to remove the remaining root filling and shape the post space.

The amount of dentin around the canal was also measured with digital caliper to ensure a 2-mm thickness on all aspects.

Post size that match the drill was selected and inserted to check the fit in the prepared canal. The post cut 2mm coronal to the root using a diamond disk.

The root canal was cleaned with 5.25% (NaOCl), and dried with paper points. Rely X Unicem capsule (3M ESPE St. Paul, MN, USA)was activated, inserted into in amalgamator for 15 seconds, dispensed inside the root canal with elongation tip and the Rely X Fiber post (3M ESPE St. Paul, MN, USA) was seated immediately. Excess cement was removed with cotton pellet and LED light cured (Bluphase, Ivoclar vivadent AG Benderestrasse 2 FL-9494 Schaan Liechtenstein) for 40 seconds.

A cylindrical plastic matrix (10 mm in diameter) was then placed around the post and an incremental technique was followed to build up the core. Each 2-mm increment of the composite core material was cured for 40 s with a LED light curing unit. The matrix was subsequently removed after being filled completely with polymerized composite.

Crown Fabrication

Impressions of the prepared specimens were made with addition silicon impression material (Virtual, Vinylpolysiloxane impression material Ivoclar Vivadent AG, FL-9494 Schaan/ Liechtenstein). Metal crowns were fabricated using Ni-Cr alloy ,that had an incisogingival dimension of 6 mm from the labial aspect, and cemented to the corresponding specimen by glass ionomer luting cement (Midcem promedica dental material GmbH DomagKstr 31,24537 Naumunster /Germany). The prepared specimens were then stored in normal saline at room temperature, to prevent dentin desiccation until they were tested.

Testing of the specimens

The specimens were placed at an angle of 45° to the vertical plane of a specially designed copper block to ensure that the net force applied on the teeth was at an angle of 135° to the long axis of the tooth.[24] (Figure 1).

The test specimens were placed in the lower jaw of universal testing machine (UTM) (Maxi-torq, Model: 4z128, USA) and a vertical round end ball four mm in diameter stylus, mounted on the upper jaw of the UTM, was aligned to apply a load on the palatal aspects of the specimen teeth 2 mm apical to the incisal edge of the metal crown at crosshead speed of 0.5 cm/min till fracture. The fracture pattern was observed and fracture load results were then statistically analyzed using One-way analysis of variance (ANOVA) in SPSS software.

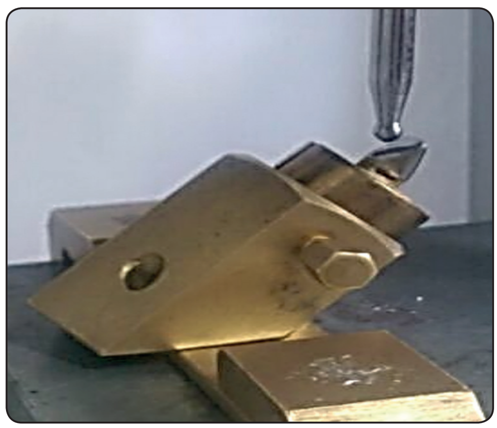

Fig. (1): Specimen loaded in the universal testing machine for testing fracture strength.

RESULT

Data were fed to the computer using IBM SPSS software package version 20.0. Quantitative data were described using mean and standard deviation for normally distributed data. For normally distributed data, comparison between more than two population were analyzed F-test (ANOVA) to be used.

Significance test results are quoted as two-tailed probabilities. Significance of the obtained results was judged at the 5% level.

Analysis of the mean fracture loads between all three groups it was found that the highest mean fracture loads for the control group CG of 991.5±54.1 N followed by group A1 (cast metal post and core, and 0.5 mm finish line width), with a mean of 780.2±67.8 N and group A2 (cast metal post and core, and 1.0mm finish line width) 521.5± 96.8 N then group B1 (glass fiber post and core, and 0.5 mm finish line width), with a mean of 489.24 ±30.61 N and the lowest mean fracture loads of 388.32± 29.45 N was for group B2 (glass fiber post and core, and 1.0mm finish line width).

It was found that there was a significant difference between the fracture loads in the three groups where P value less than (0.05), the highest fracture force was noticed in The CG then group A1, and in groupA2 with a significant difference, as shown in (Table 2, Fig. 2) and there was a significant difference between the fracture loads in group B1, and group B2, the lowest fracture loads was noticed in group B2, as shown in (Table 3,Fig 2).

There were 2 typical fracture modes in cast metal post - core groups, cervical and mid root fracture. The cervical root fracture was observed in CG and group A2, and mid root fracture was observed in group A1. Post failures were not observed in these groups. (Fig. 3,4,5). There were one fracture mode in glass fiber post –core groups, cervical root fracture, in groups B1, B2 with post fracture as shown in (Fig. 3,6).

Comparison between cast metal post - core and glass fiber post -core, there was a significant increase in the fracture resistance of cast metal post group (A1) more than the glass fiber post (B1), and a significant difference in the fracture resistance in group (A2) and, (B2).Table (4)

TABLE (2): Comparison between control group and both 0.5 and 1 group in Cast metal post and core.

Fracture resistance	Control Group CG	Group A1 "0.5mm"	Group A2 "1.00mm"
Range **Mean** **SD**	574.1-1576.8 991.5 540.1	512.4-960.3 780.2 76.7	399.8-748.5 521.5 196.8
F **P**	12.85 0.0031*		
P1		0.001*	0.011*
P2			0.001*

P1 comparison between control and both group A1and A2

P2 comparison between group A1and A2

TABLE (3): Comparison between control group and both 0.5 and 1 group in Glass fiber post.

Fracture resistance	Control Group CG	Group B1 "0.5mm"	Group B2 "1.00mm"
Range **Mean** **SD**	574.1-1576.8 991.5 540.1	440.6-550.4 489.24 30.61	350.9-450.3 388.32 29.45
F **P**	16.5 0.0016*		
P1		*0.0025	*0.0001
P2			*0.035

P1 comparison between control and both group B1 and B2

P2 comparison between group B1 and B2.

TABLE (4): Comparison between cast metal post and core and glass fiber post and core.

Fracture resistance	**"0.5mm"**	**"1.00mm"**
Cast metal post and core		
Range	512.4-960.3	399.8-748.5
Mean	780.2	521.5
SD	76.7	196.8
Glass fiber post		
Range	440.6-550.4	350.9-450.3
Mean	489.24	388.32
SD	30.61	29.45
P	0.0036*	0.025*

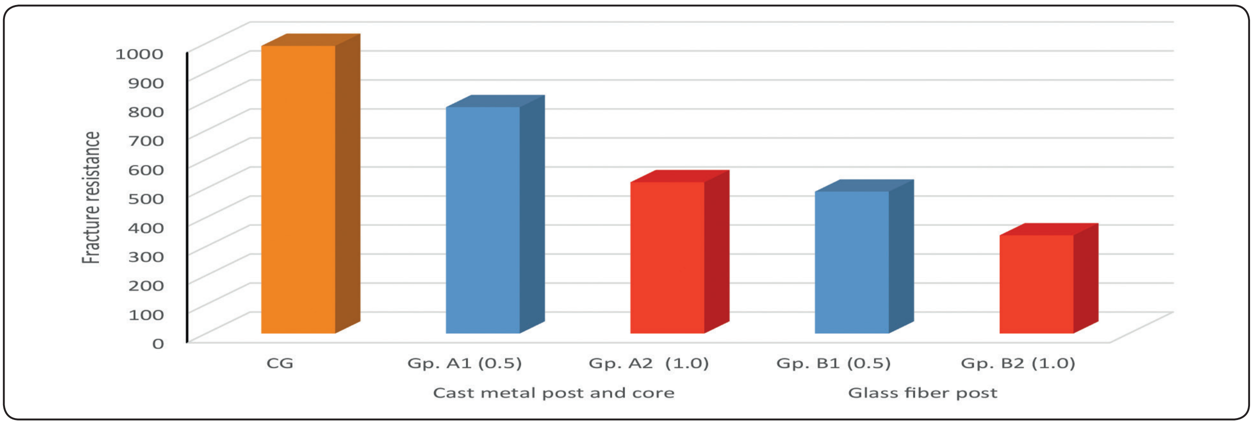

Fig. (2): Fracture resistance in different groups, cast metal post and core and glass fiber post

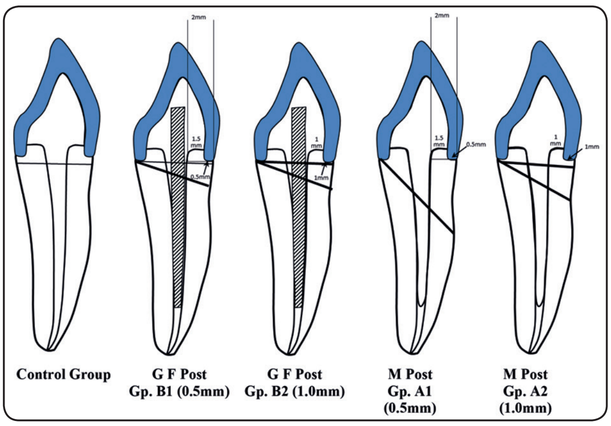

Fig. (3): Remaining coronal dentin thickness and fracture patterns associated with all tested groups.

Fig. (4) Mid root fracture Metal post Gp.A1.

Fig. (5) Cervical root fracture Meta post Gp.A2.

Fig. (6) Cervical root and post fracture Fiber post Gp.B1,B2.

DISCUSSION

Endodontically treated teeth become weak and more susceptible to fracture than vital teeth because of the considerable loss of tooth structure.

Preservation of sound coronal tooth structure and the presence of ferrule are important factors to decrease the wedging force of posts. Ferrule is a part of the artificial crown or core that resists lever forces, as a result of the post insertion and the wedging effect under functional loading some controversies exist about the optimum height and width of remaining tooth structure. [25–26]

Using polyvinylsiloxane impression as periodontal ligament in this study was due to its modules of elasticity which is similar to those of natural ligament. [23]

Several studies reported that the fracture strength of restored teeth without artificial ligaments were approximately two times greater than those with ligament because the restored teeth were directly held by acrylic resin and the acrylic resin acted as a ferrule, which result in a significant effect in preventing root fracture. [27]

The result of this study demonstrated that the fracture resistance of ETT without post were significantly higher than that with post-reinforced teeth.

Lu Zhi-Yue, and Zhang [28] compare the fracture strength of ETT with and without post reinforcement and concluded that the fracture resistance of ETT without post were significantly higher than that with post and post-core did not improve the strength of the ETT which is in agreement with the result of this study.

Lovedahl and Nicholls[29] found that ETT without post were twice resistant to fracture compared to ETTs reinforced with post which is in agreement with the result of this study.

Regarding the remaining dentin thickness, this study evaluate the fracture resistance of endodontically treated maxillary central incisors with different finish line width 0.5, and 1 mm and supposed that the presence of 1.5 - 2 mm axial dentin thickness in a tooth restored with a post, whatever post material, reduces stresses in dentin, and makes teeth more able to resist the fracture.

Libman and Nicholls.[30] reported that the strength of the remaining tooth was directly related to the remaining bulk of dentin and that fracture resistance was decreased with the reduction of the remaining dentin.

Similar study by Assif D. et al[31] who demonstrated that the strength of ETTs were directly related to the remaining tooth structure, the study also demonstrated that a post can create stresses that may lead to root fracture during function in case of diminished remaining coronal tooth structure.

Sorenson and Engleman[21] neglected the importance of the coronal dentin thickness dentin at the margin when using various contra-bevel as post ferrule designs, and have reported that the thickness of the coronal extension above the crown margin have significance effect in increasing the fracture resistance of crowned teeth which agree with the result of this study.

Another study by Joseph and Ramachandran, [32] they concluded that 2 mm dentin thickness increased the resistance to fracture of ETT restored by post and core.

The results of the current study showed that residual coronal walls thickness has a great value in resistance of ETT restored by post to fracture as the ferrule height, Samran A et al[33] reported that the coronal axial dentin walls thickness had a significant effect on the fracture resistance of ETT restored with prefabricated posts which coincide with the result of this study.

Tjan and Whang [34] studied the effect of varying thicknesses of remaining buccal dentin on root fracture and they concluded that there is no significant differences between the different dentin thicknesses on root fracture and they added that 1 mm thickness of dentin may leads to root fracture rather than cement failure. This result is not in agreement, to some extent, with the result of this study may be because they looked for the buccal dentin only and neglected the remaining aspect of axial coronal wall thickness.

This current study showed that the strength of the ETT is directly related to the remaining bulk of dentin and the fracture resistance has diminished with decrease in the thickness of the remaining dentin.

Kurer(35) considered 1.0 mm remaining dentin thickness was needed for ferrule after tooth preparation and reported its viability in resistance of the root to fracture.

In an attempts to compare different amounts of remaining dentin width after preparations for various types of restorations. Soew et al(36) concluded that the longevity of restorations that restore the endodontic treated tooth was influenced in a great extent by the amount of the remaining tooth dentin thickness. This conclusion is in agreement with the result of this study

In this study it was found that there was a significant difference in the fracture resistance between groups restored with casted metal. The highest fracture load was noticed in A1 and the lowest fracture load was noticed in group A2. Most of the fractures were found in the middle portions of the root followed by cervical portion.

Regarding the glass fiber post there was a significant difference in the fracture resistance between groups where the highest fracture load was noticed in group B1 and the lowest fracture load was noticed in group B2. The fractures were limited to the cervical portion.

These results indicated that cast posts have higher fracture resistance compared to fiber posts. The difference in fracture load and mode can be explained by the stiffness and stress distribution within the pulpless teeth restored with post-core.

The mid root fracture in teeth restored by cast posts is due to the propagation of fracture lines along the metallic post over the middle portion of the root including the post apex.

A metal post has high modulus of elasticity, when it is forced against radicular dentin which has lower modulus, the stress is transferred from the rigid post to the less rigid dentin cause its fracture on the other hand a fiber post has a similar modulus of elasticity to that of radicular dentin, so less stress is transferred from the post to the dentin and consequently less liable to fracture. (38)

Many studies showed that fiber posts have some advantages in contrast to metal posts as the modulus of elasticity of the fiber posts is close to that of dentin however, the modulus of a material is not the only parameter that influence stress development. (37)

The majority of the fracture patterns in this study of the fiber post were limited to the cervical portion of the root combined with fiber post fracture since the stress was concentrated in the cervical area.

Several studies support this result Pegoretti et al. (39) and Santos et al(40) concluded that fiber posts induce lower stresses than metal posts. The cast post produced the greatest stress concentration at the post - dentin interface on the other hand, the fiber posts presented high stresses at the cervical region due to their flexibility and fractures are less likely to occur in the root.

Al-Omiri and Al-Wahadni (41) reported that coronal restorations that rest on sound dentin affect stresses distribution more than the type of core materials and also reported that using of fiber posts in teeth without enough supragingival structure can lead to post debonding and failure of the coronal restoration.

Several studies showed that cast metal posts have the highest resistance to fracture and high survival rate compared to fiber posts, but may result in non-repairable fractures, on the other hand fiber posts provided adequate resistance to fracture and lower incidence of root fracture with repairable fractures these results were in agreement with this study. (42-45)

Anterior teeth are exposed to lateral forces consequently aesthetic restorations require a careful evaluation, and analysis of the remaining coronal tooth structure to improve the ferrule effect (both height and width), so it is necessary to select the suitable crown finish line after considering the aesthetics and structural durability of these restorations. (18)

CONCLUSION

Under the limitation of this study, it was concluded that the thickness of remaining coronal dentin significantly affects the fracture resistance of endodontically treated teeth restored whatever by casted metal or fiber post and core.

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