Ferrule Effect on Fracture Resistance of Endodontically Treated Teeth Restored With Two Esthetic Post and Core Materials Fabricated With Different Techniques

Mohamed W. Abdullah[1], Amina M. Hamdy[2], Ghada Abdelfattah[3]

Abstract:

Objective: Assessment of ferrule effect on fracture resistance of Customized fiber post and Custom-made PEEK post with a core. **Materials and Methods:** Twenty eight single-rooted mandibular premolars with approximate similarity in shape and size and no cracks or caries were selected for this study. The length of the root was measured from the root apex to the middle point of the cementoenamel junction in the labial surface; it was about (16±1 mm). Teeth were divided into two groups, each group contained 14 teeth, with a ferrule group and without a ferrule group followed by coronal decapitation of all samples. Endodontic treatment was performed for all samples followed by mounting samples in acrylic blocks and then preparation of post space. Each group of the two groups was subdivided into two subgroups (n=7/subgroup), the first subgroup was restored with custom-made polyether ether ketone (PEEK) post and core, and the second subgroup was restored with customized fiber post and composite resin core. **Results:** Samples with ferrule (651.68±66.34) had a significantly higher fracture strength value than samples without ferrule (528.86±60.85) (p<0.001). **Conclusions:** based on the results and conditions of this study, the following findings can be drawn: With ferrule samples are more resistant to fracture than ferrule samples with the two different post types.

Introduction:

The completion of endodontic treatment doesn't indicate the end of the management of the patient. A tooth that needs root canal treatment usually has a large destructed part of the tooth structure so it is more susceptible to fracture. Fracture ranges from cusp fracture to catastrophic root fracture that may require extraction of the tooth.[1]

The remaining tooth structure influences the survival rate of the endodontically treated tooth.[2] Most studies agreed that the most important factor in the survival of the teeth that were endodontically treated when restored with post and core is the ferrule effect.[3] Ferrule effect helps in stress distribution within the restored endodontically treated teeth under functional load.[2,3] The more remaining coronal dentin the more will be fracture resistance.[2] It was proved in many studies that the cervical area of the endodontically treated teeth is more exposed to high load and the presence of ferrule decreases the load level.[3] Therefore, preservation of the coronal part of the tooth structure plays a significant role in increasing fracture resistance of the endodontically treated teeth.[3]

post and core are required in teeth that have lost most of the coronal tooth structure. There are two main types of posts; custom-made posts, and readymade posts.[4]

Cast metal posts and core systems have high physical properties so they have historical success in restoring endodontically treated teeth. However, they have poor esthetic properties due to their gray color especially when they are used with all-ceramic restorations that have high translucency. Cast post and core systems use may cause root fracture due to stress concentration around the post as they have high elastic modulus.[5]

prefabricated posts were made from metal that didn't have good esthetics and may be visible through the root canal-treated teeth, especially in the anterior area. Metal posts may have different degrees of stiffness.[6] Development in dental restorations and esthetic characteristics of restorations, bonding, and adhesive systems lead to the development of nonmetal posts.[7]

Prefabricated fiber post systems became an alternative to a metal post in the restoration of endodontically treated teeth. They have mechanical properties close to that of dentin resulting in similar patterns of stress as those of intact teeth. However, poor adaptation of fiber posts in oval canals leads to decreased retention and increased thickness of the cement.[8] Stress concentration and excessive deformation could result during function leading to marginal failure due to insufficient post-rigidity.[9]

PEEK is a thermoplastic polymer that has high mechanical properties and has been used recently in dentistry. It has high biocompatibility, lower reactivity than other materials do not corrode, and has a low modulus of elasticity close to that of cortical bone and dentin tissue and this property is the most important property that makes it beneficial in dental prostheses. Due to numerous positive advantages, PEEK material is considered an alternative to metal-supported ceramics that have long been used in dentistry.[10] PEEK is a semi-crystalline polyaromatic material with

a high melting point.[11,12,13] It has high thermal stability up to 335.8c. PEEK has a density of 1300kg/m3, it has a thermal conductivity of 0.29W/mK.[12] it is a radiolucent very rigid material that has flexural strength (140-170MPa). It doesn't attrite the opposing natural teeth. US FDA Drug & Device Master files supported polyether ether ketone (PEEK) bio-stability and biocompatibility.[11]

According to the previously mentioned characteristics, this study was made to evaluate the ferrule effect on fracture resistance of endodontically teeth restored with PEEk material that was used in the fabrication of custom-made post and core using CAD/CAM technology and fiber post that was customized. The null hypothesis was that there is no difference would be found in fracture resistance between the tested groups.

Materials and Methods:

Preparation of specimens: To determine the number of samples required for this study, A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that there is no difference would be found in fracture resistance between different tested groups. By adopting an alpha level of (0.05) a beta of (0.2) i.e. power=80% and an effect size (f) of (0.851) calculated based on the results of a previous study.[14] the predicted sample size (n) was a total of (28) samples (i.e.14 samples per group and 7 samples per subgroup). Sample size calculation was performed using G*Power version 3.1.9.7.[15]

A sample of 28 single-rooted extracted mandibular premolars with approximate similarity in shape and size with no cracks or caries was used in this study. length of each root was measured from the apex to the middle point of the cementoenamel junction in the labial surface, it was about (16±1 mm) for all samples. Dimensions of samples were measured labiolingually and mesiodistally at the cervical margin level using a caliper. The labiolingual dimension was about (7±1 mm) and the mesiodistal dimension was about (4±1 mm).

An ultrasonic scaler was used to clean samples with water coolant and at low power to prevent making any microcracks in teeth. Teeth were stored in saline solution at room temperature to prevent dehydration before the study.

Samples were divided into two groups according to preparation design, group 1 contained 14 samples with the ferrule, and group 2 contained 14 samples without a ferrule. Each group was subdivided into two subgroups according to the type of the post. Group 1 was subdivided into subgroup A which contained 7 samples restored with custom-made posts with core from PEEK and subgroup B which contained 7 samples restored

with customized fiber post and composite core. Group 2 was subdivided into Subgroup C which contained 7 samples restored with custom-made posts with core from PEEK and Subgroup D which contained 7 samples restored with customized fiber posts.

By using a diamond disc, Samples of group 1 were decoronated at 2mm above CEJ while samples of group 2 were decoronated at CEJ. In group 1, a chamfer finish line 2mm in height was created with a diamond bur around the full circumference of the tooth with a highspeed handpiece creating a 2mm ferruled collar following the contour of CEJ. Endodontic treatment was done in all the specimens.

Each sample was mounted in an acrylic resin block using a circular polyvinyl cylinder with a diameter of 0.75 inches and height of 0.78 inches that worked as a mold to accommodate the acrylic resin. Samples were mounted at 2mm apical to the cementoenamel junction simulating biological width and acrylic blocks simulate alveolar bone.

post space preparation: the Gutta percha was removed to the specified depth (9mm) by gates glidden drills size 1 and 2. Preparation was continued using the ITENA DENTO CLIC fiber post-drilling system. A Pilot drill was used first to the specified depth (9mm) to ensure complete removal of the gutta percha then the rest of the drills were used successively from the smallest size (purple drill) to the largest size (red drill) producing post space 1.4mm at the apical end of preparation.

Subgroup A and Subgroup C Samples scanning: Each sample was scanned by an intraoral scanner (CEREC OMINICAM, CEREC premium SW4.4. Dentsply Sirona). Intracanal and cervical margin scanning were made from several directions. Scan data was exported as an STL file for designing the post and core using EXOCAD (EXOCAD, 2.4 plovidv). The margin of the core was made to adapt to the cervical margin of each sample. In Subgroup C samples, the margin of the core was made to leave a 0.8mm thickness finish line surrounding the core margin. Core height was set to be 4mm in Subgroup A and 6mm in Subgroup C. Cement space was 70micron. A milling machine (Roland 52D
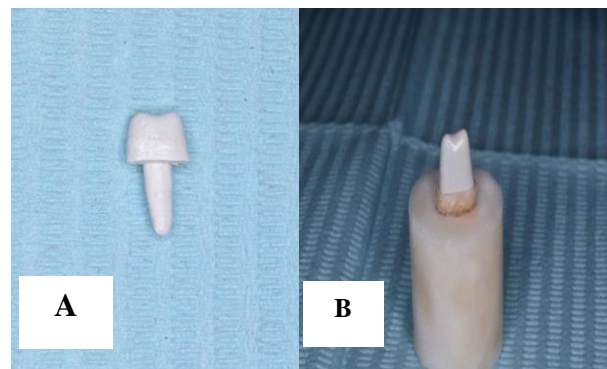

Figure 1 : Milled PEEK post and core from subgroup C(without ferrule).

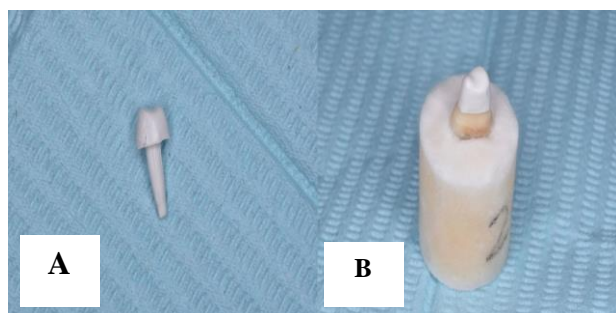5 axis) was used to mill the final design using Bio HPP

Figure 2: Milled PEEK post and core, subgroup A (with ferrule).

PEEK milling blank (Brecam BioHpp Blank 98.4 x 16 White) giving PEEK post and core, Figures1&2.

Customization of fiber post: Two transparent silicone templates were fabricated on the PEEK core of two samples, one of them was with ferrule and the other one was without ferrule for core size standardization. Purple fiber posts were used in all samples of subgroups B and D. The root canal and the cervical margin were coated with a gel that is water soluble (KY Gel, Johnson & Johnson, São José dos Campos, SP, Brazil). The silane coupling agent was applied to the surface of the post and then dried before applying the adhesive. Application of adhesive on the post surface and curing for 20 seconds then Core build-up material was applied with an auto-mixing tip and intra-canal tip inside the deepest part of the canal from inside to outside with the tip embedded in the core build-up material to avoid air bubbles formation then fiber post was inserted in a clockwise direction with the rotational movement then light curing for 20 seconds at the orifice of the canal then post was removed from the canal to check customization and additional curing for 40 seconds. On both the post and tooth, the insertion and removal axis was marked with a marker pen. The customized fiber post was applied again inside the canal, core build-up material was injected inside the template and then applied on the customized fiber post and then cured for 40 seconds then removed the template so ending with the customized fiber post and core as one piece. Figure 3,4

Before cementation, 2 ml of distilled water was used to wash the root canals to remove any residues of water-soluble gel. Dryness of Canals was achieved using a triple syringe with oil-free air and absorbent paper points were used to ensure complete dryness of canals.

In subgroups A and C manufacturer instructions were followed, PEEK posts and cores were sandblasted with 110 μm aluminum oxide at a pressure of 2 to 3 bar. A thin, uniform layer of Visio.link (Visio.link, Bredent, Germany) was applied and cured in a light polymerization device for 90 seconds.

Self-adhesive dual cure resin cement (G-CEM, GC

Corporation, JAPAN) was injected inside the roots, PEEK posts and customized fiber posts were inserted and seated by finger pressure, then light curing for 5 seconds to allow removal of excess cement and then complete curing for 40 seconds in the cervical part of the roots.
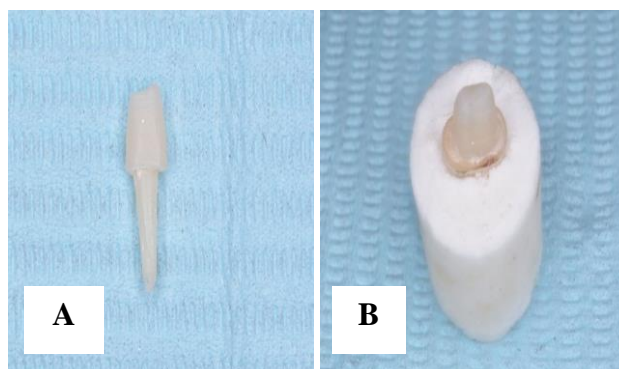

Figure 3: customized fiber post and core (without ferrule sample)

Aging and testing: Aging of all specimens was applied using thermocycling. Specimens were submerged in 2 tanks of cold and warm water for 5000 cycles (15 seconds cold, 15 seconds warm, 5 seconds water drip), representing around 6 months of clinical service. 5°C was the temperature in the cold tank and 55°c in the warm tank.[16]
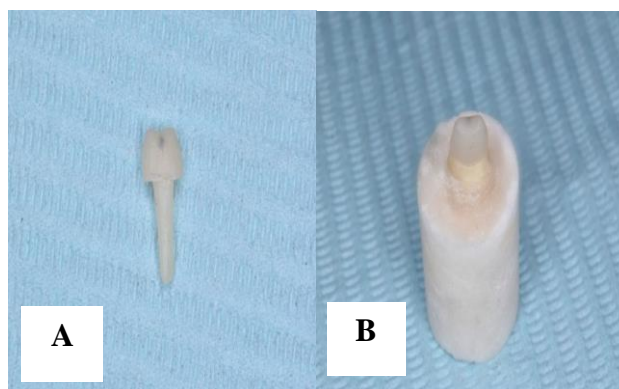

Figure 4 : customized fiber post and core (with ferrule sample)

Using a universal testing machine with a tip that has a blunt end and diameter of 1mm to load all the samples along their long axis. Application of load was done in an ascending manner to the core center with a crosshead speed of 1mm/min till the occurrence of fracture at special load which was recorded in Newtons (N).

Statistical analysis: Numerical data were presented as mean and standard deviation values. They were checked for normality using Shapiro-Wilk test. Data showed parametric distribution and were analyzed using the independent t-test. The significance level was set at p ≤0.05 within all tests. Statistical analysis was performed with R statistical analysis software version 4.1.3 for Windows.

Results:

Effect of ferrule condition: Mean and standard

deviation (SD) values of fracture strength (N) for different ferrule conditions were presented in Table 1 and Figures5.

Table 1: Mean ± standard deviation (SD) of fracture strength (N) for different ferrule conditions

Fracture strength (N)[1](mean ± SD)[2]		P value[3]
With ferrule	**Without ferrule**	
651.68±66.34	528.86±60.85	<0.001*

* Significant (p ≤ 0.05) ns; non-significant (p>0.05)

Samples with ferrule had a higher fracture strength value than samples without ferrule (p<0.001).
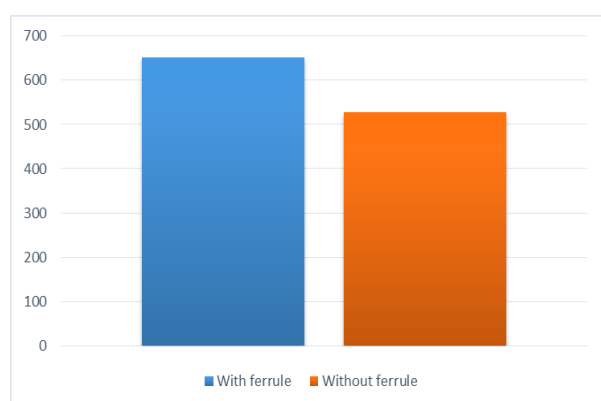

Figure (5): Bar chart showing average fracture strength (N) for different ferrule conditions

Discussion:

In this study extracted mandibular premolars with approximate similarity in dimensions were used as they can be endodontically treated and prepared to receive the dental post so it can simulate the normal condition inside the patient mouth.[17]

Fracture resistance testing in this study was made using the Universal testing machine to load all the samples along their long axis, this vertical load examined the cohesive properties of the materials used in this study and simulated the physiological occlusion by the distribution of load between the restorative material and the tooth structure.[18]Data gained from this study after the fracture resistance test showed that Samples with ferrule (651.68±66.34) had a significantly higher value than samples without ferrule (528.86±60.85) (p<0.001).
The outcomes of this study were found to be in harmony with the findings of the study that was conducted by Asvanund et al.[2] To examine the failure load and degree of cracking in teeth that were endodontically treated and restored with metal cast and fiber-reinforced resin post-and-core under compressive and cyclic loading. Lower premolars that had been extracted and endodontically treated were divided into

3 groups: ferrule, no-ferrule, and less dentin wall. Fiber-reinforced resin post and core and metal cast post and core were used to reconstruct teeth. The crown was produced to restore the teeth after the placement of the post and core. The findings were consistent with this study and revealed that ferrule-restored teeth were more fracture-resistant than teeth that had no ferrule.
This study's findings were in harmony with the results of the study that was made by Bacchi et al.[19] to evaluate the influence of ferrule and the post type on the fracture strength and stress distribution in premolars. Extracted mandibular premolars were endodontically treated and decoronated and then allocated into four groups. The first group was without ferrule and restored with cast post and core. The second group was with ferrule and restored with cast post and core. The third group was without ferrule and restored with glass fiber post and composite core. The fourth group was with ferrule and restored with glass fiber post and composite core. Test of fracture resistance was done using a universal machine after aging of samples and the results showed that samples that were with ferrule had higher fracture resistance values than samples that were without ferrule and this confirms the results obtained in this study.

Another study was made by zhi-yue et al.[20] to evaluate the effects of post and core design and ferrule on the fracture resistance of endodontically treated maxillary central incisors restored with metal-ceramic crowns. Extracted maxillary central incisors were endodontically treated and divided into four groups. The first group was restored with PFM crown. The second group had 2 mm ferrule and was restored with cast post and core and PFM crowns. The third group was without ferrule and restored with cast post and core and PFM crowns. The fourth group had 2mm ferrule and was restored with ready-made posts with core from composite and PFM crowns. After the fracture resistance test, the results showed that the second group had the highest fracture strength. There was no significant difference among the fracture resistances of the other 3 groups. These findings showed that there was no significant difference between with and without ferrule samples in the two groups which were different from the results of this study. This difference may be due to the difference in the materials of restoration that were used in the two studies.

Conclusion:

Based on the results obtained in this study, the following conclusions can be derived; ferrule samples are more resistant to fracture than Without ferrule Samples with the two different post types.

References:

1. Mannocci F, Cowie J. Restoration of endodontically treated teeth. Br Dent J. 2014;216(6):341-6.
2. Asvanund P. Fracture resistance of Pulpless Teeth Restored with Cast-Post-and-Core versus Fiber

Reinforced Composite Resin. M Dent J. 2016;36(3):297-305.

3. Mohamed M. The Effect Of Remaining Coronal Dentin Wall Thickness On Fracture Resistance Of Endodontically Treated Teeth Restored With Post And Core. Egyptian Dental Journal. 2018;64(4):3661-3671.

4. Sudhanshu S, Sanjeev M. Permanent Restoration in Endodontically Treated Permanent Restoration in Endodontically Treated Teeth: Clinical Dilemma, Future Trends and Review Teeth: Clinical Dilemma, Future Trends and Review of Literature. International Journal of Dental and Medical Specialty. 2015;2(3):29-36.

5. Dilmener FT, Sipahi C, Dalkiz M. Resistance of three new esthetic post-and-core systems to compressive loading. J Prosthet Dent. 2006;95(2):130-6.

6. Bandéca M, El-mowafy O, Shebl A, Porto-Neto S. Nonmetallic post-endodontic restorations: a systematic review. IJD, Int. j. dent. 2010;9(2):57-62.

7. Stewardson DA. Non-metal post systems. Dent Update. 2001;28(7):326-32, 334, 336.

8. SatiJa R, Singla M G. Customizing the prefabricated fiber post: A case report. IP Indian Journal of Conservative and Endodontics.2021;6(3): 176-180.

9. Bru E, Forner L, Llena C, Almenar A. Fibre post behaviour prediction factors. A review of the literature. J Clin Exp Dent. 2013;5(3):150-3.

10. Tekin S, Adiguzel O, Cangul S, Atas O, Erpacal B. Evaluation of the use of PEEK material in post-core and crown restorations using finite element analysis. Am J Dent. 2020;33(5):251-257.

11. Bathala L, Majeti V, Rachuri N, Singh N, Gedela S. The Role of Polyether Ether Ketone (Peek) in Dentistry - A Review. J Med Life. 2019;12(1):5-9.

12. Sheiko N, Kekicheff P, Marie P, Schmutz M, Jacomine L, Perrin-Schmitt F. PEEK (polyether-ether-ketone)-coated nitinol wire: Film stability for biocompatibility applications. Applied Surface Science. 2016;389:651-665.

13. Stawarczyk B, Beuer F, Wimmer T, Jahn D, Sener B, Roos M, Schmidlin PR. Polyetheretherketone-a suitable material for fixed dental prostheses? J Biomed Mater Res B Appl Biomater. 2013;101(7):1209-1216.

14. Maroulakos G, Nagy WW, Kontogiorgos ED. Fracture resistance of compromised endodontically treated teeth restored with bonded post and cores: An in vitro study. J Prosthet Dent. 2015;114(3):390-397.

15. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods. 2007;39(2):175-91.

16. Amaral FL, Colucci V, Palma-Dibb RG, Corona SA. Assessment of in vitro methods used to promote adhesive interface degradation: a critical review. J Esthet Restor Dent. 2007;19(6):340-53; discussion 354.

17. Teixeira KN, Duque TM, Maia HP, Gonçalves T. Fracture Resistance and Failure Mode of Custom-made Post-and-cores of Polyetheretherketone and Nano-ceramic Composite. Oper Dent. 2020;45(5):506-515.

18. Abdelmohsen NA, Zohdy MM, Abdelfattah G, wahsh M. Fracture Resistance of Different Post-core Systems Restoring Mandibular Premolars. Mansoura Journal of Dentistry. 2021;8(4):6-11.

19. Bacchi A, Caldas RA, Schmidt D, Detoni M, Matheus Albino Souza, Cecchin D, Farina AP. Fracture Strength and Stress Distribution in Premolars Restored with Cast Post-and-Cores or Glass-Fiber Posts Considering the Influence of Ferule. Biomed Res Int. 2019;2019:2196519.

20. Zhi-Yue L, Yu-Xing Z. Effects of post-core design and ferule on fracture resistance of endodontically treated maxillary central incisors. J Prosthet Dent. 2003;89(4):368-73.