ATATÜRK ÜNİVERSİTESİ YAYINLARI
ATATURK UNIVERSITY PUBLICATIONS

Research Article *Araştırma Makalesi* DOI: 10.17567/currresdentsci.1424571

A Comparison of the Fracture Resistance of Maxillary Central Incisors With a Ferrule With Various Post Systems

Farklı Post Sistemleriyle Restore Edilen Ferruleli Maksiller Santral Dişlerin Kırılma Direncinin Karşılaştırılması

Esra KUL [1]
[1]Atatürk University, Faculty of Dentistry, Department of Prosthodontics, Erzurum, Türkiye

Münevver KILIÇ [1]
[1]Başkent University, Faculty of Dentistry, Department of Pedodontics, Erzurum, Türkiye

Beyza Betül ŞENCAN [1]
[1]Atatürk University, Faculty of Dentistry, Department of Prosthodontics, Erzurum, Türkiye

Ruhi YEŞİLDAL [1]
[1]Atatürk University, Faculty of Engineering, Department of Mechanical Engineering, Erzurum, Türkiye

ABSTRACT

Objective: In the literature, the influence of different post types utilized on ferrule-formed maxillary central teeth on fracture resistance and restoration life is not clearly explained. This study aims to investigate how fiber reinforced composite posts (FRC), fiber posts (FP), and zirconia ceramic posts (ZCP) effect fracture resistance of endodontically treated central teeth with a ferrule.

Methods: Ferrule was created to preserve 2 mm of coronal dentin structure for 30 maxillary central teeth that undergone root canal therapy. Thirty maxillary central teeth were separated into three distinct groups, and three distinct posts were applied: FRC, FP, and ZCP. After constructing the post core, the strip crown was applied. Thermal cycling and chewing simulation were performed on the samples. The samples were exposed to a refractive test in a universal testing machine. The samples were subsequently analyzed at x10 magnification using an optical microscope. A one-way ANOVA and Chi-square test were used to assess fracture resistance between groups.

Results: In terms of fracture resistance and fracture type, the statistical analysis revealed no statistically significant differences between the groups.

Conclusion: Despite the fact that the type of post is particularly critical for the survival of endodontically treated teeth, the presence of a ferrule considerably improves survival. Endodontically treated teeth that have been prosthetically restored with post implantation are more likely to survive because to the ferrule effect.

Key words: Ferrule, post, fracture resistance

ÖZ

Amaç: Literatürde, ferrulesi olan maksiller santral dişlerde kullanılan farklı post tiplerinin, kırılma direnci ve restorasyon ömrü üzerindeki etkisi net bir şekilde açıklanmamıştır. Bu çalışma, fiber takviyeli kompozit postların (FRC), fiber postların (FP) ve zirkonyum seramik postların (ZCP) endodontik olarak tedavi edilmiş, ferrulesi olan maksiller santral dişlerin kırılma direncini nasıl etkilediğini araştırmayı amaçlamaktadır.

Yöntem: Kök kanal tedavisi yapılmış, 30 maksiller santral diş için 2 mm ferrule, koronal dentin yapısını korumak için oluşturuldu. Otuz maksiller santral diş üç ayrı gruba ayrıldı ve üç ayrı post uygulandı: FRC, FP ve ZCP. Postlar yerleştirildikten sonra kompozit kuron yapıldı. Örnekler üzerinde termal döngü ve çiğneme simülasyonu yapıldı. Örnekler, evrensel bir test cihazında kırılma dayanımı için teste tabi tutuldu, daha sonra optik mikroskop kullanılarak x10 büyütmede analiz edildi. Gruplar arasındaki kırılma direncini değerlendirmek için tek yönlü ANOVA ve Ki-kare testi kullanıldı.

Bulgular: Kırılma direnci ve kırık tipi açısından gruplar arasında istatistiksel olarak anlamlı bir fark yoktu (p=0.910).

Sonuç: Endodontik olarak tedavi edilen dişlerin restorasyonu için kullanılan post tipi, sağkalımı için kritik olmasına rağmen, ferrule varlığı sağkalımı önemli ölçüde artırır. Post implantasyonu ile protetik olarak restore edilen endodontik olarak tedavi edilmiş dişlerde, ferrule etkisi varsa sağkalma olasılığı daha yüksektir.

A**nahtar kelimeler:** Ferrule, post, kırılma dayanımı.

Geliş Tarihi/Received 23.01.2024
Kabul Tarihi/Accepted 09.09.2024

Sorumlu Yazar/Corresponding author:
Esra KUL
E-mail: esra.kul@atauni.edu.tr

Cite this article: Kul E, Kılıç M, Şencan BB, Yeşildal R. A Comparison of the Fracture Resistance of Maxillary Central Incisors With a Ferrule With Various Post Systems *Curr Res Dent Sci. doi 10.17567/currresdentsci.1424571*

INTRODUCTION

Many assert that endodontically treated teeth are more brittle than untreated teeth, hence root canal therapy may be necessary for both primary and permanent teeth.[1] This may be due to the preparation of the root dentin during root canal therapy, when the root canal is also drained. The treatment of devitalized.

teeth becomes crucial for these reasons. Restoration of teeth following endodontic treatment is essential for the survival of endodontically treated teeth. In contrast to restorations produced on vital teeth, restorations performed on teeth with endodontic therapy have a greater complication risk and may ultimately lead to tooth loss.[2, 3] Among the failure types identified in root canal-treated teeth are those that can be repaired. Repairable failures include cohesive and cohesive/adhesive fractures, tooth structure chipping, and frequently horizontal fractures. Catastrophic failure is another form of failure, which involves tooth and root fractures necessitating tooth extraction. [3-5] In circumstances where the coronal tooth structure is not supported, post application with support from the root structure will be necessary. It is believed that the essential root preparation for posting endodontically treated teeth weakens the root.[5]

The ferrule effect is one of the most essential ideas in the prosthetic treatment of root canal-treated teeth, and it has been stated that the presence of a minimum of 2 mm of dentin in the coronal region is one of the most important elements in enhancing fracture resistance. [6-9] Formation of ferrules is necessary for optimal biomechanics in root canal-treated teeth.[10,11] This retained dentin structure enhances the biomechanical performance of the preform and the success of post-core restorations.[12] It is believed that the ferrule effect is required to stabilize endodontically treated and repaired teeth and enhance prognosis.[12]

Recent researches have mostly focused on which materials and post core procedures are necessary to enhance the life of restorations placed on teeth that have received endodontic treatment and require post application.[13] These posts may be metallic or non-metallic (gold or non-gold alloys).[12,14] Non-metallic examples include glass fiber, carbon fiber, and zirconium. Zirconium-based glass ceramic posts have some restrictions. They induce more root fractures than fiber posts, which is the most clear example.[15] Posts with an adhesive cementation method result in increased retention and less microleakage.[15] In addition, they exhibit greater resistance to root fracture.[16]

In recent years, these non-metallic post systems have gained popularity because to the ease of application procedures, the ability of the doctor to complete the operation in a single consultation, and their superior aesthetic features.[17] Fiber posts cemented to root dentin with adhesive techniques are being utilized more frequently to enhance esthetics.[11, 17] Fiber-based posts are composed of carbon fibers encased in a polymer resin, often epoxy resin. The primary benefit of these posts is that they are somewhat flexible and transmit load-induced stresses to the root dentin more effectively than metal posts.[18] As an alternative to typical cast or prefabricated metal posts, bundled glass fiber-reinforced composite (FRC) resin posts have evolved. Since these posts do not require laboratory procedures, their clinical treatment duration is short and they offer aesthetic benefits. Due to their modulus of elasticity that is closer to dentin than that of metal posts, bundled glass FRC posts are gaining in popularity.[19, 20] Currently, posts made from a mix of glass fiber and composite resin are utilized often. Widespread use has been made of a new bunch-shaped post system that conforms to the canal's anatomy by assuming the form of the root following insertion into the canal (Rebilda Post GT; VOCO GmbH).[21]

In this study, it was hypothesized that there would be a statistically significant difference between the three analyzed groups, and this was accepted as the null hypothesis. As the first hypothesis, it was determined that there would be no substantial variation in fracture resistance. The second hypothesis of this study was that there would be a statistically significant difference in fracture type between the examined post groups.

MATERIALS AND METHODS

This study was approved by the ethics committee (Date: 15.04.2021, Number:2021/3-24) of Atatürk University Faculty of Medicine. In this investigation, 30 extracted maxillary central teeth were used. All used maxillary central teeth were cleaned and residues were stored in distilled water. All of the teeth had a single root and canal. The straightest canals were chosen. Each tooth's pulp chamber has a similar form. Teeth having root fractures, root canal therapy, and cracks were excluded from the study. Using a high-speed handpiece, the crowns of the teeth were removed, leaving 3 mm of dentin in the coronal area, and the teeth were separated into three groups (n=30). Root canal treatment was performed on these teeth. This root canal treatment followed the standard endodontic protocol.[22] Root canals were instrumented to a minimum size of 0.40/.06 using K3XF rotary files (Kerr Corp., USA). During the replacement of each used canal instrument, the canal was treated with 5 mL of 5.25% NaOCl, followed by 1 minute of application of 5 mL of 17% EDTA solution, and then 5 mL of 5.25% NaOCl. Finally, it was cleaned with distilled water after being irrigated with NaOCl (5 mL). After final irrigation, absorbent paper was used to dry the canal. The channel was afterwards filled with gutta-percha using a pat (AH Plus; Dentsply Sirona, Germany). During canal filling, the cold lateral compaction method was applied. Cavit-G (3M ESPE, USA) was utilized to temporarily seal the endodontic access cavity.

After root canal treatment, the teeth were stored for seven days at 37°C and 100% humidity. The samples were then implanted in parallel acrylic resin blocks (Palapress vario; Kulzer GmbH) 2 mm below the cemento-enamel interface. The preparation of the root canal cavity for the post was then initiated. Root canal filling was emptied to a length of 10 mm with No. 1 Peeso Reamer (Mani Inc. Japan) and post cavity preparation in the root canal was performed with No. 1 drill (DT Light-Post System; BISCO, Inc.USA). Using a stereomicroscope, the post cavity was checked to confirm that the filling was entirely inserted. All teeth were given a 2 mm tall ferrule with the aid of a diamond bur, a high-speed hand tool, and water spray cooling. In this investigation, three distinct types of posts were employed: group FRC (Rebilda Post GT bundled glass FRC posts), group FP (Rebilda fiber posts), and group ZCP (Komet prefabricated zirconia ceramic posts) (Table 1). The teeth were separated into three groups of ten based on the post type to be chosen. Before cementing the posts, the root canal was cleaned with distilled water, dried with a paper point, and treated with a bonding agent (Futurabond; VOCO GmbH, Germany). Again, the posts were washed with alcohol and dried with air before ceramic bond (VOCO GmbH, Germany) was applied to the post's circumference and air dried. Around the post, dual polymerized self-etching resin cement (Rely X U200,3M ESPE, USA) was applied, and the post was inserted into the post cavity.

Table 1. Materials used

Posts	Abbreviation	Manufacturer	Lot Number
CeraPost	ZCP	Komet Dental	981828
Rebilda	FP	VOCO GmbH	1725147
Rebilda Post GT	FRC	VOCO GmbH	1745496
Resin cement			
Rely X U200		3M ESPE	7615713

After the post had been installed, the cement was lit (VALO LED Curing Light; Ultradent Products, Inc). The length of the post was reduced to 11 mm (8 mm below and 3 mm above the cervical margin). This was how all post-cementation processes were carried out. After all of these FP, ZCP, and FRC posts were cemented, the cores were

fabricated from dual polymer adhesive composite resin core foundation system and honed using diamond burs. After the posts were cemented, all groups utilized strip crowns to restore the maxillary central tooth. According to the manufacturer's instructions, the strip crowns were cut with sharp scissors and an exit hole was drilled to allow extra composite to escape through the palatal portion of the strip crowns. Each group's teeth were dried and etched for fifteen seconds with five milliliters of Vococid acid (VOCO, Germany). The dentin surface was dried with a mild air freshener so as not to overdry the tooth once the acid was removed. Bonding agent (G-Premio BOND, GC, Tokyo, Japan) was applied and light-cured for 20 seconds at 1,200 mW/cm2. The composite (Genial A2 Anterior, GC, Tokyo, Japan) was put into the strip crown, which was then bonded to the tooth. Using a probe, excess composite in the cervical area was removed. The composite was then light-cured for 20 seconds from the vestibule and palatal (VALO Grand LED, Ultradent Products Inc, USA). After the light-curing was complete, the excavator was used to remove the strip crown from the tooth.

After twenty-four hours, specimens implanted in acrylic resins were exposed to heat cycling and chewing simulation. A device was utilized to secure the acrylic cylinders at a 45-degree angle. Chewing forces were recreated using a closed-loop electrodynamic artificial mouth machine (Acumen III; MTS Systems Corp). Samples underwent heat cycling. All samples were transported to hot water tanks at 5 °C and 55 °C for 6000 cycles (16 seconds each, 4 seconds). To conduct the static loading test, each specimen was mounted on a universal test device (Model 3344; Instron, USA) with a mechanism that holds the specimens at a 45 degree[23] angle and at a single point at a 135 degree[24] angle to the long axis at the incisal of the crowns. On specimens standing at the prescribed inclination, a metal cylinder is positioned parallel to the ground. It was positioned at a 90-degree angle to its axis and its crosshead speed was adjusted at 2.54 mm/min. The maximum load in Newtons was measured, as determined by an abrupt reduction in pressure force (Figure 1). At the conclusion of the test, all of the samples were inspected using an x10 optical microscope to determine if the fractures were catastrophic (Figure 2) or repairable (Figure 3). Following the test result and evaluation using an optical microscope, a statistical analysis was conducted. A one-way ANOVA was done to compare groups' fatigue resistance. The Chi Square test was performed to assess fracture types between groups. The Shapiro-Wilk test was employed to assess for normalcy. The Levene test was performed to determine homogeneity.

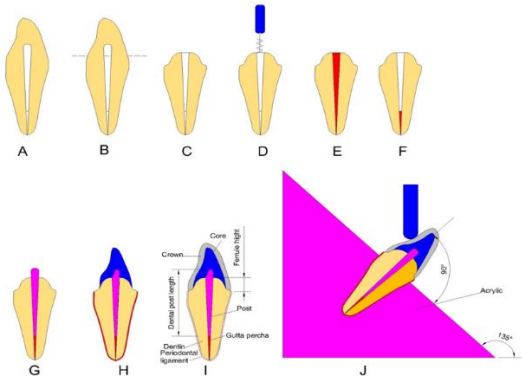

Figure 1. Illustration of procedure

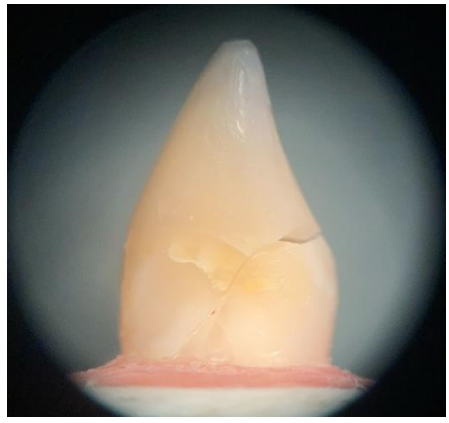

Figure 2. catastrophic failure

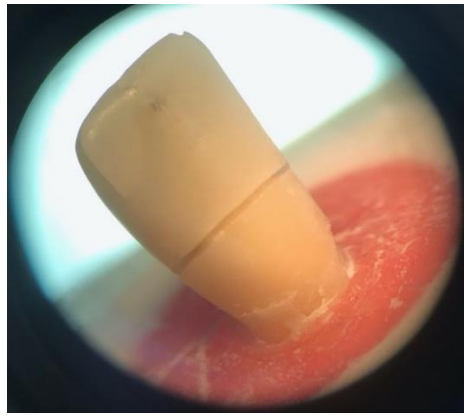

Figure 3. Reparable failures

RESULTS

According to the statistical analysis (Figure 4), there was no significant difference in fracture resistance between the groups employing different types of posts (P=0.910). The Chi-square test was used to see whether there was a significant difference between the groups in terms of fracture type, and no significant difference was discovered. The Shapiro Wilk test was used to test for normality, and this test revealed a normal distribution. The use of the Levene test revealed a homogenous distribution. The light microscopy study revealed that catastrophic fracture was less prevalent in FRC posts.

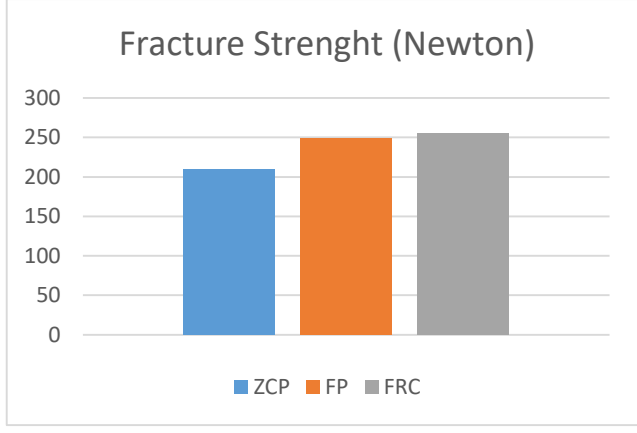

Figure 4. Fracture Strenght of Post Systems

DISCUSSION

In this investigation, it was determined that there was no significant difference in fracture resistance across the groups, as predicted by the first hypothesis. The second hypothesis of the study predicted that there would be a substantial difference in fracture resistance across the groups. The second hypothesis was not supported. Due to the loss of tooth structure during endodontic treatment, the weakening of the remaining tooth structure, and the decrease in resistance, the restoration of endodontically treated teeth is exceedingly challenging for clinicians.[25] Due to the deterioration of the tooth structure, it may not always be viable to restore the tooth using simply the crown. Therefore, endodontic posts are utilized to strengthen the durability of restorations that will be placed on teeth that have been impaired by material loss prior to and after root canal therapy.[25, 26] If post support is necessary for the restoration of endodontically treated teeth, it is crucial to construct a ferrule during tooth preparation.[27] When the ferrule is formed in the tooth, the parallel walls of the dentin extending coronally from the crown edge protect the tooth by decreasing the pressures on the tooth when it is surrounded by a crown.[28] In this manner, the development of the ferrule offers a protective function. According to the research, the ferrule must be made at least 2 mm above the cemento-enamel junction in order to provide suitable resistance.[28] All mandibular premolar teeth with zirconium posts, fiber posts, and fiber reinforced composite posts without ferrule formation failed catastrophically, according to Kul et al.[29]

To reasonably evaluate the dynamic and continuous changes occurring in the oral cavity, thermal cycling and mechanical loading simulations were performed on the specimens in this study. These repetitive mechanical, thermal and chemical stresses represent the most advanced in vitro technique available for evaluating under biomechanical conditions.[30] Since maxillary anterior teeth are predominantly subjected to non-axial loads, the resulting stresses increase the risk of mechanical failure in the restored teeth, therefore the fracture strength test was performed at an angle of 135 degrees to clinically test its durability.[30]

In addition to constructing a ferrule, one of the most important aspects of endodontically treated teeth may be selecting the proper post.[31] Additionally, the adhesive qualities of post systems, particularly fiber posts, influence the fracture resistance of posts.[31] Fiber posts flex under incoming stresses, and this elongation distributes the stress between the dentin and the post. This is the most valuable benefit of fiber posts. According to Nam et al.,[32] the fracture resistance of endodontically treated premolar teeth with 1 to 4 coronal walls is enhanced when they are repaired with fiber posts. When there is no remaining coronal wall, however, the introduction of fiber posts does not increase fracture resistance. Numerous studies have revealed that cast post core restorations with prefabricated metal posts increase the likelihood of root fractures.[33] In other studies, however, it has been discovered that the use of fiber afterwards yields extremely good outcomes.[34] Lazari et al,[35] In their investigation, he revealed that 100% of the fracture forces applied to the incisors with ferrule-free, fiber post, and titanium post resulted in catastrophic fracture. Consequently, regardless of the kind of post used, forming a ferrule in the tooth boosts the restoration's success and the tooth's survival rate. High elastic modulus zirconia post-core samples exhibited catastrophic fractures. In a separate investigation, it was shown that most zirconium posts failed due to fractures 2 mm below or above the root's cervical margin.[35]

A recent study showed that cementation methods did not affect the load capacity of the maxillary central incisor tooth restored with a post and that the post systems used did not make a difference in terms of creating positive and negative fractures.[36]

The type of restoration placed on root canal-treated teeth is also crucial to the repair's endurance. In the study by Kul et al.,[29] there were no fractures in the CAD CAM lithium disilicate restorations created on teeth with endodontic posts. However, in the current investigation, half of the samples with strip crown restorations were broken. Due to the high fracture resistance of restorations such as ceramic, metal-based porcelain, and zirconium as a result of excessive material loss, which is frequently observed in endodontically treated teeth, incoming forces are transmitted to the root of the tooth more, which may result in catastrophic fractures. This study also had some limitations; if different restorations and different post types had been included in the study groups or if the amount of ferrule had been changed and more groups and more samples had been obtained, perhaps different results could have been achieved. According to the findings of this study, the failures may be more reparable if composite restorations are preferred. The study can be expanded with different post types and the effectiveness of thermoplastic resin posts can also be evaluated.

CONCLUSION

The type of post used in endodontically treated teeth has no impact on the treatment's success. Existence of ferrule in post preparation is the most significant factor impacting tooth and restoration survival.

Etik Komite Onayı: Bu çalışma Atatürk Üniversitesi Tıp Fakültesi Etik Kurulu tarafından onaylandı (Tarih: 15.04.2021, Sayı: 2021/24).
Hasta Onamı: In vitro çalışma olduuğu için hasta onam formu alınmamıştır.
Hakem Değerlendirmesi: Dış bağımsız.
Yazar Katkıları: Fikir– E.K.,M.K.; Tasarım- M.K., B.B.Ş.; Malzemeler- E.K., R.Y., M.K.; Literatür Taraması- B.B.Ş., E.K.; Yazım- B.B.Ş., E.K.,; Veri toplama ve/veya işleme-R.Y., E.K.,M.K.; Eleştirel İnceleme- E.K.
Çıkar Çatışması: Herhangi bir çıkar çatışması bulunmamaktadır.
Finansal Destek: Bu çalışma için herhangi bir finansman sağlanmamıştır..

Ethics Committee Approval: This study was approved by the ethics committee (Date: 15.04.2021, Number:2021/24) of Atatürk University Faculty of Medicine.
Informed Consent:: Since this was an in vitro study, patient consent form was not obtained.
Peer-review: Externally peer-reviewed
Author Contributions: Concept- E.K.,M.K.; Design- M.K., B.B.Ş.; Materials-E.K., R.Y., M.K.; Literature Review- B.B.Ş., E.K.;Writing- B.B.Ş., E.K.,; Data collection and/or processing-R.Y., E.K.,M.K.;Critical Review-E.K.
Conflict of Interest: There is no conflict of interest..
Financial Disclosure: No funding was obtained for this study.

REFERENCES

1. Sokol DJ. Effective use of current core and post concepts. *J Prost Dent.* 1984;52:231-234.
2. Naumann M, Schmitter M, Frankenberger R, Krastl G. “Ferrule comes first. Post is second!” Fake news and alternative facts? A systematic review. *J Endod.* 2018;44:212-219.
3. Zicari F, Van Meerbeek B, Scotti R, Naert I. Effect of ferrule and post placement on fracture resistance of endodontically treated teeth after fatigue loading. *J Dent.* 2013;41:207-215.
4. Magne P, Lazari P, Carvalho M, Johnson T, Del Bel Cury A. Ferrule-effect dominates over use of a fiber post when restoring endodontically treated incisors: an in vitro study. *Oper Dent.* 2017;42:396-406.

5. Magne P, Goldberg J, Edelhoff D, Güth J. Composite resin core buildups with and without post for the restoration of endodontically treated molars without ferrule. *Oper Dent.* 2016;41:64-75.
6. Ferrari M, Vichi A, Fadda G, et al. A randomized controlled trial of endodontically treated and restored premolars. *J Dent Res.* 2012;91:S72-S78.
7. Crysanticagidiaco M, Franklingarcia-godoy D, Alessandrovichi D. Placement of fiber prefabricated or custom made posts affects the 3-year survival of endodontically treated premolars. *Dent* 2008;21:179-184.
8. Schwartz RS, Robbins JW. Post placement and restoration of endodontically treated teeth: a literature review. *J Endod.* 2004;30:289-301.
9. Peroz I, Blankenstein F, Lange K-P, Naumann M. Restoring endodontically treated teeth with posts and cores--a review. *Quintessence Int.* 2005;36.
10. Juloski J, Radovic I, Goracci C, Vulicevic ZR, Ferrari M. Ferrule effect: a literature review. *J Endod.* 2012;38:11-19.
11. Kishen A. Mechanisms and risk factors for fracture predilection in endodontically treated teeth. *Endod topics.* 2006;13:57-83.
12. Figueiredo FED, Martins-Filho PRS, Faria-e-Silva AL. Do metal post–retained restorations result in more root fractures than fiber post–retained restorations? A systematic review and meta-analysis. *J Endod*. 2015;41:309-316.
13. Bolla M, Muller-Bolla M, Borg C, Lupi-Pegurier L, Laplanche O, Leforestier E. Root canal posts for the restoration of root filled teeth. *Cochrane Database Syst Rev.* 2007.
14. Balkenhol M, Rupf S, Laufersweiler I, Huber K, Hannig M. Failure analysis and survival rate of post and core restorations under cyclic loading. *Inter endod J.* 2011;44:926-937.
15. Koch ATA, Binus SM, Holzschuh B, Petschelt A, Powers JM, Berthold C. Restoration of endodontically treated teeth with major hard tissue loss–influence of post surface design on pull-out bond strength of fiber-reinforced composite posts. *Dent Traumatol.* 2014;30:270-279.
16. Ozel E, Dikbas I, Tanalp J, Koksal T, Ersoy M. Evaluation of the effect of different ferrule designs on the fracture resistance of endodontically treated maxillary central incisors incorporating fiber posts, composite cores and crown restorations. *J Contemp Dent Pract. 2007;8:62-69.*
17. Garcia PP, Wambier LM, de Geus JL, da Cunha LF, Correr GM, Gonzaga CC. Do anterior and posterior teeth treated with post-and-core restorations have similar failure rates? A systematic review and meta-analysis. *J Prosthet Dent.* 2019;121:887-894. e884.
18. Ricketts D, Tait C, Higgins A. Post and core systems, refinements to tooth preparation and cementation. *Br Dent J.* 2005;198:533-541.
19. Zavattini A, Feitosa V, Mannocci F, et al. Bonding ability of experimental resin-based materials containing (ion-releasing)-microfillers applied on water-wet or ethanol-wet root canal dentine. *Inter J Adhesion and Adhesives* 2014;54:214-223.
20. Ferrari M, Cagidiaco MC, Goracci C, et al. Long-term retrospective study of the clinical performance of fiber posts. *Am J Dentistry* 2007;20:287.
21. Santos TdSA, Abu Hasna A, Abreu RT, et al. Fracture resistance and stress distribution of weakened teeth reinforced with a bundled glass fiber–reinforced resin post. *Clin oral invest.* 2021:1-11.
22. Kul E, Yeter KY, Aladag LI, Ayrancı LB. Effect of different post space irrigation Procedures on the bond strength of a fiber post attached with a self-adhesive resin cement. *J Prost Dent.* 2016;115:601-605.
23. Wang H-W, Chang Y-H, Lin C-L. Mechanical resistance evaluation of a novel anatomical short glass fiber reinforced post in artificial endodontically treated premolar under rotational/lateral fracture fatigue testing. *Dent Mater J.* 2016;35:233-240.
24. Kim A-R, Lim H-P, Yang H-S, Park S-W. Effect of ferrule on the fracture resistance of mandibular premolars with prefabricated posts and cores. *J Advanced prosthodont.* 2017;9:328-334.
25. Dietschi D, Duc O, Krejci I, Sadan A. Biomechanical considerations for the restoration of endodontically treated teeth: a systematic review of the literature, Part II (Evaluation of fatigue behavior, interfaces, and in vivo studies). *Quintessence Inter.* 2008;39.
26. Roscoe MG, Noritomi PY, Novais VR, Soares CJ. Influence of alveolar bone loss, post type, and ferrule presence on the biomechanical behavior of endodontically treated maxillary canines: strain measurement and stress distribution. *J Prost Dent.* 2013;110:116-126.
27. Pereira JR, De Ornelas F, Conti PCR, Do Valle AL. Effect of a crown ferrule on the fracture resistance of endodontically treated teeth restored with prefabricated posts. *J Prost Dent.* 2006;95:50-54.
28. Stankiewicz N, Wilson P. The ferrule effect. Dental update 2008;35:222-228.
29. Kul E, Yanıkoğlu N, Yeter KY, Bayındır F, Sakarya RE. A comparison of the fracture resistance of premolars without a ferrule with different post systems. *J Prost Dent* 2020;123:521-25.
30. Albashaireh ZSM, Sbeih YK. The effect of ferrule and core material on fracture resistance of endodontically treated anterior teeth restored with ceramic crowns after artificial aging. *J Dent.* 2024 Aug;147:105106.
31. Maroulakos G, Nagy WW, Kontogiorgos ED. Fracture resistance of compromised endodontically treated teeth restored with bonded post and cores: An in vitro study. *J Prost Dent.* 2015;114:390-397.
32. Nam S-H, Chang H-S, Min K-S, Lee Y, Cho H-W, Bae J-M. Effect of the number of residual walls on fracture resistances, failure patterns, and photoelasticity of simulated premolars restored with or without fiber-reinforced composite posts. *J Endod.* 2010;36:297-301.
33. Santos-Filho PCF, Veríssimo C, Soares PV, Saltarelo RC, Soares CJ, Martins LRM. Influence of ferrule, post system, and length on biomechanical behavior of endodontically treated anterior teeth. *J Endod.* 2014;40:119-123.
34. Plotino G, Grande NM, Bedini R, Pameijer CH, Somma F. Flexural properties of endodontic posts and human root dentin. *Dent Mater.* 2007;23:1129-1135.
35. Lazari PC, de Carvalho MA, Cury AADB, Magne P. Survival of extensively damaged endodontically treated incisors restored with different types of posts-and-core foundation restoration material. *J Prost Dent.* 2018;119:769-776.
36. Beh YH, Halim MS, Ariffin Z. The load capacity of maxillary central incisor with simulated flared root canal restored with different fiber-reinforced composite post and cementation protocols. *PeerJ.* 2023;17;11:e16469.