Original Research
Dental Materials

Application of polyetheretherketone (PEEK) posts: evaluation of fracture resistance and stress distribution in the root: *in vitro* and finite element analyses

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Abstract: To evaluate the feasibility of using a milled polyetheretherketone (PEEK) post and core in endodontically treated teeth with or without a ferrule. Sixty bovine tooth roots were endodontically treated followed by cementation of intraradicular retainers (IR), according to each experimental group: a) non-ferrule glass fiber post (f0FP); b) 2-mm-ferrule glass fiber post (f2FP); c) non-ferrule resized glass fiber post (f0PR); d) 2-mm-ferrule resized glass fiber post (f2PR); e) non-ferrule PEEK post and core (f0PPC); and f) 2-mm-ferrule PEEK post and core (f2PPC). Metal crowns were made and cemented. A periodontal ligament was simulated using polyether. A force was applied to the palatine portion of each sample at 45°, until fracture. Fracture resistance data were submitted to two-way ANOVA and Tukey's test (α = 0.05). Three-dimensional digital models were developed to calculate the tensions formed in the root using finite element analysis. Models of glass fiber posts and PEEK posts and cores were evaluated with or without a ferrule. The results were analyzed by the Mohr-Coulomb criterion. The type of IR was not influenced by fracture strength (p = 0.243). There were significant statistical differences among the remaining factors. Ferrule groups had greater fracture resistance, and the failure mode of teeth with a ferrule was more catastrophic than the non-ferrule group. A ferrule increases fracture resistance and influences failure mode; the PEEK post and core did not modify the biomechanics of endodontically treated teeth, and resembled the glass fiber post results. The crack initiation point differed between the ferrule and non-ferrule groups.

Keywords: Polyetheretherketone; Dental Impression Materials; Dental Bonding.

Introduction

Roots with minimal or no coronal tooth structure have been commonly restored with a cast post and core to increase retention of the dental restoration.[1] A cast post and core system is a single element, and, as such, provides advantages to promoting root stress distribution. This

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system enhances stress concentration at the post dentin interface, and represents a plus factor. This is because lower stress is generated at the adhesive layer when there is a single material, as opposed to layers of different materials, such as fiber-reinforced composite posts, where different materials are involved in the system, resulting in several elastic moduli.[2,3] However, the high elastic modulus of a metal cast post and core is associated with a more catastrophic failure, compared to a fiber post.[4]

In this context, it would be interesting to develop an anatomical post and core made from a material with a lower elasticity modulus to form a single-piece intraradicular retainer, thus avoiding interfaces of different elasticity. Several studies have focused on the development of medical and dental prostheses milled with a polymer produced from polyetheretherketone (PEEK) resin.[5-7]

PEEK consists of a thermoplastic polymer, which exhibits good dimensional stability, biocompatibility, easy polishing and machinability.[7,8] In dentistry, PEEK has been proposed for fixed prosthesis and removable partial denture bases.[6] However, its chemical composition and low surface energy could hinder bonding with resin materials.[9] Manufacturing a PEEK polymer post and core using CAD/CAM milling is a concept that could provide a laboratory-produced, premolded intraradicular retainer. This process would be indicated especially for cases of great loss of tooth structure. The advantage of this process stems from the lower elasticity modulus of PEEK, compared to that of metal alloys. The outcome is that PEEK could provide a single interface between the post and tooth, unlike the techniques using relined glass fiber posts with composite resin, or conventional fiber posts.

The resulting single interface could provide greater resistance to the restorative system, reducing adhesive failures and preventing premature fracture of the post/core.[3] In addition, the use of digital dentistry to manufacture intraradicular retainers could lead to a higher clinical success rate, and reduce the failure rate due to operator mismanagement of the tooth-restoration complex.[10]

Thus, the aim of the present study was to compare the in vitro fracture resistance and the in vitro root stress distribution of a CAD/CAM-milled PEEK polymer post and core with a resized or non-resized glass fiber post, and with or without a ferrule. In view of the increased demand for dental rehabilitation procedures using digital dentistry technologies, this pioneering study is one among others that all add to the existing body of research into the different in vitro and finite element analyses of how several promising materials (PEEK and CAD/CAM system) perform in different tooth root situations. The hypotheses tested were: a) a single-piece post and core could compensate the absence of a ferrule, and b) a PEEK post and core would improve the fracture resistance of endodontically treated teeth.

Methodology

Sample preparation and laboratory analyses

Sixty mandibular bovine incisors were extracted and stored in a 0.1% thymol-buffered solution. The teeth were decoronated at 13 mm or 15 mm from the apex, according to each experimental group. Each specimen was examined and selected according to the following criteria: a) root canal diameter: the canal space should be among the more circular and/or have a maximum diameter of 2 mm, measured with a digital caliper; b) no root curvature; c) complete rhizogenesis with closed radicular apex. Subsequently, the roots were divided into 6 groups: non-ferrule glass fiber post (f0FP); 2 mm-ferrule glass fiber post (f2FP); non-ferrule resized glass fiber post (f0PR); 2 mm-ferrule resized glass fiber post (f2PR); non-ferrule PEEK post and core (f0PPC); and 2 mm-ferrule PEEK post and core (f2PPC).

The same operator prepared all the specimens. Endodontic treatment was performed using K-files and #3 to #5 Gates-Glidden files (Dentsply Maillefer, Ballaigues, Switzerland), according to the step-back technique[11] under saline solution irrigation. After preparation, the root canals were irrigated with ethylenediaminetetraacetic acid (EDTA). Root obturation was performed using the lateral condensation technique, medium-large gutta-percha cones (Dentsply, Petrópolis, RJ, Brazil), and endodontic cement (Sealer 26, Dentsply, York, USA).

Root surfaces were dipped in melted wax (New Wax, Technew, Rio de Janeiro, Brazil), and the specimens were fixed with acrylic resin (Classico, Campo Limpo Paulista, Brazil), using a polyvinyl chloride pipe (Tigre S/A, Joinville, SC, Brazil), and embedding 11.5-mm of the root. Then, the root was removed along its long axis, and the wax was also removed. A polyether-based material (Impregum Soft, 3M ESPE, St. Paul, USA) was inserted between the root and the resin block to simulate the periodontal ligament. The root specimens were prepared with #5 Largo drills (Dentsply Maillefer, Ballaigues, Switzerland), compatible with the thickness of a #3 glass fiber post (Exacto, Ângelus, Londrina, PR, Brazil), leaving the endodontic material 3 mm short of the apex. Specimens with a 2 mm ferrule were prepared by the same operator, using diamond drills (4072- KG Sorensen, Cotia, Brazil).

Root specimens in PEEK post and core groups were previously lubricated with hydrosoluble gel, and molded with acrylic resin (Duralay - Reliance Dental Manufacturing, Chicago, USA). Standardization of the coronary portion was achieved using a NucleoJet core (NucleoJet, Ângelus, Londrina, PR, Brazil). The intraradicular impression was sent to the prosthetic laboratory, and scanned by CEREC inLab CAD/CAM software (Sirona-Bensheim, Germany). A PEEK polymer block (PEEK OPTIMA - Juvora, Lancashire, UK) was made from the digital models, and milled to produce a post and core. The canal walls of the f0PR and f2PR groups were lubricated with a hydrosoluble gel and molded with bulk-fill composite resin (Filtek Bulk Fill, 3M ESPE, St. Paul, USA). The composite resin and the fiber post were positioned inside the root canal and photoactivated with a light-emitting diode (Valo, Ultradent Products, South Jordan, USA) in High Power mode for 5 s. The resized posts were removed from the canal, and complete polymerization was performed for 15 s.

The dentin of all the specimens was etched with 35% phosphoric acid (Ultra-Etch; Ultradent, Salt Lake City, USA) for 15 s, rinsed for 20 s, and then gently dried with paper points (Endopoints, Manacapuru, Brazil), followed by application of Adper Scotchbond Multi-purpose Plus adhesive system (3M ESPE, St. Paul, MN, USA), using an activator and a catalyst, according to the manufacturer's recommendations.

Prior to the luting procedure, all the fiber posts were cleaned with alcohol and air-dried, and then received a layer of silane (RelyX Ceramic Primer, 3M ESPE),[12] whereas PEEK posts and cores were etched with 98% sulfuric acid for 60 s, then rinsed for 60 s and air-dried.[9,13] A layer of Visio.Link (Bredent, Senden, Germany) was applied on the PEEK surface, followed by photoactivation for 90 s, according to Uhrenbacher et al.[13]

All the posts were cemented to the root with RelyX ARC luting agent (3M ESPE, St. Paul, USA).[14] Groups receiving fiber posts had core foundation restorations made with bulk-fill composite resin, followed by the same procedure used for preparing the coronary portion in PEEK post and core groups, as described above. Acrylic crowns were fashioned from a silicone molding (5.0 mm mesiodistal width and 9.0 mm cervical-incisal width) of the upper central incisors, for sample crown standardization. The acrylic crowns were relined on the cores, numbered, and cast with nickel-chromium alloy (Durabond, São Paulo, Brazil). The metal crowns were adjusted as needed, then adapted on the, USA), according to the manufacturer's instructions. Excess material was removed, and the specimens were stored at 37°C for 48 h.

Fracture resistance (N) was evaluated in a universal testing machine (Instron 1144, Instron, Canton, USA), with the load applied on the palatal portion of the crown specimens at a 45º angle to the horizontal plane, and at a speed of 1 mm/min, until fracture (Figure 1). The fracture strength (N) value of each specimen was defined as the highest point observed in the load vs. displacement curve.

Failure mode

The fracture resistance of all the samples was evaluated, and analyzed visually to detect the failure type. A visual distinction was made among 4 fracture modes, using a classification system modified from Rippe et al.,[15] considering the fracture location as follows: (Type 1) root fracture up to 1 mm below the simulated bone level; (Type 2) root fracture up

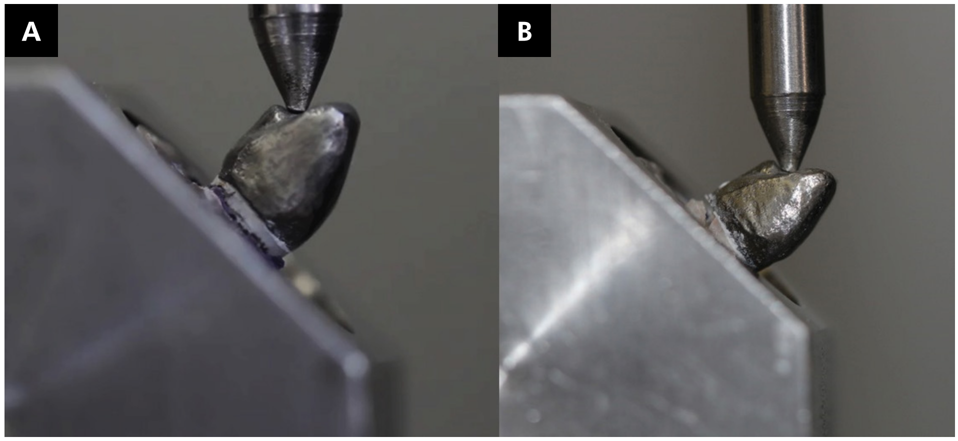


Figure 1. Representative image of specimens during fracture resistance test. A: Positioned specimen in the machine before fracture; B:- Specimen during the fracture.

to 2 mm below the simulated bone level; (Type 3) root fracture up to 3 mm below the simulated bone level; and (Type 4) root fracture more than 4 mm below the simulated bone level.

Finite element analysis

A three-dimensional (3D) human incisor tooth model was obtained from an open-access online database[10,16]. The tooth model was resized to the dimensions compatible with a laboratory study. According to the cervical conditions used in the experiments performed herein, two dental preparations were modeled: no ferrule (f0) and 2 mm ferrule (f2). The dimensions of the #5 Largo drills (Dentsply Maillefer, Ballaigues, Switzerland) were taken into account to fashion the endodontic treatment. Three-dimensional geometries (3D) and assemblies were created with computer-aided design (CAD) software (SolidWorks 2010, Concord, USA). Intraradicular retainers were created, representing the experimental groups: glass fiber post, and PEEK post and core. A total of four 3D models were created, including periodontal ligament, acrylic resin cylinder, tooth root, dental coronal remnants, and prosthetic crown.

The 3D models were imported to computer-aided engineering software (ANSYS Workbench 11, Ansys, Pittsburg, USA). Meshes were composed by 10-node tetrahedrons, checked for element quality and refined in the areas of interest. Elements were assigned material properties. All the materials were considered linear elastic, isotropic, and homogeneous, except the orthotropic glass-fiber posts (Table 1). The properties of the applied materials were obtained from published data (Table 1). A total simulated load of 100 N was applied at the cingulum at a 45° angle to the long axis of the tooth. Model movements were restricted by fixing all six degrees of freedom at the bottom and lateral surface of the base nodes of the acrylic resin cylinders. Complete bond failure was simulated between the tooth and restorative materials, following a previously described protocol,[10] to achieve better correlation for finite element analysis and in vitro studies.

The Mohr–Coulomb failure theory was used to analyze the dentin stress ratio, according to a previous study,[16] and the ultimate tensile strength of the dentin, at an ultimate compressive strength of 96 MPa[18] and 295 MPa,[19] respectively. Maximum and minimum principal stress are presented and compared herein.

Statistical analysis

The exploratory analysis indicated a logarithmic conversion for the data to satisfy the analysis of variance (ANOVA) assumptions. Two-way ANOVA was applied after the conversion to investigate the influence of the retainer type and remaining coronary condition on the fracture resistance data. The Tukey HSD test was used as a post-hoc

Table 1. Material properties used in finite element analysis.

Material	Elastic modulus (GPa)	Poisson's ratio	Shear modulus (GPa)	References
Dentin	18	0.31		Santos Filho (2014)[20]
Polyester	0.05	0.45		Santos Filho (2014)[20]
Acrylic resin	13.5	0.31		Santos Filho (2014)[20]
Composite resin	15.8	0.24		Santos Filho (2014)[20]
Resin cement	8.3	0.24		Oyar (2014)[21]
NiCr alloy	205	0.33		Oyar (2014)[21]
PEEK	4	0.25		Kim (2012)[22]
Glass fiber post*	x = 37 y = 9.5 z = 9.5	xy = 0.34 yz = 0.27 xz = 0.34	xy = 3.54 yz = 14.57 xz = 3.54	Caldas (2018)[16]

*x- Axis of the glass fiber post long axis.

technique when needed. Analysis was performed using the R program, considering a 5% level of significance.

Results

Fracture resistance

The results of the fracture resistance analysis are displayed in Table 2. Fracture resistance was significantly higher when a ferrule was used ($p < 0.0001$). There was no significant difference among the types of intraradicular retainers ($p = 0.2432$).

Failure mode

According to our experimental design, 100% of the catastrophic failures (cracks propagated vertically in the middle and apical root thirds) were expected, because a metal crown was used to keep crown material fractures from interfering in the results. The ferrule groups had a more catastrophic fracture mode (Types 3 and 4) than the groups without a ferrule (Figure 2), and were characterized as having mesiodistal fracture, and detachment of the root from the crown fragment (Figure 3). The different cracks originated in different regions, depending on the presence or absence of a ferrule. The fracture in the ferrule groups started closer to the lingual face (Figure 3B), whereas that of the non-ferrule groups began in the medial region of the proximal faces (mesial and distal faces) (Figure 3A).

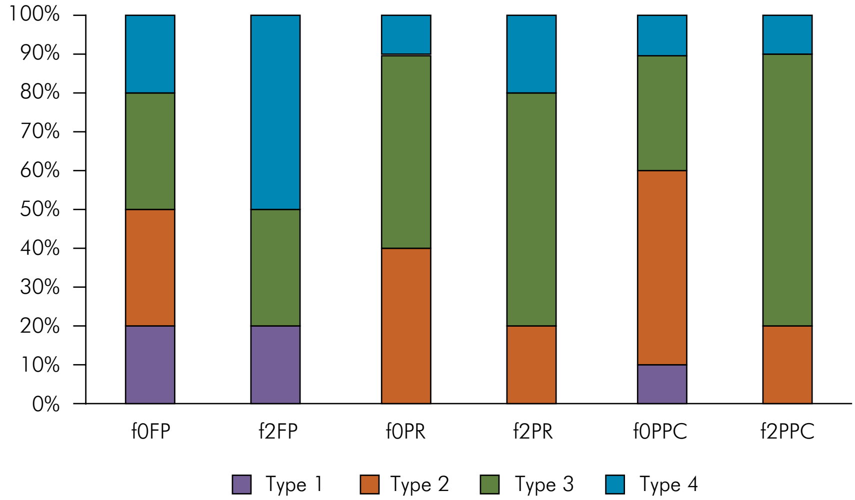
Table 2. Mean (standard deviation) maximum load to fracture (N), according to intraradicular retainer type and remaining coronary condition (ferrule).

Type of retainer	Remaining coronary condition	
p = 0.2432	p < 0.0001	
	Ferrule	No ferrule
Glass fiber post	720.44 (190.29)	426.95 (55.61)
Resized glass fiber post	849.06 (98.44)	449.26 (92.06)
PEEK post and core	820.66 (240.17)	439.47 (80.93)
Pooled average Tukey treatment (p < 0.05)	796.72 (67.57) A	438.56 (11.18) B

Only one individual factor (remaining coronary condition) resulted in a statistically significant difference, and no significant differences were recorded for retainer type or interaction between factors. Pooled average of retainer type for each remaining coronary condition is displayed in a separate row for statistical comparisons. Different uppercase letters indicate statistically significant differences between ferrule and no-ferrule conditions, regardless of the retainer type ($p < 0.05$; Tukey HSD test).

Finite element analysis (FEA)

The maximum principal stress, minimum principal stress, and Mohr-Coulomb stress ratio were evaluated when a load was applied to the tooth lingual cingulum. According to all the parameters analyzed (maximum principal stress, minimum principal stress and Mohr-Coulomb stress ratio), the stresses that formed in the root were similar among the groups of different posts, although the PEEK post and core had higher stress values than the glass fiber post (Figures 4–6). The absence of a ferrule led to a higher concentration of compressive and tensile stresses in the cervical area (Figures 4



Type 1: radicular fracture up to 1 mm below the simulated bone level; Type 2: radicular fracture up to 2 mm below the simulated bone level; Type 3: radicular fracture up to 3 mm below the simulated bone level; Type 4: radicular fracture more than 4 mm below the simulated bone level.

Figure 2. Fracture mode distribution. f0FP: no-ferrule glass fiber post; f2FP: 2 mm ferrule glass fiber post; f0PR: no-ferrule resized glass fiber post; f2PR: 2 mm ferrule resized glass fiber post; f0PPC: no-ferrule PEEK post-and-core; f2PPC: 2 mm ferrule PEEK post-and-core.

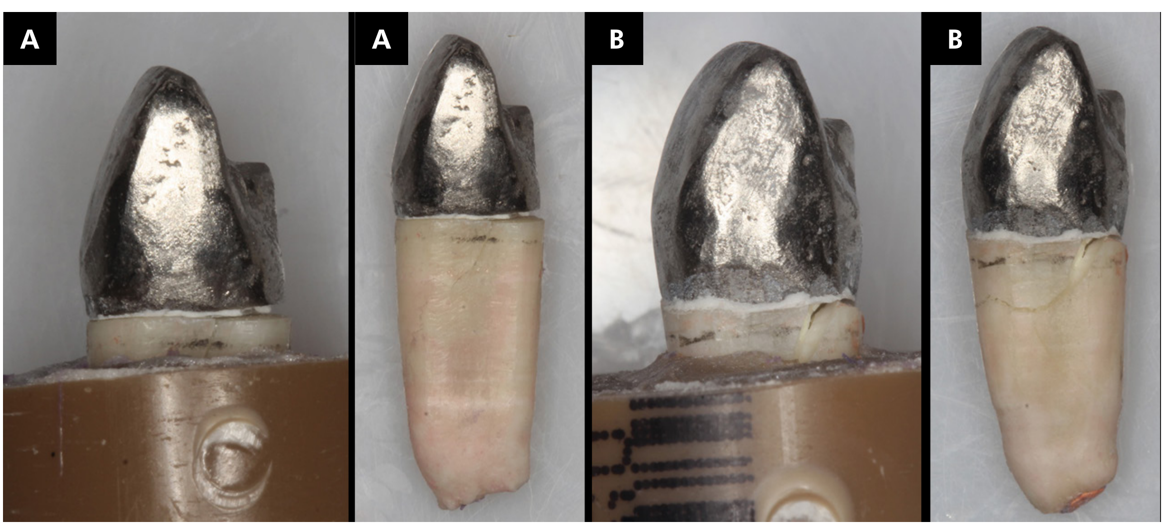


Figure 3. Specimens classified with catastrophic failure mode. A: Failure mode in roots with absence of ferrule. B: failure mode in roots with ferrule.

and 5). Conversely, FEA indicated that the presence of a ferrule caused a more pronounced effect on fracture resistance than the type of restorative material, hence corroborating the laboratory results herein (Figure 6).

Stress vectors that form in FEA simulations with or without a ferrule indicate that cracks originate in different regions, depending on the presence or absence of dental coronal remnants. Cracks occur perpendicular to the maximum principal vectors (red vectors indicate the maximum principal stress). In our study, the fracture in the ferrule groups started in the region closer to the lingual face, whereas that in the non-ferrule groups started at the medial region

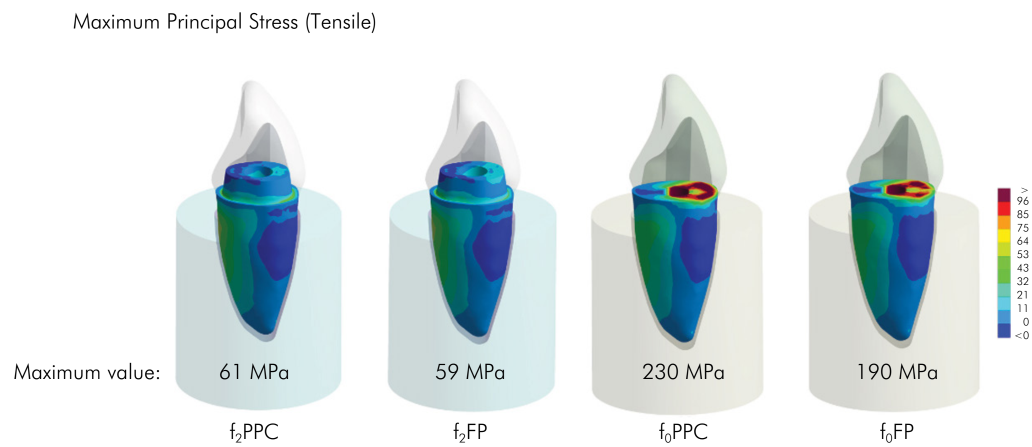


Figure 4. Maximum Principal Stress data demonstrating the effects on root surface caused by loading. f0FP: no-ferrule glass fiber post; f2FP: 2 mm ferrule glass fiber post; f0PPC: no-ferrule PEEK post-and-core; f2PPC: 2 mm ferrule PEEK post-and-core.

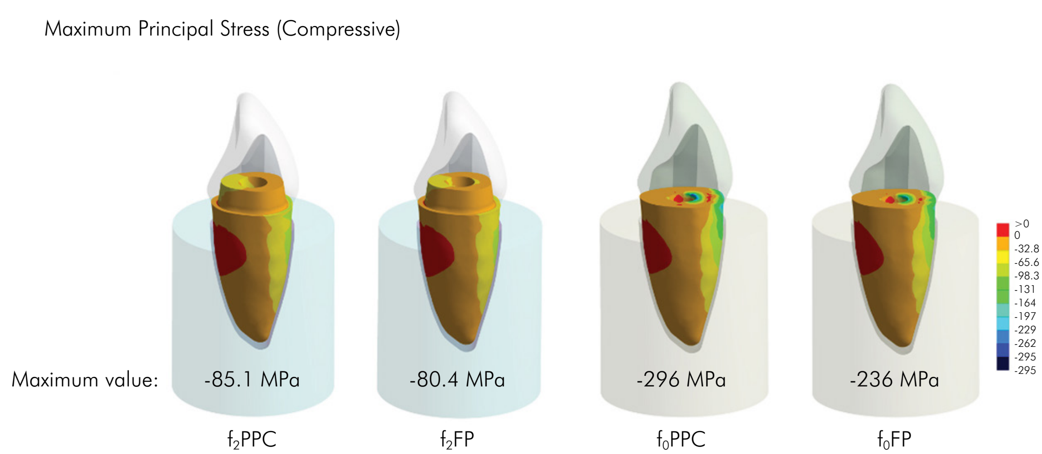


Figure 5. Minimum Principal Stress data demonstrating the effects on root surface caused by loading. f0FP: no-ferrule glass fiber post; f2FP: 2 mm ferrule glass fiber post; f0PPC: no-ferrule PEEK post-and-core; f2PPC; 2 mm ferrule PEEK post-and-core.

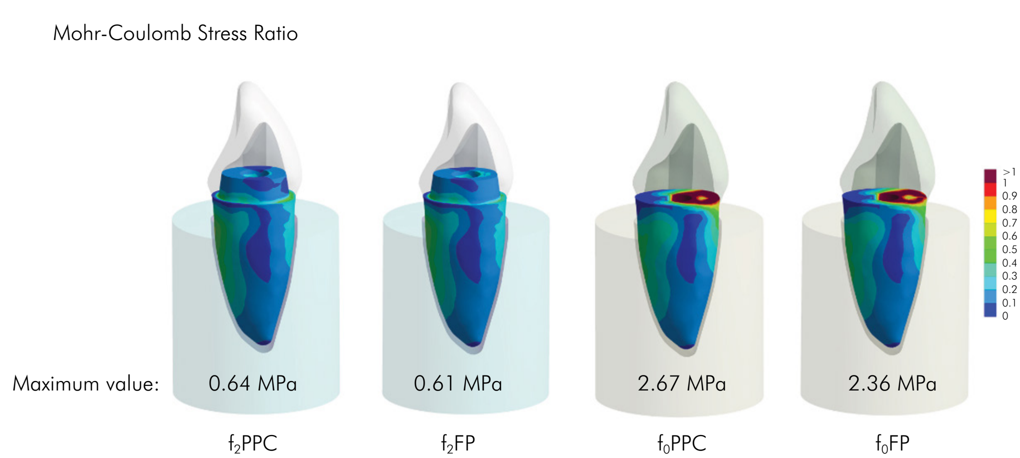


Figure 6. Mohr-Coulomb Stress Ratio data demonstrating the effects on root surface caused by loading. f0FP: no-ferrule glass fiber post; f2FP: 2 mm ferrule glass fiber post; f0PPC: no-ferrule PEEK post-and-core; f2PPC: 2 mm ferrule PEEK post-and-core.

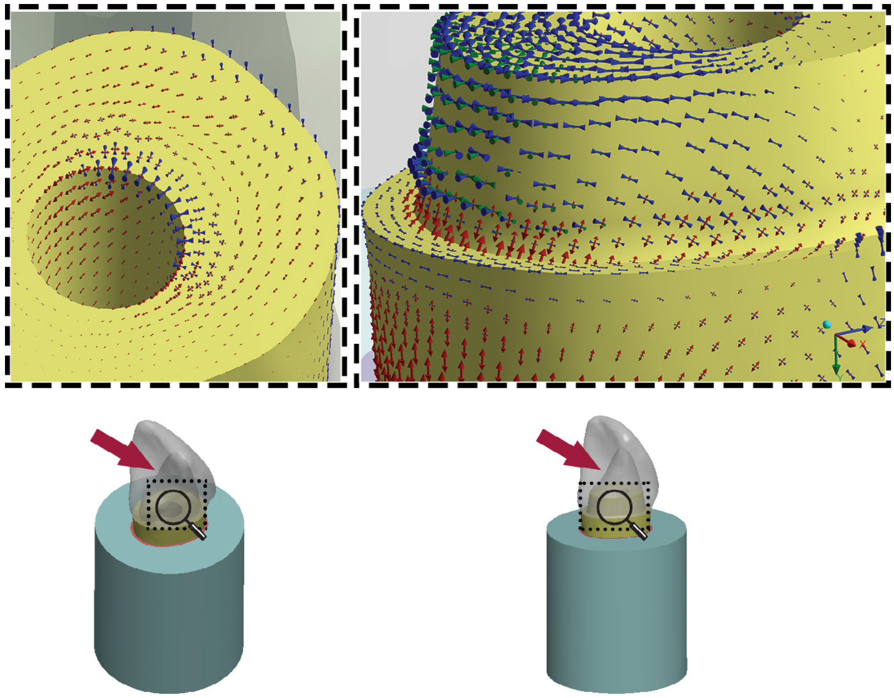


Figure 7. Stress vectors generated in FEA simulations with ferrule and without ferrule demonstrate the origin of the crack. Red vectors: indicates the maximum principal stress (the crack occurs perpendicularly to maximum principal vectors).

of the proximal faces (Figures 3 and 7). The vector size was proportional to the value of a crack, and the greater size vectors were located at the site and in the direction of the initial crack.

Discussion

The results of the present study suggest that the presence of a ferrule is fundamental for increasing the fracture strength of endodontically treated teeth, regardless of the type of post material. The tested hypotheses were that a) use of a single-piece post and core would compensate the absence of a ferrule, and that b) a PEEK post and core would improve the fracture resistance of endodontically treated teeth. According to the results found, both hypotheses were rejected.

The purpose of using posts is to provide retention to definitive restorations when endodontically treated teeth have lost much dental structure, and the remaining clinical crown is insufficient.[23,24] Preparation of the canal space, and the amount of coronal and root dentin remaining after root canal treatment, are important factors for the performance and longevity of the tooth and restorations.[25,26] The amount of remaining dentin after preparation is a more relevant factor influencing longevity than the type of post and core.[27] A 1.5–2-mm minimum dentin ferrule provides higher fracture resistance than no ferrule, and enhances the longevity of endodontically treated teeth restored with post and crown.[25,26,28] This improvement is enabled by the increased fracture resistance to any mechanism that increases the amount of energy required to propagate the primary crack.[29] A ferrule acts as an additional barrier that keeps the crack from propagating, and consequently increases the intrinsic resistance of the core.[30]

In the present study, the crack started in the region of highest stress concentration (tensile stress), and probably caused root fractures, as can be seen in Figures 4, 5, 6 and 7. In Figure 7, stress vectors evidently became dissipated throughout the inner dentine, and could not be detected clinically. Moreover, the inner dentin matrix adjacent to the root canal was less mineralized, and presented a high density of dentinal tubules.[29]. This could have led to higher susceptibility of the inner dentine, forming a crack initiation point.

Figures 4, 5 and 6 show that the strength concentration of the ferrule groups occurred next to the lingual face of the teeth, whereas that of the non-ferrule groups was in the internal region of the dentin, more precisely in the proximal areas (mesial and distal) of the teeth. Figure 7 corroborates this findings, showing the resulting strength vectors of tension and compression, where the red vectors (maximum principal stress) indicate the position of perpendicular cracks. This pattern could be also observed in the laboratory test, which showed the same initial crack position and the fracture displacement (Figure 3) for groups with or without a ferrule.

Furthermore, another important aspect observed was the primary adhesion failures that caused a gap and separation between crown and root[16,31] (Figure 3). An abrupt adhesion failure at the lingual margin was accompanied by a gap that opened between root and crown, then intensified, and eventually led to total failure.[31] In this respect, the FEA of this material can explain the differences and changes in adhesion and stress distribution along the root.[16] The initial adhesive gap gave rise to a fracture along the stress vectors shown in Figure 7. In the teeth with a ferrule, the fracture started and propagated in a region nearest to the lingual face, in contrast to the teeth with no ferrule, where the fracture initiated and propagated in the central region of the proximal faces (Figure 3). This occurred because of the changes in tooth strength concentration with and without a ferrule.

The present study observed 100% of catastrophic failures (fractures reaching the middle and apical root thirds), regardless of the post material. These results were expected because of our experimental design, which used metal crowns to keep crown material fractures from interfering in the results of the intraradicular posts. The results herein show that the presence of a ferrule causes a more catastrophic fracture mode (Type 3 and 4 were more frequent – Figure 2) than the absence of one (Type 1 and 2 were more frequent – Figure 2). Nevertheless, the fracture resistance was highest for teeth with a ferrule (Table 2).

It is worthwhile mentioning that the amount of energy needed to cause the catastrophic failures in the ferrule groups herein was about 796.72 N (Table 2). A previous study reported that the mean bite strength for men is about 304.9 N, and 284.9 N for women,[32] whereas the mean bite strength of a patient with a parafunctional nocturnal clenching and gnashing habit is 795.7 N.[33] This reinforces the importance of a ferrule for teeth that require post-and-core treatment, and also points out that the catastrophic failures for the ferrule groups herein occurred under extremely specific situations, in which there was a parafunctional habit. Caldas et al.[16] found results similar to those herein, in relation to the presence or absence of a ferrule, and also confirmed that there was an increase in fracture resistance in the ferule groups. Thus, groups with a ferrule presented greater fracture resistance, and delayed onset of fracture, but the final crack was more catastrophic, because of the accumulated strength concentration until failure. These findings are in accordance with a previous study[29], in which detected failure modes tended to be more favorable when little or no core buildup was used.

Although FEA indicated that PEEK post and core presented higher stress values than glass fiber posts, fracture resistance data revealed that no relevant statistical differences were observed among the retainer materials (Table 2). This may be related to the high resistance properties of PEEK[9,34], even though it presents a lower elasticity modulus than glass fiber posts, thus warranting rejection of the second hypothesis. Even so, from a clinical point of view, the fact that PEEK is easier to use and has a shorter core production time makes it more advantageous to use.

The elastic modulus of an intraradicular post is associated with the stress transmitted to the root. This has been reported as one of the most important factors of the fracture mechanism.[35,36] Materials having an elastic modulus more similar to that of dental structures have lower interface stress, thus minimizing stress transmission to root walls, and allowing the restored system to mimic the mechanical behavior of a natural tooth.[37,38] The elastic limit of a post can be influenced by many factors that modify stress distribution and fracture resistance, including the composition and diameter of the material.[39]

In this study, the increase in the intraradicular diameter of the glass fiber posts relined with resin composite did not significantly influence the fracture resistance of endodontically treated teeth. This finding corroborates that of a study by Farina et al.,[37] which described dentinal wall thickness as an important factor for fracture resistance, but one with no significant influence on relined posts.

Although there are several studies[11] indicating that anatomical posts have a great influence on retention and push-out bond strength, not much is known about the fracture resistance of relined or non-relined posts. The lack of statistical differences between relined and non-relined posts in the fracture resistance tests reported herein can be attributed to the similar elastic modulus between resin cement and resin composite. The relining procedure increases post adaptation to the root walls, and decreases the amount and thickness of resin cement around the fiber post, thereby improving frictional retention and reducing blister formation.[37,40] However, these techniques are not easy to perform, and require more clinical time than what is required for conventional fiber post cementation.

Thus, experimental, milled materials might reduce laboratory and chairside time. The development of scanning technology could allow dental professionals to obtain 3D virtual images by rapidly scanning the root space, and then produce an intraradicular post and core using CAD/CAM. In turn, CAD/CAM technology could create a single-piece post and core structure that would fit any tooth. In addition, the possibility of milling both the post and core would simplify the technique by eliminating use of the composite resin needed to build up a resin core.[23,41]

Therefore, application of CAD/CAM technology to produce anatomic prefabricated custom intraradicular retainers seems to be a viable option. This technique could provide a cement layer of minimum thickness, and eliminate having to bind a composite resin adhesively in order to build up an adequate core to aid in retaining the restoration. The monolayer intraradicular retainer system[41] thus created could promote greater longevity of the rehabilitation procedure, enabled by the absence of interfaces. Hence, the intraradicular PEEK post and core provided a fracture resistance result similar to that of the glass fiber post. However, more laboratory and clinical research must be conducted to validate the conclusions on using intraradicular PEEK post and cores.

Conclusion

The results obtained by laboratory tests and finite element analysis led to the following conclusions:

a. The PEEK post and core retainer did not modify the fracture resistance of endodontically treated teeth.
b. The presence of a ferrule provided higher fracture resistance to endodontically treated teeth restored with a post and crown, but induced a more catastrophic failure mode than teeth with no ferrule.
c. Results of the finite element analysis indicated that the initial crack position is influenced by the presence or absence of a ferrule.

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