

Original Article

Fracture resistance of polyetheretherketone, Ni-Cr, and fiberglass postcore systems: An *in vitro* study

Hossein Pourkhalili¹, Donya Maleki²

¹Department of Prosthodontics, Dental Sciences Research Center, Faculty of Dentistry, Guilan University of Medical Sciences, ²Department of Prosthodontics, Student Research Committee, Faculty of Dentistry, Guilan University of Medical Sciences, Rasht, Iran

ABSTRACT

Background: It is unclear which the material is a better choice for post and core rehabilitation systems in endodontically treated teeth. This study aimed to compare the fracture resistance of three different postcore systems.

Materials and Methods: In this *in vitro* study, 33 extracted premolars were treated endodontically and divided into three groups, namely (A) the prefabricated fiberglass postcomposite core, (B) the Ni-Cr cast postcore, and (C) the polyetheretherketone (PEEK) postcore groups. After postcementation, the core was restored with Ni-Cr crown. By a universal testing machine, the fracture resistance of the posts was assessed. Furthermore, types of fractures were determined with radiography and confirmed objectively by cutting the acrylic resin boxes. The data of the fracture resistance were analyzed using the one-way ANOVA and Tukey test, and the data of the fracture pattern were analyzed using Fisher's exact test ($P < 0.05$).

Results: The fracture resistance was significantly higher in Group B (Ni-Cr) than in Group C (PEEK) ($P = 0.001$) and Group A (fiberglass) ($P < 0.001$). Moreover, the fracture resistance was higher in Group C (PEEK) than in Group A (fiberglass) but was not statistically significant ($P = 0.405$). The fracture pattern was different in all the groups based on the types of fracture ($P = 0.009$) and the reparability of fracture ($P = 0.036$).

Conclusion: The present study showed that the fracture resistance was significantly higher in the Ni-Cr post than in the fiberglass and PEEK posts. Further, the fracture mode was more repairable in teeth restored with the PEEK post, as compared to the other posts.

Key Words: Bicuspid, Fiberglass, Polyetheretherketone, post and core technique

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Address for correspondence:

Dr. Donya Maleki,
Dental Faculty of
GUMS Complex,
Fuman-Saravan Ring
Road, Rasht, Guilan, Iran.
E-mail: donyamaleki93@
gmail.com

INTRODUCTION

The destroyed coronal portion of endodontically treated tooth, which is unable to support the restoration, needs either a prefabricated or a custom-made postcore system to reconstruct the lost structure for long-term clinical success.^[1-4] The actual challenge begins by choosing the right material^[5] as

a wrong choice can cause a catastrophic fracture and tooth extraction at the end.^[5-7] In past years, different materials have been studied such as metal alloys, fiberglass, and zirconia. Galvanic corrosion, metallic taste, and allergic reaction can be considered the disadvantages of metal.^[8] Moreover, the significantly

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different elastic modulus (EM) between metal and dentine results in imposed stress on teeth.^[9] On the other hand, fiberglass has lower EM than metal, but it is still three times more than dentin. Moreover, fiber postdebonding is the main reason for reported fiberglass post failures.^[10,11] Zirconia is one of the best materials proposed recently in dentistry. The debate over root fracture due to zirconia high EM has been highlighted in previous studies.^[7,12] Clinicians still have hope to introduce a substance with favorable properties. Polyetheretherketone (PEEK) as a polyaryletherketone family member has similar abrasion resistance to metal,^[13] low solubility^[14], biocompatibility, and low EM (3 – 4 MPa);^[13,15] it also has a tooth-colored appearance and a practical application in radiography.^[15,16] Low EM leads to reduction of fracture risks by impressive stress relief. Moreover, carbon amplification can reinforce the EM of PEEK to be closer to that of dentine.^[5,13,17] All these properties lead to the wide application of PEEK in fields such as orthodontic wires, implants, crowns, bridges, and removable prosthesis frameworks.^[13,14,16] Using resin composites and ceramics accompanied through PEEK is not only acceptable but also necessary in the esthetic zone to overcome the limitations of PEEK (low translucency and grayish shadow) which is a challenging step.^[15,18] Studies have compared posts fabricated with fiber composite, zirconia, gold, and quartz fiber.^[1,5] However, no study has ever evaluated possible preferences of the PEEK post over the mentioned substances. In this regard, clinicians' wrong decisions about designing posts or choosing the best material result in catastrophic damages like root fractures or tooth extraction.^[5-7] Thus, attempts are required to find new substances with optimal characteristics. This is why it is of fundamental importance to study PEEK as a unique polymer gaining growing interest so that its superiorities in comparison with other materials can be highlighted. This *in vitro* study aimed to compare the fracture resistance of three postcore systems reconstructing endodontically treated teeth. Based on our hypothesis, the fracture resistance was significantly different in the three systems and the PEEK post and core led to more favorable fracture.

MATERIALS AND METHODS

Approval code for this *in vitro* study was obtained from Ethics Committee (IR.GGUMS.REC.1398.504).

Thirty-three premolar teeth were selected based on:

Inclusion criteria: (1) extracted for orthodontic and periodontal reasons, (2) intact crown (no root canal therapy, restoration, crack, amelogenesis imperfecta, or decay), (3) single and straight root canal, (4) mature root (close apex), (5) similar shape and size, and (6) root diameters being almost equal at the cemento-enamel junction (CEJ).

Exclusion criteria: Fracture of teeth in any step.

All the preparation steps were performed by one of the researchers to avoid any operator errors. The specimens were cleaned from blood and debris, and then, were conserved in normal saline. The prepared teeth were mounted in cold cure acrylic resin (Acropars, Marlic Medical Industries Co., Tehran, Iran) in wax boxes to consider the centering of the tooth (an interval of 5 mm from the tooth to the walls). The resin was extended up to 2 mm below the CEJ to reconstruct the biological width. A notch was embedded using a bur on the buccal wall to guide the insertion of the index in the next steps.

From each specimen, an index covering the tooth and notch was prepared using additional silicon with putty consistency (Bonasil, DMP Dental Industry, Greece) for the wax-up step.

After primary radiography, the anatomic crown was cut up to 2 mm above the CEJ with a diamond disk flushing with cold water.

The teeth were treated using the step back approach measuring the working length from the reference point to 1 mm above the radiographic apex. The cleaning and shaping were performed (master apical file = 30) using K and H files (Mani, Japanese), size-3 pizorimer drills (Dentsply-Maillefer Instruments SA, Ballaigues, Switzerland), and 5.25% sodium hypochlorite. The canals were obturated with gutta-percha cones (ARIA DENT, Asia Chemi Teb Mfg. Co, Tehran, Iran) and a sealer (AH26, Dentsply, detrey, Kon-stanz, Germany) using the lateral condensation method (accessory gutta-percha cones = 15). To regain the postspace, two-thirds of the obturation was removed, and a 0.6 mm wide chamfer finishing line was prepared.

The teeth were divided into three groups of 11 using the stratified random allocation rule, and each group received different treatment: (a) a prefabricated post with a composite core, (b) A Ni-Cr custom post and core (Veroband, America), and (c) a PEEK custom post and core (Beredent, Germany).

For the Group A, prefabricated posts were covered with silane (Silano, Brazil) for 60 s and then were dried. The canals were rinsed with 0.5% hypochlorite and water. After drying, the posts were cemented using the panavia F2 resin cement (Panavia F2.0, Kuraray Medical Inc., Okayama, Japan) following the manufacturer's instructions, and the excess was removed. The cores were formed by hybrid resin composite incrementally (Tetric Ceram, Ivoclar Vivadent, Amherst, NY) so that the clearances of 1.5 mm and 1 mm cusps could be observed for functional and nonfunctional based on the prepared indexes.

For the Groups B and C, the post and core patterns were fabricated with auto-polymerizing acrylic pattern resin (Duralay, Reliance, Dental Mfg Co., Worth, Ill, Japan), and the acrylic core was formed according to the silicone index so that the functional cusp had 1.5 mm and the nonfunctional cusp had 1 mm clearance. In the Group B, the patterns were invested and cast in Ni-Cr alloy (Verabond, Aalba Dent Inc., Cordelia, CA). Moreover, the patterns in the Group C were processed using the heat-press approach. Thereupon, the cementation was performed as in the Group A. The excess cement was ingathered through brushing.

After preparing an acrylic tray for each specimen, an impression was made with additional reaction silicon using the two viscosity two impression putty extra-light technique (Bonasil, DMP Dental Industry, Greece) and poured using the type IV stone.

The wax-up was done, and Ni-Cr crowns were reconstructed on the basis of indexes. Then, they were cemented using a zinc-phosphate luting agent (Master-Dent, Dentonics, Monroe, NC, USA) with finger pressure.

Assessment of the fracture resistance

all the specimens were tested with a universal testing machine (STM-250, Santam, Tehran, Iran). A 4-mm spherical indenter was positioned to load the force in the central fossa of the teeth with an angle of 135 degrees to the long axis with a speed of 0.5 mm/min until a visual or an auditory fracture occurred [Figure 1]. The applied force being recorded at MPa had a drop at this moment in the force-time diagram. Eventually, the fracture pattern was checked with radiography and confirmed objectively by cutting the acrylic resin boxes using burs. Six patterns occurred:



Figure 1: Specimen setting on the universal testing machine.

- I = Interface de-bonding
- II = Post or core fracture
- III = Root fracture in the cervical third
- IV = Root fracture in the middle third
- V = Root fracture in the apical third
- VI = Vertical root fracture.

The first three patterns were repairable, but the last three were classified as nonrepairable fractures.

Data analysis was performed using the SPSS software version 21(IBM Crop., Armonk, NK, USA). The normal distribution of the fracture resistance variable in the subgroups was measured using kurtosis, skewness, the Q-Q plot chart, and the Shapiro – Wilk test. Then, considering the normal distribution of the fracture resistance variable in the subgroups, the mean and standard deviation (95% confidence interval) along with minimum and maximum values were used to describe the distribution. Moreover, one-way ANOVA and Tukey test were used to compare the fracture resistance between the three different post and core systems. Finally, Fisher exact test was used to compare the fracture patterns of the teeth. Statistical significance was set at $P < 0.05$.

RESULTS

In the present study, the Ni-Cr post and cores showed the highest fracture resistance value (1248.35 N), while the fiberglass posts with composite cores presented the lowest resistance value (668.25 N). The mean fracture resistance for the PEEK post and cores was reported as 811.30 N. As examined using ANOVA and Tukey test, these differences were statistically significant in the Ni-Cr post and cores in comparison with the other two groups ($P < .001$).

However, the higher value of the fracture resistance in the PEEK group compared with the fiberglass posts with composite cores was not statistically significant ($P = 0.405$). The confidence interval was 95% in this study [Table 1].

In seven cases of the PEEK group, a root fracture was observed in the cervical third. However, of the other four cases in this group, one half had a root fracture in the apical third, whereas the other half had a vertical fracture. In the Ni-Cr group, the vertical root fracture was the main fracture pattern, as observed in nine cases. Moreover, one root fracture occurred in the middle third and one occurred in the cervical third. Eventually, among the fiberglass posts and composite cores, the vertical root fracture was dominant. Accordingly, three cases had root fractures in the cervical third, two cases had fractures in the middle third, and one case showed interface de-bonding [Table 2].

For the PEEK group, most of the fractures were repairable, unlike in the Ni-Cr group where most of cases were non-repairable. In addition, almost one third of the fiber cases were confirmed to be repairable [Table 3].

DISCUSSION

This *in vitro* study investigated the fracture resistance of Ni-Cr, fiberglass, and PEEK postcore systems prepared for endodontically treated premolars with full-metal crowns and their fracture patterns. The null hypotheses were that the fracture resistance

was significantly different in the three systems and the PEEK post and core led to more favorable fracture. According to the statistical analysis, the null hypotheses were accepted in some aspects.

Based on the results of this study, the fracture resistance of Ni-Cr alloy was significantly higher than that of fiberglass and PEEK. This is confirmed in studies by Fokkinga *et al.*,^[19] Maroulakos *et al.*,^[1] and Zhou and Wang.^[20] Further, Sadeghi^[5] determined a higher failure load for cast posts compared to zirconia and quartz fiber posts in maxillary canines.^[5] To fabricate a metal post, a custom acrylic resin pattern is necessary, which provides a better adaptation compared to a prefabricated fiberglass post.^[5] As well the casting postresin bond is stronger than the fiber postresin bond.^[5] These factual claims may be the reasons for the findings of these studies.^[1] Controversially, Habibzadeh *et al.*^[7] believed that the fracture resistance of fiberglass posts was higher than that of casting Ni-Cr posts, although it was not statistically significant.^[7] The authors asserted that dentine-like EM and bonding capacity to dentin were the possible causes.^[7] Along with this statement, previous investigations claimed that fiberglass posts failed in greater load in comparison with stainless steel (SS) posts because the SS post would absorb stress instead of scattering it to surrounding surfaces.^[21] This biomechanical behavior of fiberglass is an account of their dentine-like EM executing de-bonding of the post while the stress distribution property of metal posts causes root fracture.^[11]

Table 1: Fracture resistance (by ANOVA)

Post	Average within each groups (MPa)	Comparison between groups				
		Groups	Average different (MPa)	CI	P	F
PEEK	811.30	Ni-Cr	-437.05	-707.68–166.41	0.001	15.157
		Fiberglass	143.05	-127.59-413.69	0.405	
Ni-Cr	1248.35	PEEK	437.05	166.41-707.68	0.001	<0.001
		Fiberglass	580.10	309.46-850.74	<0.001	
Fiberglass	668.25	PEEK	-143.05	-413.69-127.59	0.405	<0.001
		Ni-Cr	-580.10	-850.74–309.46	<0.001	

PEEK: Polyetheretherketone, CI: Confidence interval

Table 2: Comparison of fracture pattern divided into 6 part

Post	Interface de-bonding (n)	Post/core fracture (n)	Root fracture in the cervical third (n)	Root fracture in the middle third(n)	Root fracture in the apical third (n)	Vertical root fracture (n)	Fisher’s exact test (P)
PEEK	0	0	7	0	2	2	0.009
Ni-Cr	0	0	1	1	0	9	
Fiberglass	1	0	3	2	0	5	

PEEK: Polyetheretherketone

Table 3: Comparison of fracture pattern based on repair-ability

Post	Repairable (n)	Nonrepairable (n)	Fisher's exact test (P)
PEEK	7	4	0.036
Ni-Cr	1	10	
Fiberglass	4	7	

PEEK: Polyetheretherketone

In the current study, the fracture resistance of PEEK was higher than that of fiberglass, although the difference was not statistically significant. As PEEK has excellent mechanical characteristics, it is a newly recommended material in the prosthodontics field.^[22] Tekin *et al.*^[23] proposed the use of PEEK in dental posts to reconstruct endodontically treated teeth. In a study on properties of polyetherketoneketone (PEKK) as a member of the same family as PEEK, it was reported that the PEKK post and core had the highest fracture resistance in comparison with gold and fiberglass posts.^[9]

In the PEEK group, the most frequent fracture was the root fracture in the cervical third. Lee *et al.*^[9] reported that the PEKK postdisturbed stress better than gold and fiberglass posts, leading to postdebonding instead of root fracture.^[9] Based on this study, the cervical half of the root was suffering the most pressure compared to the other part of the post.^[9] A root fracture is the most serious reason for casting postfailure since these posts are essentially rigid and have physical properties, leading to inappropriate stress distribution.⁵ The results of the current study support this statement that the root fracture mainly vertically is the only proof of Ni-Cr postfailure. Moreover, Sadeghi^[5] evaluated that 92% of Ni-Cr posts cause tooth fracture, while all zirconia and quartz fiber posts with composite cores have core breakdown.^[5] In Maroulakos *et al.*'s study,^[1] similar results were obtained in groups of gold and titanium posts.^[1] Fiberglass posts offer acceptable esthetics results as well as a low chance of root fracture.^[5] However, the most frequent fracture mode observed in fiberglass posts in this study was vertical root fracture. Some reports considered postdebonding as a dominant cause of failure,^[1,24] while others experienced no postdebonding.^[5,25] The result of this study supports Gbadebo *et al.*'s report determining that only a single fiberglass postfaced adhesive failure.^[25] The reason is the use of dual cure resin cement in both studies, which has great retention and admissible fracture resistance.^[25] Sadeghi^[5] showed composite core fracture and no postdebonding for

all specimens treated with zirconia and quartz fiber posts, while separation of crowns was the prevalent destruction of fiber postgroups in Habibzadeh *et al.*'s study.^[5,7] The difference may result from the fact that crowns in Sadeghi's study^[5] were not reconstructed and thus loading was directly applied to cores.^[5] In this study, it is found that the fracture pattern in the fiberglass group was mostly nonrepairable. However, Akkayan and Gülmez,^[26] Sadeghi,^[5] and Zhou and Wang^[20] concluded that fiber posts made a suitable fracture that had the chance of restitution.^[5,26] This is in accordance with Rezaei *et al.*'s study^[2] stating that all breakdowns of fiber posts are restorable.^[2] The reason is the perception of the EM-pattern of fracture relation.^[20] A higher EM leads to a more severe fracture.^[20] The present study also demonstrated that a great portion of Ni-Cr postfailure is dedicated to catastrophic failures. This is confirmed by Rezaei *et al.*^[2] who reported the statistical data of 58% of the same failure in Ni-Cr posts and also by Zhou and Wang.^[2,20] Although the nonmetallic color of PEEK is preferable, some papers reported a tooth-colored aspect with a grayish shadow.^[15,16]

In some studies, an admitted solution to overcome this shade was an accompaniment of resin composites and ceramics.^[15] However, other studies believed that the gray-beige shade was well-favored.^[27,28] Moreover, radiographic appearance is acceptable, despite being radiolucent.^[27]

Leakage as a result of dental material's shrinkage and tooth fracture as a result of substance's expansion are related to their thermal characteristics, which can cause the postcore system to have a disastrous failure.^[29] However, as PEEK has excellent thermal properties, clinicians can count on its exclusivity.^[28] However, the stability of chemical and mechanical features of PEEK at high temperature due to its specific chemical structure enables both toleration of any sterilization methods (even the heat approach) and exemplary processability.^[23,28,30]

No study showed a toxic or mutagenic trait for PEEK, confirming its great biocompatibility.^[23,28,31] Because of the positive property of PEEK, it is applicable for metal allergy cases.^[28] On the other hand, low density, persistence to chemical agents, nonimmunogenic features, and bone-like mechanical performance make PEEK an option for craniomaxillofacial reconstruction surgery.^[31] The PEEK tensile property is another reason to motive clinicians to choose PEEK.^[28]

This survey has some limitations. The periodontium was not reconstructed by silicone polymer on surfaces of roots thus; the forces were directly inserted in acrylic resin. Furthermore, the *in vitro* nature of this study is one of its limitations and that is why this study suggests evaluating the behavior of PEEK under dynamic load to simulate the masticatory forces of humans. Furthermore, more studies should assess the efficacy of PEEK post and its fracture resistance in different levels of the remaining structure of endodontically treated tooth.

CONCLUSION

The following conclusions were obtained:

1. The Ni-Cr post and core group had the significantly highest fracture resistance
2. The failure load of the PEEK post and core group was greater than that of the fiberglass group, but it was not statistically significant
3. The main fracture mode in the Ni-Cr and fiberglass post and core groups was vertical root fracture, while cervical third root fracture was more common in the PEEK group
4. The mode of failure was mostly repairable in the PEEK group, unlike the other two groups.

Eventually, as PEEK had a moderate fracture resistance and the highest number of repairable fractures compared to the other two groups, it can be recommended as a material of choice with acceptable characteristics.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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