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Effect of Post Construction Alloy Type (NPG and Ni-Cr) and Cement Type on Fracture Resistance of Endodontically Treated and Restored Teeth by Cast Post-Core

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Objectives It is claimed that non-precious gold (NPG) alloys with a modulus of elasticity (MOE) very close to that of dentin can enhance the fracture resistance of endodontically treated teeth. Since limited studies have been conducted on these alloys, in this study, we tried to investigate the effect of cast alloys with MOE close to that of dentin and resin and zinc phosphate cement on the fracture resistance of endodontically treated teeth.

Methods Forty mandibular single canal premolar teeth were assessed. The samples were randomly divided into four groups: Group A: Ni-Cr alloy + zinc phosphate cement, group B: Ni-Cr alloy + resin cement (Panavia® F2), group C: NPG alloy + zinc phosphate cement, and group D: NPG alloy + resin cement (Panavia® F2). The force needed for fracture and the fracture pattern of each tooth were recorded. The Shapiro-Wilk test was used to examine the normality of data distribution, Levene's test was used to examine the equality of variances, and Fisher's test was used to examine the equality of qualitative variables in the groups.

Results A statistically significant difference was observed between the two post-core construction alloys (P<0.0001) and also between the two types of cement used (P<0.001). However, the interaction between alloy and cement types was insignificant (P=0.144). NPG alloy and Panavia® F2 cement showed better results than the other groups.

Conclusion The NPG alloy + Panavia® F2cement technique is preferred in reconstructing endodontically treated teeth.

Keywords NPG alloy; Ni-Cr alloy; Zinc phosphate cement; Resin cement; Fracture resistance

Introduction

Dental caries, as a multifactorial chronic destructive lesion, causes the loss of dental tissue and damage to the pulp. The decision-making for endodontic treatment and tooth reconstruction as an abutment depends on some factors, including the amount of remaining structure, root morphology, and periodontal status of the tooth. [1-3]
Endodontically treated teeth face a higher risk of fracture than vital teeth, which can occur for various reasons, such as the loss of a large part of the structure, dehydration of dentin, and pressure imposed during the obturation process. [3] The most crucial factor in the fracture resistance of endodontically treated teeth is the amount of remaining coronal dentin after canal preparation. [1-3] Teeth with thin walls and highly widened canals due to extensive caries and excessive preparation cause restorative problems during the treatment. [3] In these teeth, crowns can maintain the tooth as the final restoration of the remaining tooth structure and help its rigidity. [4]
Currently, restorative techniques use an external element to support and hold the crown, which can be an interior canal post. [4] The interior canal post helps maintain coronal stabilization and anchorage in materials forming the core part. [4, 5] Choosing the proper post-core system is challenging and complicated due to some reasons as follows:

1- A Single post-core system cannot be appropriate for all situations.

2- The post-core types are so diverse in the market, making it difficult to choose among them.

3- There are only partially obvious biomechanical factors for evaluating different post-cores in various situations.

Some of the post's relevant efficiency factors are flexibility, stiffness, residual tooth tissue, lateral forces imposed on the whole post and tooth, and post-fatigue strength. [5] Cast posts are the gold standard in post-core restorations because they successfully reconstruct teeth with fragile structures. [4, 5] This type of post-core has no risk of post separation from the core due to being integrated. It appropriately matches the canal wall, allowing the forces to be correctly distributed on the tooth structure. [6]
The cast post-core construction materials play a vital role in force distribution in the tooth and the biomechanical performance of the endodontically treated tooth. [6] The post system can be supplied with various materials with different rigidity and modulus of elasticity (MOE). A post system with MOE close to dentin creates a uniform unit with better biomechanical performance. [6] The high MOE difference between post and dentin can be a source of stress for the root, increasing the likelihood of root fracture theoretically. [7] Ideally, the post construction material should possess MOE, compressive strength, and thermal expansion features close to those of dentin. [7] Some researchers propose using a post with a MOE higher than that of dentin (18 Gpa). Although metal cast posts are more resistant to fracture, they increase the stress on the root because of having MOE higher than that of dentin, while others believe that using a post with MOE similar to that of dentin has better outcomes. [7, 8] Fiber posts, a prefabricated post type, previously had the most similarity to dentin in terms of MOE. [8] NPG alloy

(non-precious gold) has MOE very close to that of dentin and is used in constructing cast post-core and various restorations and crowns. [8]

The presence of a stable cement between the canal wall dentin and the post is essential for the long-term success of the restoration. [9] A thin layer of cement can fill the extra space between the post and the canal wall dentin, leading to additional stress concentration on the cement during functional forces. [9] Cementing the post into the canal is crucial because the cemented post must have an appropriate seal and sufficient retention along the canal, which is achieved by enhancing the flowability and penetration of cement into the dentin inside the post space. [10] All posts are retained by being cemented into the root canal. [11] The ability of various types of cement depends on factors such as the mechanical features of cement, the ability to bond to both the post and dentin surfaces, the longevity of cement, and the adaptation of post to the canal space. [11] Close contact between the cement and dentin is essential to promote the frictional retention of the post. [12] Using posts along with cement and coronal restorative materials can induce an integrated structural and functional complex with the root dentin. [12]

Thus, numerous factors such as the amount of remaining tissue, the possibility of providing ferrule effect, the choice of prefabricated or cast post, the post material, shape, dimensions, MOE, and strength, cement type, the length of the remaining root, the patient’s occlusion and forces imposed on teeth generally affect the success level of endodontically treated teeth restored with post-cores and crowns. [1, 4, 7, 9, 10]

The current study aimed to investigate the effect of post and cement type on the occurrence and type of tooth fracture. The aim was to specify whether using NPG alloy, which is claimed to have MOE very close to that of dentin, could reduce root fracture in endodontically treated teeth.

Methods and Materials

This invitro experimental study was approved by the institutional ethics committee under the code IR.SBMU.RIDS.REC.1394.70. Forty healthy mandibular single canal premolar teeth were used in this study. The sampling method was the random sampling method. The number of groups was estimated based on pilot studies and similar articles to be four groups considering the 95% confidence level and the type I error equal to 0.05 (α = 0.05) using the PASS software (NCSS software), and ten samples were assigned to each group. Thus, 40 samples were investigated in this study.

Several human mandibular single canal premolar teeth extracted due to periodontal and orthodontic problems with similar root length and diameter were collected and disinfected by Chloramine T (%5) (Delmichimica® Scientific glassware, Naples, Italy). The teeth were kept in physiological serum (Razi Vaccine and Serum Research Institute) at room temperature during the collection process. Forty healthy, identical teeth were then selected, based on their mesiodistal and buccolingual dimensions measured by a caliper (Vernier®, China) with a 10% deviation from the mean size. [5] All the selected teeth were also examined for the lack of any cracks or fractures via direct observation and transillumination test by a single observer, and the observer was examined for validity and reliability. [11]

Then the teeth underwent prophylaxis to remove all the calculus and plaque from their surfaces. Moreover, the remaining periodontal fibers on the root surfaces were removed by a scaler (Dental USA Instrument, USA). The selected teeth were kept in normal saline at room temperature until the next stage of work.

Afterward, the teeth were decoronated by a diamond fissure bur (Kerr©, Germany) and a low-speed handpiece (NSK©, Japan). All teeth underwent root canal treatment using the step-back technique with 15-30 k-file (USA - lexicon Dentsply©) and gates glidden number 2 and 3 (USA- lexicon Dentsply©), one millimeter shorter than the specified root length. For irrigation, EDTA lubricant (Ultradent© product, USA) and sodium hypochlorite disinfectant (chloride V, Ultradent© product, USA) were used inside the canals. The canals were then dried out by paper points (gutta-percha, UK), and obturation was performed by the lateral condensation method using gutta-percha (gutta-percha, UK) and AH plus sealer (Dentsply©, USA). The canal taper was 5%.

Each tooth was mounted inside an acrylic block (acrylic rezinDey acryl autopolymerizing, GC, USA) so that 1.5 mm apical alignment of the tooth CEJ was placed outside the generator to detect the actual position of the tooth (long axis) in the bone. In order to create the post space, gutta-percha was removed by piezo number 1-2-3 (Roydent© Dental Products, USA) so that the post length would be three-quarters of the total root length. Further space preparation was also performed by reamer number 5 (Roydent© Dental Products, USA) (Figure 1).

Then, molding was performed from interior surfaces of the canal with the Acryl Gc pattern material (GC©, USA) using the direct method [1], and the post-core pattern was prepared accordingly (Figure 2).

Casting of the posts was performed under relevant laboratory standards. Twenty samples were cast by nickel-chromium alloy (VERA BOND II, Albadent©, USA) and 20 by NPG alloy (Albadent©, USA). The prepared posts were then placed inside the canals. A guiding groove was created on each post for cement removal and correct post seating.

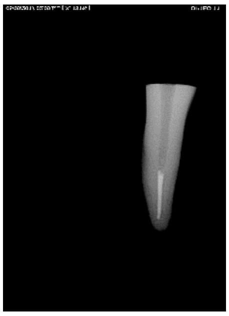

Figure 1: Radiograph of root canal treatment with the STEP-BACK technique and gutta-percha obturation and the post space created by piezo.

Figure 2: Moulding from interior surfaces of the canal by Gc pattern in groups 1 and 2 (right side) and groups 3 and 4 (left side)

Post seating was assessed using Fit Checker (GC©, USA). Early contact points were reformed with a bur, and the posts were placed into the canals uniformly. Post seating was also confirmed by radiographs (Figure 3). Then, the post-cores were cemented with finger pressure according to the intended groups in a back-and-forth manner. Ten samples of Ni-Cr posts were cemented with zinc phosphate cement (Hoffman©, Germany) and ten samples cemented with PANAVIA F2 (Kuraray©, Japan) resin cement (Table 1). Ten samples of NPG posts were cemented with zinc phosphate cement (Hoffman©, Germany) and ten samples cemented with PANAVIA F2 (Kuraray F2©, Japan) resin cement (Table 1).

Figure 3: Radiographs of posts' seating

Table 1- The investigated groups

Groups	Alloy and Cement Type
A	Ni-Cr alloy + zinc phosphate cement
B	Ni-Cr alloy + resin cement (Panavia F2)
C	NPG alloy + zinc phosphate cement
D	NPG alloy + resin cement (Panavia F2)

After 24 hours, the core part was finished with a diamond bur and an air cooler.

The prepared teeth were then placed into a retainer and transferred to the Universal Testing Machine. The 5 N/S force was imposed on the tooth buccal surface at an angle of 45 degrees with a speed of 1 mm/min. Afterward, the force needed to break each tooth was recorded in Newton (N). The tooth fracture pattern was observed in all samples, and a photo was taken of them (Figure 4).

Figure 4: (a) Vertical root fracture; (b) 1/3 apical root fracture; (C) 1/3 middle root fracture; (D) 1/3 cervical root fracture

The research data were entered into the SPSS software version 20 for statistical analyses. The Shapiro-Wilk test was used to examine the normality of data distribution, Levene's test was used to examine the equality of variances, and Fisher's test was used to examine the equality of qualitative variables in the groups. It is worth mentioning that the two-way analysis of variance was used to compare the mean quantitative variables, including the fracture resistance of endodontically treated and restored teeth. Also, Fisher's test was used to examine qualitative variables such as the fracture pattern of the samples. The fracture resistance values of the samples were calculated in different study groups using dispersion indices, including mean and standard deviation. At last, the data were analyzed based on the two-way analysis of variance (α=0.05).

Since the present research was conducted on extracted teeth in vitro, there was no special ethical consideration.

Results

This research investigated the effects of post construction alloy and cement types on the fracture resistance of endodontically treated and restored teeth by the cast post-core. Forty samples were assessed in this study in four groups (A-D); 20 posts were cast by Ni-Cr alloy and 20 by NPG alloy. Then, half of the posts were cemented with Panavia F2 cement and the other half with zinc phosphate cement.

Comparing Fracture Resistance Between Groups

The statistical indices of the mean and standard deviation of fracture resistance by the types of groups and cement type are presented in Table 2.

Table 2- The statistical indices of the mean and standard deviation of the fracture force of the endodontically treated teeth

Dependent Variable: Force				
Post Type	Cement Type	Mean	Standard Deviation	Number
Ni-Cr	ZINC PHOSPHATE	970.2100	129.65093	10
	PANAVIA F2	1319.2900	112.39824	10
NPG	ZINC PHOSPHATE	1476.0800	142.37117	10
	PANAVIA F2	1934.1200	58.09482	10

Generally, the mean fracture force with Ni-Cr post (using both cement types) was lower than that with NPG post (using both cement types). The mean fracture force of teeth using zinc phosphate cement (using both alloy types) was lower than that using Panavia F2 cement. The mean fracture force of teeth in Ni-Cr post using zinc phosphate cement was lower than that using Panavia F2 cement. The mean fracture force of teeth in NPG post using zinc phosphate cement was also lower than that using Panavia F2 cement.

Based on the Shapiro-Wilk test, the data in the investigated subgroups followed a normal distribution (P>0.05). The assumption of the equality of variances was confirmed in the investigated groups based on Levene's test (P=0.191). The two-way analysis of the parametric variance test indicated that the mutual effect between post and cement types was insignificant (P=0.144) due to P>0.05. However, post (P<0.0001) and cement (P<0.001) types significantly affected the fracture resistance of teeth.

Table 3 presents the Tukey honestly significant difference (HSD) test results. NPG post shows a higher mean fracture resistance.

Table 3- The Tukey honestly significant difference test

Groups		Mean Difference between Groups	Standard Deviation	Sig.	95% Confidence Interval	
					Low Level	High Level
Ni-Cr zin	Ni-Cr pan	-349.08000*	51.52052	.000	-487.8365	-210.3235
	NPG zin	-505.87000*	51.52052	.000	-644.6265	-367.1135
	NPG pana	-963.91000*	51.52052	.000	-1102.6665	-825.1535
Ni-Cr pan	NPG zin	-156.79000*	51.52052	.022	-295.5465	-18.0335
	NPG pana	-614.83000*	51.52052	.000	-753.5865	-476.0735
NPG zin	NPG pana	-458.04000*	51.52052	.000	-596.7965	-319.2835

The mean fracture resistance of endodontically treated and restored teeth by cast post-core in the four groups is depicted in Figure 1. The highest fracture resistance is related to NPG post and Panavia F2 cement, NPG post and zinc phosphate cement, and Ni-Cr post and Panavia F2 cement, respectively. The lowest fracture resistance is related to Ni-Cr post and zinc phosphate cement.

Comparing Fracture Modes Between the Investigated Groups

Various fracture modes are shown in Figure 4, none of which can be restored. Twenty-three cases of vertical root fracture (VRF) took place among the samples. Table 4 presents the distribution of fracture locations among the groups.

The most common fracture type was VRF (57.5%), and the least common was 1.3 cervical root fracture (2.5%).

Table 4- The fracture location pattern of the samples

		Fracture Location				Total
		1/3APICAL	1/3 MID	1/3 CERVICAL	VRF	
Ni-Cr zinc phosphate	Count	2	1	0	7	10
	% within groups	20.0%	10.0%	0.0%	70.0%	100.0%
Ni-Cr panavia	Count	2	2	1	5	10
	% within groups	20.0%	20.0%	10.0%	50.0%	100.0%
NPG zinc phosphate	Count	3	1	0	6	10
	% within groups	30.0%	10.0%	0.0%	60.0%	100.0%
NPG panavia	Count	3	2	0	5	10
	% within groups	30.0%	20.0%	0.0%	50.0%	100.0%
Total	Count	10	6	1	23	40
	% within groups	25.0%	15.0%	2.5%	57.5%	100.0%

Discussion

Endodontically treated teeth usually are more fragile than vital teeth due to losing their structure as a result of carious lesions, trauma, loss of pulp during the access cavity preparation in root canal therapy (RCT), dehydration of dentin, and loss of the tooth flexibility. [7] Moreover, the lack of a protective feedback mechanism after removing the pulp can be the main factor in the failure to restore endodontically treated teeth. [12]

Posts prepared by direct molding from inside wall of the canal can induce a good fit with the interior space of the canal. However, they only induce frictional retention, and lead to root fracture due to homogeneity dryness between metal and dentin. [11-13] The prevalence of fractures in endodontically treated teeth is still high, causing an irreparable condition (between 2-5%). [3, 7, 8]

Research suggests that 11-13% of extracted endodontically treated teeth have VRF. [10] The main reason for the fracture of endodontically treated teeth is VRF, and other reasons are improper sealing, leakage of oral fluid, and penetration of microorganisms into post marginal adaptation. [12]

Post-core systems include components with different rigidity. The most rigid component can resist forces without distortion; stresses are transferred to the material with the lowest rigidity and cause failure. The MOE difference between the dentin and post materials is a source of stress for the root structure. [10] In order to achieve appropriate results, the material used for post construction should have physical features similar to dentin [11] and, as a shock absorber, transfer limited stress to the remaining root structure. [12] Antony et al. believe that endodontically treated teeth without post-core are two times more resistant than post-core treated teeth [9], while Kumar et al. believe that endodontically treated teeth with or without post-core are in a similar status regarding fracture resistance. [10] Concerning the post material, some studies suggest that this factor does not affect the fracture resistance of the endodontically treated teeth. However, based on the results of the present study and several other studies, this hypothesis is rejected. In an article, Dutta et al. propose that the survival rate of the endodontically treated and restored teeth with different post-core systems will be very different and that there needs to be a consensus on the best technique and the best materials. [11] For example, in Habibzadeh et al.'s study, the highest rate of fracture was in fiber posts [12], while in Martins et al.'s [13] and Tsukahara et al.'s [14] studies, the highest rate of fracture was shown to be in metal posts.

The results of our research were in line with the results of Haghigi et al.'s study in 2014 [15] and Khalidi et al.'s study in 2015 [16], showing that the fracture resistance amount of endodontically treated and restored teeth by NPG and Ni-Cr post-core is significantly different. NPG alloy provides more resistance to the teeth. The mean fracture resistance of the tooth is 1476±142 N with zinc phosphate cement and 1934.1±58 N with Panavia F2 cement in NPG alloy and 970.2±129 N with zinc phosphate cement, and 1319.2±112 N with Panavia F2 cement in Ni-Cr alloy.

Nodehi et al. reported a success level of 90.6% for post-core treated teeth by NPG alloy after six years. [17] The high success level of NPG alloy can be attributed to the high similarity of its MOE with that of dentin. The exact MOE rate of NPG alloy is not available, but its difference with that of dentin is much smaller compared to the MOE difference between Ni-Cr alloy (200 Gpa) and dentin (18 Gpa). [14]

Cementing plays an essential role in distributing stress, filling disorganizations between the tooth and the post, and increasing retention [14]; the amount of post retention depends on cement strength and adhesive power. [15] Closer contact between cement and dentin types effectively promotes frictional retention. [14, 15] Cracks, micro-leakage, and coronal or apical fractures can be induced by pores and voids in the bonded post-dentin interface. [15] Self-adhesive resin types of cement have been introduced to the market because of their simple clinical process. These new systems creating bonding with a simple mechanism have led to eliminating the preparation stage and the use of acid etchant in dentin and enamel and also have solved the problem of dentin moisture. [18] Therefore, it is assumed that their usage reduces the likelihood of treatment failure. [18] The mechanism of these resin cements is based on micromechanical retention and chemical adhesion. [18] In this study, a resin-based cement manufactured by the Kurary factory in Japan called Panavia F2 and a common water-based cement called zinc phosphate were used and Panavia F2 cement had better results than the other type.

Moreover, in studies by Shafiei et al. [19] and Afkhami et al. [20], Panavia F2 cement was more successful than All Bond 2 (BISCO).

Similar to studies by Haghighi et al. [15], Kanduti et al.[21], and Thakur et al. [22], in the current study, premolar teeth were used because of the small cusps, smaller tooth structure, and increased need to receive post-core treatment.

Regarding the fracture location in the samples, it was found that the most common type of fracture was VRF. The higher prevalence of fracture types was reported to be VRF (57.5%), apical (1.3; 25%), middle (1.3; 15%), and cervical (1.3; 2.5%), respectively.

It has been shown in a study that 100% of cast post-core fractures occur in the root area [18], often appearing as VRF. An extremely high post MOE prevents post deformation, which induces a localized stress peak inside the root and its fracture. [18]

Retention and fracture resistance are two crucial factors that should be achieved by post-core restorations. Enhancing the retention accompanies the removal of the coronal structure, reducing root resistance. During post placement, the dentist should evaluate the status of each tooth separately and choose the best method to obtain the highest failure resistance level.

There are different post-core systems to gain the maximum balance between post retention and root fracture resistance, allowing the dentist to successfully restore most of the endodontically treated teeth under different conditions. [15]

<u>Suggestions for future studies</u>

1) Using mechanical and chemical surface preparations on the post surface
2) Evaluating the amount of fracture resistance in anterior teeth and post-core reconstructed molars
3) Evaluating the amount of fracture resistance in endodontically treated teeth with other types of cement
4) Using the crown on the post-core and imposing force on the post-core-crown and tooth complex
5) Performing the test after thermocycling
6) Performing the test along with periodontal ligament (PDL) simulation surrounding the tooth root using suitable resins
7) Using a control group without post-core, comparing the fracture resistance of the endodontically treated teeth without post-core and the teeth restored with and without post-core

<u>Limitations</u>

1. PDL simulation was not possible in the current study.
2. The samples might have different behaviors in both in-vitro and in-vivo studies.
3. Canal anatomy may affect fracture resistance.

Conclusion

NPG alloy showed significantly better results than Ni-Cr alloys in post-core construction.

Also, Panavia F2 was much more effective in increasing the resistance fracture of endodontically treated teeth than zinc phosphate.

Finally, the NPG alloy + Panavia F2 cement technique was the preferred technique in the restoration of endodontically treated teeth.

Conflict of Interest

No Conflict of Interest Declared ■

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