

# Effect of Noble Metal Alloy Post and Core Material on the Fracture Resistance of Endodontically Treated Teeth

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**Abstract** - The aim of this study was to investigate the effect of one particular brand of post and core system (ER Post) consisted of different post and core materials on the fracture resistance of endodontically treated teeth. Fifty caries-free maxillary central incisors were randomly assigned to five groups (n=10). All teeth were sectioned at the cemento-enamel junction except for the teeth in the control group. Four experimental groups consisted of cast gold post-and-core group (GG), Heraplat post/cast gold core group (HG), titanium post/composite core (TC), and titanium post/cast gold core (TG). The control group (ETT) consisted of endodontically treated teeth without posts. All posts were cemented in the roots with zinc phosphate cement. Following thermal cycling (5000 cycles between 5°C and 55°C with a dwell time of 30 seconds) a static load was applied to 2 mm below the incisal edge on the palatal surface of each specimen until they were fractured. Fracture data obtained and statistically analyzed with one-way ANOVA and a Tukey's test ( $p < 0.05$ ). Means of the fracture resistance during static loading were: 423.76 N (GG), 529.46 N (HG), 389.08 N (TC), 408.7 N (TG), 404.4 N (ETT, control). Heraplat post with cast gold core exhibited the highest fracture load than the other groups ( $p < 0.05$ ). Specimens in groups HG and ETT (control) showed the most repairable failure. Heraplat post with cast gold core had the highest fracture resistance of endodontically treated teeth.

KEY WORDS: endodontically treated tooth, metal alloy post, noble metal alloy, fracture resistance

## INTRODUCTION

Endodontically treated teeth often require partial or complete coverage restorations according to the amount of remaining tooth structure. Endodontic treatment is usually the consequence of caries followed by pulpal infection or traumatic damage to a tooth. Therefore, these teeth also suffer from loss of structural integrity, necessitating restoration of the tooth for aesthetic and functional rehabilitation.

It was believed that insertion of a post into an endodontically treated tooth reinforced and increased fracture resistance<sup>1</sup>. This concept is not supported by scientific studies and so has been rejected<sup>2,3</sup>. Posts should be used only to retain the core when there is not enough retention for the artificial crown<sup>2,3</sup>. Although the use of fiber-based posts is becoming more common, cast or prefabricated metallic posts are still used most widely<sup>4</sup>. Several types of metallic posts, both cast and prefabricated, such as titanium and gold alloy have been used in the clinical practice. Gold alloys have always been used in fabrication of custom cast post-and-core because of their superior success rate<sup>5</sup>. The main disadvantage of base metal alloy post-and-core is their corrosion. The corrosion products cause a change in volume that has been postulated to cause root fracture<sup>6</sup>. Cast post-and-core buildups are indicated in cases with massive coronal destruction of endodontically treated teeth,

especially when these are exposed to increased functional loading as anchors for further prosthetic replacement<sup>7</sup>.

Most popular is the use of prefabricated metal posts in combination with polymer core buildups e.g. composite, because they can be performed at chair-side during one appointment<sup>8,9</sup>. Individual metal posts-and-cores are manufactured in the laboratory<sup>8</sup>. One-piece post-and-core can be produced either by a single wax pattern of the root and core portion or by casting the metal core directly over a prefabricated metal post<sup>10,11</sup>.

The purpose of this in vitro study was to compare the fracture resistance of endodontically treated teeth received different noble metal alloy post-and-core restorations. The null hypothesis was that different post material would have no significant effect on fracture resistance of endodontically treated teeth with severe coronal destruction.

## MATERIALS AND METHODS

A total of 50 human maxillary central incisors free of cracks, caries and fractures were used in this study. All external debris was removed with an ultrasonic scaler and the teeth were stored in saline solution at 4°C and used within 3 months following extraction. Bucco-palatal and mesio-distal dimensions at cemento-enamel junction and root lengths of all teeth were measured with a digital caliper (Absolute Digimate Calipers), so that teeth of similar dimensions could be evenly distributed between control and test groups. Teeth with curved roots and wide or atypically shaped root canals, and/or roots shorter than 16 mm were excluded.

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Having standardized the post preparations, the previously recorded bucco-palatal and mesio-distal measurements taken at the cemento-enamel junction of each tooth were used to ensure that each of the five groups of 10 teeth had comparable dimensions. Groups, materials and their composition were given in Table 1. These five groups were then randomly assigned. Coronal sections of teeth were removed using low speed diamond saw (EXAKT Apparatebau) under water cooling at the level of the cemento-enamel junction and perpendicular to the long axis of the teeth except for the teeth in control group. The root canals were then shaped to size 60 using Hedström files (Dentsply Maillefer, Ballaigues, Switzerland). After irrigation with 2.5% sodium hypochlorite (NaOCl) the canals were dried with paper points (Roeko, Langenau, Germany). Each root canal was filled using lateral compaction method with gutta-percha points (VDW, Munich, Germany) and sealer (AH Plus; Dentsply, Konstanz, Germany). In the control group, the access cavity was filled with a single-dose dentine bonding agent (Excite DSC) and a fine hybrid composite (Tetric Ceram), polymerized separately for 60s (Optilux 500). The specimens were stored at 37°C in distilled water for 1 week.

Prior to post placement, gutta-percha was removed from the root canals with Gates Glidden burs, leaving 3 mm of root filling in the apical portion. The root canals were then prepared with a drill of the same diameter and shape as the posts that was available in the Komet ER post kit. A length of 12 mm was ensured for each post hole in each root canal. A 1 mm deep central inlay cavity was prepared in a rotation-protecting oval shape, leaving a minimum dentine thickness of at least 1.5 mm using a special drill 2.5 mm in diameter in ER post system. Root canal was roughened using the diamond roughening instrument of the post system (Fig. 1). The post spaces were then irrigated with 2.5% sodium hypochlorite intensively and dried with paper points. All teeth were restored by the same operator who is experienced in the field of restorative dentistry for more than 8 years (MT).

In group GG, prefabricated plastic post (Castpost) in the ER post kit was tried-in and seated into the root canal. A core pattern was built up with an autopolymerizing acrylic

resin (Pattern Resin LC). The acrylic patterns were prepared to the desired shape with a low-speed rotary instrument. A silicone stent was used during core build up for all teeth in all groups except for the teeth in control group to ensure standardized core size. The post-and-core patterns were then sprued, invested, and cast-on with a Type IV gold alloy (Degunorm). Investment was removed; all surfaces were carefully air-abraded. Gold alloy posts-and-cores were then cemented with zinc phosphate cement (PhosphaCem PL).

In group HG, gold alloy cores were cast on prefabricated gold posts (ER-Heraplat) for anchorage. Cores were modelled onto the posts according to the dimensions specified as in group GG with an autopolymerizing acrylic resin (Pattern Resin LC). The post/pattern assemblies were invested, and the cores were cast-on with a Type IV gold alloy (Degunorm). After being cleaned and air-particle abraded, the posts -and-cores were cemented as described in group GG. In group TC, after the try-in procedure of the titanium posts (ER Titanpost), the cementation procedures of the titanium posts were performed as mentioned in group GG. A dimensionally standardized core was built-up with a dual-curing composite core material (Rebilda DC) and an appropriate dentine bonding agent (Solobond Plus) according to the manufacturer's instructions by using the silicone stent used in group GG. Composite core material was not light-polymerized. In group TG, after the try-in procedure of the titanium posts (ER Titanpost), cores were modelled with an autopolymerizing acrylic resin (Pattern Resin LC) using a silicone stent used in group GG. Cores were then invested and casted with a Type IV gold alloy (Degunorm). After trimming and cleaning procedures titanium posts and gold cores were cemented as described in group GG.

Specimens were subjected to thermal cycling between 5°C and 55°C for a total of 5000 cycles with 30 s per cycle. Root surfaces were then marked 2 mm below the cemento-enamel junction to simulate the biologic width<sup>12</sup> and covered with wax in 0.3 mm thickness. Specimens were stabilized on a fixator (Herbst) with vertically moving rods, from the most coronal tip of each core, with sticky



**Figure 1.** ER post system. Cast prefabricated plastic post (A), titanium post for cast gold core (B), titanium post for composite core (C), Heraplat (D), drill for preparation of post space (E), drill for preparation of inlay cavity (F), roughening instrument (G).

**Table 1.** Groups compared in this study and composition of the materials.

Groups	N	Type of post	Composition (Per cent by weight) [batch number]	Core	Composition (Per cent by weight) [batch number]
GG	10	Cast gold alloy	Au (74), Ag (9), Pt (9) *14.1x10 <sup>-6</sup>	Cast gold alloy	Au (74), Ag (9), Pt (9) *14.1x10 <sup>-6</sup>
HG	10	Prefabricated gold alloy	Au (61), Pt (23.8), Pd (15) [204112] *14.1x10 <sup>-6</sup>	Cast gold alloy	Au (74), Ag (9), Pt (9) *14.1x10 <sup>-6</sup>
TC	10	Prefabricated titanium	Pure titanium [491112] *11.9x10 <sup>-6</sup>	Composite (Rebildi DC) *39.4x10 <sup>-6</sup>	Base: BisGMA, UDMA, TEGDMA, catalyst CQ, Amine, fillers Catalyst: BisGMA, UDMA, TEGDMA, catalyst BPO, fillers [421040]
TG	10	Prefabricated titanium	Pure titanium [61116] *11.9x10 <sup>-6</sup>	Solobond Plus	Solobond Primer: Maleic acid, hydrophilic methacrylates, polyfunctional monomers, acetone, water [411428]  Solobond Adhesive: Hydrophilic methacrylates, polyfunctional monomers, acetone [411427]
ETT (control)	10	-	-	-	-

\*Coefficient of thermal expansion

wax. Specimens were then embedded in autopolymerizing acrylic resin (Meliodent) surrounded by plastic mould. After the first signs of the polymerization, specimens were removed from the resin blocks, and the wax on the root surface was removed using a hand instrument. Polyvinylsiloxane impression material (Affinis) was injected into resin base, and the specimens were reinserted into resin base. Standardized silicone layers that simulated periodontal ligament were created<sup>13</sup>. All specimens were stored in a condition of 100% humidity at 37°C for 24 h prior to the fracture test. In order to distribute the force evenly and to avoid peaks a 0.3 mm thick tin foil was placed between the specimen and the loading die.

Specimens were mounted in a universal load-testing machine (Schimadzu AG-50 kNG) and were loaded until fracture at a cross-head speed of 0.5 mm/min. The force was applied with an angle of 135° 2 mm below the incisal edge on the palatal surface of cores using a steel ball with 6-mm diameter. Fracture loads were determined as Newtons, and the modes of fracture were also recorded and classified as repairable if located in the cervical third of the roots and catastrophic if located below<sup>13,14</sup> by visual inspection with the aid of trans-illumination. Fracture loads were analyzed by one-way ANOVA and a Tukey test to disclose statistically significant difference between groups (p<0.05) using SPSS/PC+, Version 15.0 for Windows.

## RESULTS

Mean fracture loads, and mode and distribution of fracture for all groups are summarized in Table 2. The highest fracture load was recorded for group HG (Heraplat/cast gold alloy core) at 529.46 N, followed by group GG (cast gold alloy post-and-core), group TG (titanium post/cast gold alloy core), group ETT (control), and group TC (titanium post/composite core) at 423.76, 408.7, 404.3 and 389.08 N, respectively. There were statistically significant differences among the groups according to one-way ANOVA ( $p=0.001$ ). Heraplat post with cast gold alloy core (group HG) showed greater fracture load than the other groups according to the Tukey's post hoc test ( $p<0.05$ ).

Titanium post/composite core (group TC) and cast gold alloy post-and-core (group GG) showed the most catastrophic failure. While only 1 specimen in group GG exhibited the root fracture, specimens in other groups showed no fractures at the root or post.

## DISCUSSION

In this study, extracted human maxillary central incisors were used for the preparation of the test specimens. Human teeth have been commonly used in several in vitro fracture resistance of posts studies<sup>13-15,16</sup>. The main disadvantage of using human teeth is their relatively large variation in size and mechanical properties<sup>17</sup>, often resulting in large standard deviations. In addition, dentinal changes can be caused by different water content, pulpal condition before tooth extraction, patient age, and composition of dentine. These variations can affect the fracture pattern during loading. On the other hand, plastic teeth can be standardized in size and material but do not properly simulate the modulus of elasticity and bonding properties of human teeth. In this study, special care was taken in the selection process of natural teeth in same size.

Posts having the same size and same shape as one particular brand of post and core system (ER Post) were used

in this study. They were cemented with the same luting cement. Teeth used in this study were sectioned 16 mm coronal to the most apical point, so post length for experimental groups was standardized. Special care was taken to standardize the dimensions of core. Thus, the effect of post material on the fracture resistance of endodontically maxillary central incisors was evaluated and any other variations were eliminated.

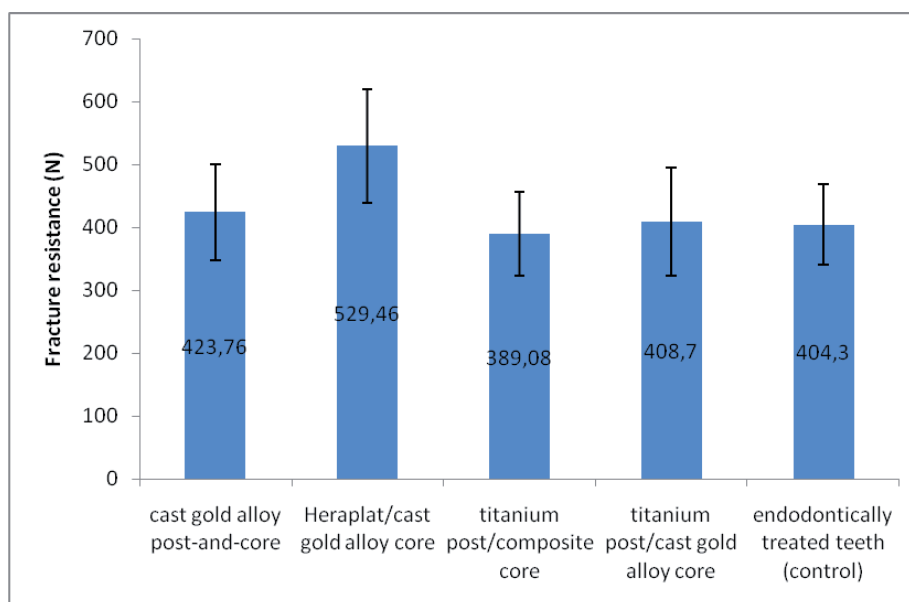
Coronal dentine above the shoulder significantly increased the fracture load of endodontically treated teeth received post-and-core restoration<sup>18-20</sup>. Natural teeth were sectioned

**Table 2.** Mean fracture loads, standard deviations, and mode of fracture of pulpless teeth.

Groups	Mode of root fracture	Number of crack/fracture propagation in roots		
GG	Cervical	3	Crack	9
	Middle	1	Fracture	1
	Apical	6		
HG	Cervical	8	Crack	10
	Middle	2	Fracture	-
	Apical	-		
TC	Cervical	2	Crack	10
	Middle	8	Fracture	-
	Apical	-		
TG	Cervical	6	Crack	10
	Middle	4	Fracture	-
	Apical	-		
ETT (Control)	Cervical	8	Crack	-
	Middle	2	Fracture	10
	Apical	-		

There were statistically significant differences among the groups according to one-way ANOVA ( $p=0.001$ )

Heraplat post with cast gold alloy core (group HG) showed greater fracture load than the other groups according to the Tukey's post hoc test ( $p<0.05$ )



**Figure 2.** Means and standard deviations of fracture resistance for all groups

at the cemento-enamel junction to simulate the substantial horizontal loss of the clinical crown in this study. In this situation, there is no alternative solution to fabricating a post-and-core build-up. The preparation of a post hole in an intact endodontically treated tooth may weaken such a tooth and it can be restored with filling material without post-and-core restoration<sup>2</sup>. Crown restorations were not performed since the ferrule effect would not be obtained. It is true that a crown creates a ferrule effect when placed over a core buildup if the margins encircle a sound dentine collar<sup>18</sup>. On the other hand, a clinician can create ferrule effect when there is tooth tissue above the preparation margin with ER Post system used in this study in the clinical situation. Loading was applied directly onto the core, as no crown was used in accordance with previous studies, for simplification purposes and to exaggerate the load effect on the tooth<sup>21</sup>. Tin foil was placed on the palatal surface of the core to standardize the surface that load applied. However, this might have affected the stress distribution within the tooth and thus the magnitude of fracture loads and the fracture modes of the specimens. Besides, core and remaining tooth structure are protected by the crown restoration in the clinical situation. The application of crown restoration decreased the effect of thermal cycling on various dental materials and tooth structure that have the different coefficient of thermal expansion.

Polymerization reaction of an autopolymerizing acrylic resin is an exothermic reaction. In the embedding process of specimens into the autopolymerizing acrylic resin, specimens were removed from the resin blocks after the first signs of the polymerization. Thus, the effect of heat of polymerization in dentine was eliminated. The heat generated may lead to decreased moisture content, crazing, and weakening of the specimen, which may indirectly affect the fracture resistance value<sup>2</sup>. It has been attempted to simulate the periodontal ligament by use of a low viscosity silicone impression material<sup>13,14</sup>. On the other hand, it was reported that the benefits of using such materials are questionable since the elasticity is different from that of the periodontal membrane and the elastic nature of the alveolar bone is not taken into account. The elastic modulus of silicone impression material used to simulate the periodontal ligament has a modulus that is much higher than periodontal ligament and the force was absorbed by the tooth tissue primarily, which may have resulted in a lower failure load than would be seen in vivo.

In this study, the teeth were loaded palatally at 135 degrees to the long axis. This angle reflects the positions, contacts and loading characteristics of maxillary central incisors in Class I occlusion<sup>13</sup>. Additionally, all specimens in this study were subjected to 5000 thermal cycling representing an aging of the bonding with approximately 6 months in vivo function<sup>22</sup>. This ageing technique induces stress to the post-and-core, luting cement, and the dentine/cement interface and cement/post interface. Stress concentration resulting in loss of adhesion between cement and post increases the risk of root fracture<sup>23</sup>.

Prefabricated gold alloy posts with cast-on gold alloy cores significantly increased the fracture resistance of endodontically treated teeth. Additionally, the most repairable root fractures were recorded in prefabricated gold alloy posts with cast-on gold alloy core and control groups. Cast gold post-and-core, titanium post/composite core and titanium

post/cast gold core did not increase the fracture resistance of endodontically treated teeth. The greatest number of catastrophic fractures was recorded for titanium post/composite core and for cast gold post-and-core. In an in vitro study<sup>24</sup>, similar results were found. This may be due to the intrusion of the air-bubbles into the casting during the casting procedure. This may weaken the cast post-and-core restoration; eventually decrease the fracture resistance of an endodontically treated tooth.

These results would be different using the different post system or different post shape as one particular brand of post system used in this study although different materials were used. In an in vitro study reported by Sahafi et al<sup>25</sup>, various post-and-core systems were intermittently loaded. It was concluded that the resistance to cyclic loading was higher for parallel-sided posts than for tapered posts that were performed with titanium and cast metal alloy.

## CONCLUSION

Prefabricated gold alloy post and cast-on gold core had the highest fracture resistance of endodontically treated maxillary central incisors with severe coronal destruction.

## MANUFACTURERS' DETAILS

- Absolute Digimate Calipers, Mitutoyo, Sussex, UK
- EXAKT Apparatebau, Norderstedt, Germany
- Roeko, Langenau, Germany
- VDW, Munich, Germany
- AH Plus, Denstply, Konstanz, Germany
- Email Preparator GS, Ivoclar Vivadent, Schaan, Liechtenstein
- Excite DSC, Ivoclar Vivadent
- Optilux 500, Demetron Kerr, Danbury, CT, USA
- Tetric Ceram, Ivoclar Vivadent
- Occlubrush, Kerr-Hawe, Bioggio, Switzerland
- Komet ER post kit, Komet-Brasseler, Lemgo, Germany
- Castpost, Komet-Brasseler
- Pattern Resin LC, GC Germany, Munich, Germany
- Degunorm, Degussa AG, Hanau, Germany
- PhosphaCem PL, Ivoclar Vivadent, Schaan, Liechtenstein
- ER-Heraplat, Komet-Brasseler
- ER Titanpost, Komet-Brasseler
- Rebuilda DC, Voco, Cuxhaven, Germany
- Solobond Plus, Voco
- Meliodent, Bayer Dental, Newbury, UK
- Affinis, Coltene Whaledent, Altstätten, Switzerland
- Shimadzu AG-50 kNG, Shimadzu Co., Kyoto, Japan
- SPSS/PC+, Version 15.0, SPSS Inc., Chicago, IL, USA

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