Original Article

Fracture Resistance of Titanium, Chrome–Cobalt, and Gold Alloy as Post and Core Materials: A Comparative Evaluation

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Aim: This study aimed to comparatively evaluate the fracture resistance of different metallic post and core materials. Materials and Methods: Twenty-four maxillary–central incisors were selected, standardized, and segregated into three groups (GP I–III) (n = 8) based on the type of alloy used for post and core preparation. GP I (gold alloy [Au]), GP II (chrome–cobalt alloy [Co–Cr]), and GP III (titanium alloy [Ti]) were comparatively evaluated for use as post and core materials. The teeth were endodontically treated and tooth preparation for post core was done. Metal post and cores were fabricated using indirect wax pattern and luted. Teeth were mounted on resin bases, fracture testing was done, and type of fractures were analyzed. Results: Mesiodistal type of fracture was the most common among experimental groups with a percentage incidence of 54.20%. The comminuted type of fracture was the next most common with a percentage incidence of 29.2%. The incidence of buccolingual, transverse, and other type of fracture was not common and had a percentage incidence of 29.2%, 4.2%, 8.3% and 4.2% respectively. Group II had the highest fracture resistance with a mean value of 742.89 N. Group III and Group I had mean values of 482.33 and 361.1123 N. Statistically significant difference between experimental groups (I and II) and (II and III) was observed in load values of root fracture (P < 0.05). Conclusion: On the basis of the protocols used and limitations of this study, among metallic post and core materials tested, GP II had the highest fracture resistance values. Further evaluation of these different post and core systems, new alloy formulations designed specifically for use as post and core materials, and assessment in a clinical setting is recommended.

Keywords: Chrome-cobalt alloy, gold alloy, metallic post and core materials, post and core, post-endodontic restoration, titanium alloy

INTRODUCTION

Excessive tooth structure removal and subsequent dehydration are responsible for affecting fracture resistance of restored tooth structure after endodontic therapy.¹ Resistance to fracture after endodontic therapy depends primarily on remaining dentin thickness, especially in a buccolingual direction.² Creation of excessive stress during obturation and use of higher concentration of irrigants with prolonged exposure times increase susceptibility of tooth to fracture, which reduces long-term survival rate, which is undesirable. Endodontic therapy should ideally

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Materials and Methods

Extracted permanent maxillary central incisors were cleansed, and analyzed using radiovisiography. Twenty-four teeth with mature, intact root apices were selected. Mesiodistal and buccolingual diameters at the level of cementoenamel junction were tabulated with digital vernier calipers. Samples were weighed using precision weighing scale, tested for normality, and were evenly distributed across three experimental groups (n = 8) and stored (4°C, normal saline) [Figure 1].

Access was done and 15K-file (Dentsply Maillefer, Ballaigues, Switzerland) was inserted passively in canal until tip was visualized and adjusted to apical foramen. Working length was calculated by subtracting 0.5 mm from the recorded value, and canal preparation was done to master apical file size 40 using hand files (step-back preparation). A 3% sodium hypochlorite (8 mL) as initial and 17% ethylenediaminetetraacetic acid (EDTA) (5 mL/3 min) final were used for irrigation. A post-final rinse of 5 mL of distilled water was done. Gutta-percha from canal was removed using Touch N Heat device (SybronEndo Orange, CA, USA), walls were cleared of sealer using Hedstrom files and size-1 Peeso reamer with care not to remove radicular dentin. A minimum apical seal of 5 mm was retained. Samples were assessed using radiovisiography for consistent finish and gutta-percha removal from canal.

Crown preparation was done using TF–12 flat-end tapered fissure bur (SS White burs) with a tip diameter of 1 mm, core ferrule was given using thin-tapered fissure burs. An anti-rotation notch was given for a depth of approximately 2 mm using flat-end tapered fissure bur on the thickest portion of root. Core height of all samples was standardized to 3 mm. Apical end of the post space preparation was assessed, gauged, and standardized to a specific width. The walls were cleansed, sealed with cotton plugs, and stored. Group I post and core wax pattern was fabricated using stainless steel sprue former (18 g) with medium inlay wax (dental inlay casting wax, GC, Newport Pagnell, UK). Subsequently after debubblizing and investing, pattern was cast (BEGO induction casting machine) with Au (20 carats) using a lost wax technique. In Group II, direct technique was used to fabricate post and core wax pattern using prepared sprue former (18 g) with a modeling wax (Geo Crowax; Renfert, Hilfingen, Germany). After debubblizing and investing, casting was done (BEGO induction casting machine, BEGO Bremer Goldschlägerei Wilh. Herbst GmbH & Co. KG, Bremen, Germany) with Co–Cr (Colado CC, Ivoclar Vivadent, AG, Principality of Liechtenstein) using lost wax technique. In Group III, root canal impressions obtained using direct wax patterns were scanned with digital scanner and a three-dimensional image was generated. Post and core was then fabricated using a laser sintering process for Ti (SISMA MYSINT 100, laser metal fusion).

Samples from each group were mounted on base (1.5” × 1.5” × 1.5”) vertically at an angle of 30° to long axis, clear epoxy resin was poured and allowed to set for 72 h and coded. They were kept covered by moist cotton till fracture testing. Samples were tested with the help of universal testing machine using a custom metal indenter (3 mm) with a crosshead speed of 1 mm/min, and the results were recorded. Fracture types were observed, grouped, and recorded. The results were assessed by two different operators, compared, and tabulated. The samples were distributed across groups based on their weights and homogeneity. They were statistically assessed for normality of these variables. The results of fracture test were statistically analyzed using one-way analysis of variance (ANOVA).
test of variance with Tukey post hoc test for multiple comparisons.

**RESULTS**

Group II had the highest fracture resistance with a mean value of 742.89 N. Groups III and I had mean values of 482.33 and 361.1123 N, respectively. Statistically significant difference between the experimental groups (I and II) and (II and III) in load values of root fracture \((P < 0.05)\) [Figures 2–5] was observed.

Mesiodistal type of fracture was the most common among experimental groups with a percentage incidence of 54.20%. The incidence of comminuted, buccolingual, transverse, and other type of fractures were 29.2%, 4.2%, 8.3%, and 4.2%, respectively [Figures 6–8].

**DISCUSSION**

Endodontic therapy should reinforce residual tooth structure in a way that it prevents untoward events long term.\(^7\) To effectively access and prepare apical one-third, considerable amount of radicular dentin in coronal and middle one-third is removed. Factors

| GROUPS (n=8) | TYPE OF ALLOY |
|-------------|---------------|
| I           | GOLD ALLOY    |
| II          | NICKEL CHROMIUM ALLOY |
| III         | TITANIUM ALLOY |

**Figure 1:** Post and core grouping

**Table:**

| Experimental Groups (n=8) | PERCENTAGE OF INCIDENCE |
|---------------------------|-------------------------|
|                           | Buccolingual | Mesiodistal | Comminuted | Transverse | Others |
| I                         | 0            | 50          | 25         | 12.5       | 12.5 |
| II                        | 0            | 62.5        | 37.5       | 0          | 0    |
| III                       | 12.5         | 50          | 25         | 12.5       | 0    |
| OVERALL                   | 4.2          | 54.2        | 29.2       | 8.3        | 4.2  |

**Figure 2:** Fracture resistance Group I

**Figure 3:** Fracture resistance Group II

**Figure 4:** Fracture resistance Group III

**Figure 5:** Fracture mean

**Figure 6:** Fracture types

**Figure 7:** Fracture distribution
affecting fracture susceptibility are tooth structure loss, trauma, age, tooth type, degree of calcification, excessive dentin removal, dehydration of dentin subsequent to endodontic therapy, obturation-induced stresses, and irrigant action on canal walls, which reduces long-term survival rate. Root thickness and ability to resist lateral dislodging forces have a directly proportional relationship. Fracture resistance improves with increase in the remaining root dentin thickness buccolingually.[8]

Vertical fractures can happen before, during, or after endodontic therapy. Roots are split along their long axis in vertical fracture and rarely occur as a result of acute trauma. Clinical studies revealed that 11%–13% of extracted teeth after endodontic treatment have been associated with vertical fractures[8] and most often have unfavorable prognosis.[9] Craze lines and cracks on canal walls become areas of high stress concentration and over a period extend to surface eventually, resulting in vertical root fracture. Cracks usually begin at the apex of root and propagate at the cervical.

Horizontal fractures are the most common, and they occur mainly in the anterior region due to frontal impact. They are common in middle one-third and rarely occur in apical and coronal one-third of root. Successful management of transverse root fracture depends on fracture line position, mobility of coronal segment, status of radicular, and coronal pulp tissues. Prognosis for teeth with transverse or horizontal root fractures is usually good.[10] Verified pulp necrosis has been reported with a percentage incidence of 43.7%, and the treatment depends on the position of tooth after it was fractured, the mobility of coronal segment, the status of the pulp, and the position of fracture line.[11] Repair and healing occurs either by hard tissue union, which is a desirable, bony ingrowth, fibrous healing, or granulation tissue formation. Fractures as a result of fatigue due to repetitive occlusal forces have been reported in teeth, which are vital. The position and relationship of fracture line to gingival crevice is the most important factor, affecting the long-term prognosis. Coronal and middle one-third fractures have less favorable prognosis compared to apical root fractures. In infrabony fractures with no communication to gingival sulcus, meticulous oral hygiene and appropriate treatment options result in successful outcomes.

Rotary files used for gutta-percha removal during retreatment have been shown to remove surface dentin. Further enlargement of apical third to achieve better cleansing contributes to reduced fracture resistance. There has been a positive correlation between the removal of dentin during retreatment procedures and the reduction of fracture resistance.[12]

Newer generation of materials improve bond between radicular dentin, sealer, and sealer–core interface, which improves fracture resistance. Modulus of elasticity of obturation material should ideally be approximate to that of radicular dentin for root reinforcement.[13] Priming radicular dentinal surface improves bond between sealer, dentin, and core. Also the modulus of elasticity of obturating material, post, and sealer has to match that of radicular dentin, leading to even distribution of induced stresses, and borne by components of monoblock.[14]

Failure rates were almost double where adequate post-endodontic restoration was not done.[15] Use of intra-orifice barriers effectively decreases coronal leakage and improves fracture resistance.[16,17] Cast post and core preparation removes radicular dentin, needs multiple clinical visits, leading to more turnover time, and has an elastic modulus, which is high (200 Gpa) compared to tooth structure, which can predispose to fractures.[18] Metallic post failures are most often due to root fracture, post-fracture, or post-retention loss. In endodontically treated teeth, the amount of remaining dentin and the provision of ferrule increase survival rate. Studies with longer follow-up have been recommended.[19]

Endodontic irrigation leads to an alteration of chemical composition, organic and inorganic phases of radicular dentin, which affects microhardness, permeability, and solubility leading to changes in the ability of teeth to resist fracture under varying loads. EDTA affects fracture resistance based on the exposure time and concentration.[20]

Sealers contributing to improving fracture strength of the roots have been evaluated.[21] Adhesion to canal walls increases mechanical interlocking and reduces risk of fracture.[22] Obturation material and technique

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Figure 8: Incidence of fracture
choices impact the resistance of root to fracture. Gutta-percha along with adhesive resin sealers have been reported to improve the fracture resistance.\textsuperscript{[23]} Adhesive ionomer coating on gutta-percha for a thickness of 2 microns to which a adhesive ceramic sealer could be bonded to form a tertiary monoblock improves fracture resistance.\textsuperscript{[24]}

Gutta-percha used with a resin-based sealer has several advantages but its hydrophobic nature and its inability to sufficiently reinforce the root have fuelled the development of hydrophilic materials, which penetrate dentinal tubules and use moisture in dentinal walls, which allows the material to bond to root canal wall and core, which reinforces the root. Polymerization shrinkage of the resin-based sealers due to high C-factor associated with root canal results in sealer contraction post filling and weakening bond between sealer and canal wall, leading to reduced resistance to fracture. A novel sealer, which has the property of sealer expansion, due to its self-expanding and hydrophilic composition significantly increased the resistance to fracture.\textsuperscript{[25]}

There has been a positive correlation between the microcrack formation and the incidence of root fractures. Root fracture is a gradual propagation of craze lines and microcracks in radicular dentin.\textsuperscript{[26]} Microcracks are formed as a result of rotational forces that are being applied to canal walls. Increased incidence, reported with some rotary instrumentation techniques, is related to design features of rotary instruments such as tip size, cross-sectional geometry, pitch, and taper. Hand instruments produce a less dentinal defects compared to rotary instruments.\textsuperscript{[27]} Investigators have found a proportional relationship between rotary instrument design and vertical fractures.\textsuperscript{[28]} Migration from a rotary to reciprocating motion, involving different clockwise, counter-clockwise angles, results in minimal torsional, flexural stresses, and less radicular dentin binding. Reciprocating file systems produce significant amount of incomplete dentinal cracks in apical third when compared to rotary files.\textsuperscript{[29]} Both hand and reciprocating instruments induced the formation of dentinal defects during the canal preparation.\textsuperscript{[30]} Self-adjusting file drastically changes the way in which canal is prepared. Straightening of curved canals is reduced because of the absence of a rigid core and pliability of file.\textsuperscript{[6]} The file removes a surface layer of dentin, which results in a canal of larger dimensions but a similar cross section.\textsuperscript{[31]}

Cracks or craze lines that extend from external surface of root into dentin, which do not reach the root canal lumen and structural defects in root dentin, have been found to cause fractures due to amplification of induced stresses at these formed microcracks.\textsuperscript{[32]} They were found in areas away from direct contact of rotary instruments. One possible reason is that stress generated during instrumentation of canals is transmitted to external surface of teeth where it overcomes bonds in dentin to form these craze lines, microcracks, and eventually resulting in fractures.\textsuperscript{[33,34]}

This in vitro study evaluated the fracture strength on extracted maxillary central incisors, and due to large amount of variations in volume and weight of roots among the samples selected, sufficient protocols were followed for the standardization of controllable factors. Normality testing of these variables was assessed statistically, and distributions were found to be normal at 5\% level of significance.

**Conclusion**

Radicular dentin should be preserved as much as possible during endodontic therapy. The choice of instrumentation protocols followed, obturating technique, and the choice of materials has to be customized to individual tooth based on preoperative analysis, which would lead to better long-term outcomes. Metallic post and core preparations seem an attractive option. Development of newer alloy systems and materials, which are biocompatible and match elastic modulus of dentin, are recommended.

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**Conflicts of interest**

There are no conflicts of interest.

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