Fracture Strength of Teeth in Oval-Shaped Root Canals Restored with Posts and Accessory Post Systems

Résistance à la rupture des dents dans les canaux radiculaires de forme ovale, restaurés avec des pivots et des systèmes de pivots accessoires

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Abstract

In contemporary restorative dentistry, post-root canal adaptation always represents an important role in successful and long-lasting treatment for the restoration of endodontically treated teeth. In some cases posts have to be placed in wide oval-formed root canal spaces. However, the impact of the treatment outcome of the increasing non-uniform cement thickness around the posts has not yet reached a consensus. The purpose of this research is to assess the treatment outcome of post systems with three different post geometries, combined with/without accessory posts as an alternative technique in the oval-shaped canals. Seventy-two teeth with oval-shaped canals were selected for the study. Crowns were sectioned at the cemento-enamel junction and endodontically treated. The roots were randomly divided into 2 groups of 36 specimens and each group was split into 3 subgroups of 12 as follows; G1-A, Quartz fiber post with double tapered cross-section (QFibDT); G1-B, Quartz fiber post with circular cross-section (QFibCir); G1-C Quartz fiber post with oval cross-section (QFibOv); G2-A Quartz fiber post with double tapered cross-section + two accessory quartz fiber posts (QFibDTAcces); G2-B Quartz fiber post with circular cross-section + two accessory quartz fiber posts (QFibCirAcces); G2-C Quartz fiber post with oval cross-section + two accessory quartz fiber posts (QFibOvAcces). Root canal preparations were performed with low-speed Torpan Drill tips of ISO 90, ISO 100 and ISO 120 in increasing order. All posts were cemented with self-adhesive dual polymerizing resin cement. Two specimens from each group were randomly chosen upon the cementation of all posts and processed for stereomicroscope (SM) evaluation of the fiber post-cemented interface. All sixty specimens were then embedded in auto polymerizing acrylic resin surrounded by aluminum cylinders and light-polymerized composite cores were produced. Pressed all ceramic crowns were cemented on each core. Specimens were secured in a universal testing machine with the use of a device that allowed loading of the specimens lingually at 135 degrees to the long axis. A compressive force was applied at a crosshead speed of 1 mm/min until fracture occurred. The fracture loads (N) were determined and the obtained data were analyzed by 1-way ANOVA with interaction followed by Tukey HSD tests. Student's t test was used for between group comparisons. Representative stereomicroscope images and cement thickness measurements were performed on 2 mm sectioned specimens. Within-group comparisons for Group 1 specimens demonstrated statistically higher fracture strength values for groups cemented with G1-A, DT Light Post (590 N) and G1-B, Match Post (570,9 N) groups compared to G1-C, Ellipson Post group (400,83 N) ($p<.001$). The highest fracture resistance was recorded for G2-A (QFibDTAcces) at 764,18 N, followed by group G2-B (QFibCirAcces) at 726,5 N. Within-group comparisons of these two groups (G2-A, G2-B) resulted in statistically higher fracture resistance of teeth compared to G2-C (QFibOvAcces) at 574,96 N ($p<.001$). Regardless of the post system geometry tested in this study, Group 2 specimens resulted in statistically higher fracture strength values compared to Group 1 specimens according to between group comparisons ($p<.001$). No catastrophic failures were present and there were no root fractures. It can be speculated that when restoring with posts, especially in wide oval-shaped canals, the use of accessory posts reduces the cement thickness around the posts thus increasing the endodontically treated teeth resistance to fractures.

Résumé

En dentisterie de restauration contemporaine, l'adaptation dans le canal d'une dent d'un pivot a toujours joué un rôle important pour le succès de la longévité d'un traitement dans la restauration des dents traitées endodontiquement. Dans certains cas, les pivots doivent être placés dans des espaces de canal de dent de forme ovale, assez ouverte. Toutefois, l'impact de l'issue du traitement pour l'augmentation non uniforme de l'épaisseur du ciment autour des pivots, n'a pas encore atteint un consensus. Le but de cette recherche est d'évaluer le résultat du traitement des systèmes de pivot avec trois géométries différentes de pivot, combinées avec/sans des accessoires de pivots comme autre technique, dans des canaux de forme ovale. Soixante-douze dents, avec des canaux de forme ovale furent sélectionnées pour cette étude. Les couronnes furent sectionnées à hauteur de la jonction cement-émail, et endodontiquement traitées. Les racines furent au hasard divisées en 2 groupes de 36 spécimens, et chaque groupe fut réparti en 3 sous-groupes de 12, tels que suivants : G1-A, pivot en fibre de quartz avec double coupe transversale chanfreinée (QFibDT) ; G1-B, pivot en fibre de quartz avec coupe transversale circulaire (QFibCir) ; G1-C, pivot en fibre de quartz avec coupe transversale ovale (QFibOv) ; G2-A, pivot en fibre de quartz avec double coupe transversale + deux pivots accessoires en fibre de quartz (QFibDTAcces) ; G2-B, pivot en fibre de quartz avec coupe transversale circulaire + deux pivots accessoires en fibre de quartz (QFibCirAcces) ; G2-C pivot en fibre de quartz avec coupe transversale ovale + deux pivots accessoires en fibre de quartz (QFibOvAcces). Les traitements de canaux ont été exécutés avec une pièce à main à vitesse réduite de 90 ISO, 100 ISO et 120 ISO dans cet ordre de croissance. Tous les pivots furent cimentés avec un produit autocollant de résine à polymérisation double. Deux spécimens de chaque groupe ont été choisis au hasard après cimentation de tous les pivots, et soumis à une évaluation stéréo microscopique (SM) des surfaces de fibre post-cimentées. Les soixante spécimens furent alors ensevelis dans une résine d'acrylique auto polymérisante entourée d'un cylindre en aluminium, et des moignons en composite polymérisé à la lumière, furent fabriqués. Des couronnes en céramique pressée furent cimentées sur chaque moignon. Les spécimens furent alors sécurisés dans une machine à tester universel, avec l'aide d'un instrument qui permet un chargement sur le lingual des spécimens à 150 degrés par rapport à l'axe le plus long. Une force de compression fut appliquée en travers, d'une vitesse de 1mm/min jusqu'à ce que fracture s'en suive. Les forces de fracture (N) furent déterminées et les informations analysées par des tests d'ANOVA 1 avec interaction, suivit par Tukey HSD. Des tests par des étudiants furent utilisés, pour comparaison entre les groupes. Des images de représentation stéréo microscopique et des mesures d'épaisseur de ciment ont été effectuées sur des spécimens avec une section de 2 mm. Les comparaisons de spécimens à l'intérieur du Groupe 1, statistiquement, montrent une plus importante résistance à la rupture pour les groupes cimentés G1-A, et aux groupes DT Light Pivot (590 N) et G1-B, Match Pivot (570,9 N), comparés au G1-C et au groupe Ellipson Pivot (400,83 n) ($p \leq .001$). La plus importante résistance à la fracture a été enregistrée pour G2-A (QFibDTAcces) à 764,18 N, suivit par le groupe G2-B (QFibCirAcces) à 726,5 N. Une comparaison interne entre ces deux groupes (G2-A, G2-B), statistiquement, démontra une plus grande résistance à la fracture des dents en comparaison à G2-C (QFibOvAcces) à 574,96 N ($p \leq .001$). Sans tenir compte du système de pivot testé géométriquement dans cette étude, les spécimens du Groupe 2, statistiquement, démontrèrent une plus grande résistance de valeurs de fracture en comparaison des spécimens du Groupe 1, en relation de comparaisons entre tous les groupes ($p \leq .001$). Aucunes défaillances catastrophiques n'étaient présentes et il n'y avait aucune fracture de racine. On peut donc en déduire, qu'une restauration avec des pivots, spécialement dans des canaux de forme ovale, avec l'utilisation de pivots accessoires, réduit le ciment autour des pivots, et ainsi augmente les dents traitées endodontiquement, à la résistance aux fractures.

The primary goals of prosthetic and restorative treatment in endodontically treated teeth are to restore teeth to function and comfort combined with satisfactory esthetics. The materials and techniques change somewhat over time, but not the ultimate goals.[1] In recent years, the choice of materials used in the post and core restoration of endodontically treated teeth has changed from the exclusive use of very rigid materials to materials that have mechanical characteristics that more closely resemble dentin. Clinically irreversible failures displaying catastrophic root fractures resulting with the extraction of the tooth is less likely to occur with fiber-based post systems.[2-5] In this way, a mechanically homogeneous system can also be created.[6,7]

Root fractures have been cited as the most common cause of failure in endodontically treated teeth restored with posts.[2,8,9] Cross-sectional surveys of failed posts have shown that most failures are due to post decementation followed by caries and post fracture.

Ree and Schwartz[1] reported that the long-term success of endodontic treatment is highly dependent on the restorative treatment that follows. Once restored, the tooth must be structurally sound and the disinfected status of the root canal system must be maintained. Radicular and coronal tooth structure should also be preserved to the greatest possible extent during endodontic procedures and post space preparations within the root canals as it weakens the root.[1,4,10]

In some cases the root canals could anatomically be ribbon, ovoid or triangular shaped rather than circular[11] or the preparation of the canal during endodontic treatment may result in a wide oval form[12] or a wide

flare.[13] It has been suggested that in the case of non-circular root canals, a possible clinical option might be to only remove gutta-percha and sealer and to use several small posts or to place one master post with a few small accessory posts.[14] Otherwise the clinician inevitably needs to enlarge the canal in such cases in order to provide a rounded-shaped post space to fit a single circular prefabricated post.[15]

Techniques are currently developed focusing on fortifying the post-core-tooth complex especially with oval-shaped root canals. Post space preparation with the specially designed ultrasonic oval tip[9,16,17] (Ellipson Tip; Satelec, Acteon Group, Merignac, France) followed by restoring the root with the same size oval shaped quartz fiber reinforced esthetic post (Ellipson Post; Recherches techniques dentaires, St.Egreve, France) of the same system is a contemporary alternative technique for narrow oval-shaped canals.[9] Study findings[12,18,19] reported that the quality of the root canal space is compromised especially in narrow oval-shaped canals as they are difficult to clean and shape. On the other hand in cases with wide oval shaped canals the literature does not offer a consensus on the ideal post treatment alternative. It is a proven concept that close canal adaptation with minimal tooth structure removal provides a long-lasting treatment. In such oval-shaped canals cement film thickness will inevitably increase around the master post. However, little information is available on the role of cement thickness and its role on fracture strength of endodontically treated teeth.[15,20]

Filling the wide oval-shaped root canal post with fiber strips has been proposed as one of the options, thereby allowing a reduction in cement thickness.[9,21] It was also demonstrated that fiber posts may be relined with composite resin in wide root canals for the achievement of an anatomical post that reproduces the root canal shape, reduces the cement thickness, favours retention of the post and prevents adhesive failures.[7,15,22] Another recent proposal with the same objective is the insertion of quartz fiber reinforced accessory posts (Fibercone; Recherches techniques dentaires, St.Egreve, France) around the master post which maintain an increase in the volume of fibers and a decrease in cement thickness.[9]

However, the impact on the treatment outcome of these new treatment alternatives has not yet been clearly defined. The purpose of this research is to assess the treatment outcome of quartz fiber reinforced post systems with three different post geometries combined with/without accessory posts as an alternative technique in the oval-shaped canals.

Material and Methods

Freshly extracted maxillary canines with similar root dimensions free of cracks, caries, and fractures were used for this study and stored in 0.9% saline solution (Baxter Healthcare Corporation, IL, USA) following extraction. Mesio-distal and bucco-lingual x-rays (Digital RVG; Owandy Crystal-X Easy, Owandy Digital Imaging, USA) of each tooth were taken. The ratio between the long and short canal diameter at 5mm from the apex was calculated; if it resulted ≥2; the canal was assumed to be oval.[12] Seventy-two teeth with oval-shaped canals were selected and teeth were sectioned perpendicular to their long axis at the cemento-enamel junction (CEJ), with the use of a water-cooled diamond bur (R837.014; Diaswiss, Geneva, Switzerland) with an air-turbine at 300.000 rpm. The specimens were then endodontically treated with a step-back procedure with a #45 file (Dentsply Maillefer, Ballaigues, Switzerland). After intermittent rinsing with 3% NaOCl, root canals were dried with paper points (Dentsply Maillefer, Ballaigues, Switzerland) and obturated with lateral condensation of gutta-percha (Dentsply Maillefer, Ballaigues, Switzerland) and eugenol free sealer (AH 26; Dentsply DeTrey, Konstanz, Germany).

The post spaces were prepared 24 hours after completing endodontic procedures. Gutta-percha was removed with a warm endodontic plugger (Kerr Sybron Corp, Romulus, Mich, USA) leaving 3 mm of the endodontic filling in the apical portion.

In all the test groups the post spaces were prepared to a depth of 8 mm using 3 low-speed Torpan Drill tips of ISO 90, ISO 100 and ISO 120 (RTD; Recherches techniques dentaires, St. Egreve, France) in increasing order. The selected quartz fiber reinforced esthetic post size was #1 for all of the post systems used with similar post diameters and composition (Figure 1). These procedures served to standardize the root canal spaces and establish similarity between post diameters and cement thicknesses. The specimens were first randomly divided into 2 groups of 36 specimens (Group 1 and Group 2) and each group was split into 3 subgroups of 12 (Figure 2). Post groups and group codes are listed in Table 1.

Quartz fiber posts with double taper cross-section, (DT Light-Post; Recherches techniques dentaires, St. Egreve, France) were used in the first group (G1-A). Quartz fiber posts with circular section, (Match Post; Recherches techniques dentaires, St. Egreve, France) were placed in the second group (G1-B). Quartz fiber posts with an oval cross-section (Ellipson Post; Recherches techniques dentaires, St. Egreve, France) were used in group 3 (G1-C). One master post was placed in Group 1 test

Table 1 — Experimental post groups with quartz fiber post systems

GROUP CODE (n=12)	POST MATERIAL CEMENTED	GROUP NAME
G1-A	D.T Light Post	QFibDT
G1-B	Match Post	QFibCir
G1-C	Ellipson Post	QFibOv
G2-A	D.T Light Post & 2 Fibercones	QFibDTAcces
G2-B	Match Post & 2 Fibercones	QFibCirAcces
G2-C	Ellipson & 2 Fibercones	QFibOvAcces

samples whereas in Group 2 two accessory posts (Fibercone, Recherches techniques dentaires, St. Egreve, France) were placed on both sides of the master post used in Group 1. Thus G2-A, G2-B and G2-C test groups were formed. Schematic representation of experimental groups is illustrated in Figure 2.

All posts were cemented with self-adhesive dual polymerizing resin cement (RelyX Unicem, 3M ESPE, Seefeld, Germany) according to the manufacturer's instructions. The cementation procedure started with clicking the flexible root canal shaped application aid (Elongation tip, 3M ESPE, Seefeld, Germany) on the special aplicap of the system (Unicem Aplicap, 3M ESPE, Seefeld, Germany). After activating the aplicap for 2–4 seconds the resin cement was machine mixed for 15 seconds with the capmix machine (Rotomix, 3M ESPE, Seefeld, Germany). Then the application aid was inserted down to the bottom of the root canal and the self-adhesive resin cement was applied by slowly pulling the application aid out of the canal. The posts were seated into the root canal and excess cement was removed. In the second group specimens, 2 accessory posts were placed on both sides immediately after placing the master post. The posts were light polymerized for 40 seconds with the tip of the light curing unit (Optilux 501, Kerr, Danbury, CT, USA) directly in contact with the coronal end of each post. Two specimens from each group with a total of 12 test samples were randomly chosen and categorized for stereomicroscope (SM) evaluation of the fiber post-cemented interface.

All sixty specimens were stabilized on a surveyor (Paraflex, Bego, Bremen, Germany) with vertically moving rods, from the most coronal tip of each master post, with sticky wax. Root surfaces were marked 2 mm below the CEJ were then embedded in auto polymerizing acrylic resin (Meliodent, Bayer Dental, Newbury, UK) surrounded by aluminum cylinders. Following the complete polymerization process of all specimens, the posts were marked at a distance of 4 mm from the CEJ and the

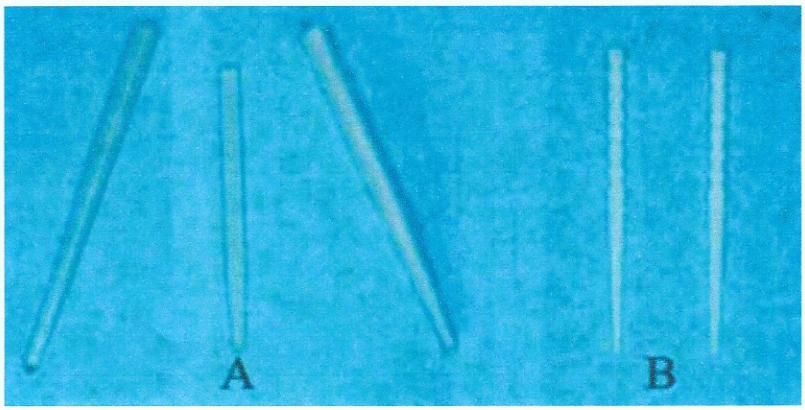

Figure 1 — Post systems used (left to right) (A) D.T. Light Post, Match Post, Ellipson Post (B) Fibercones.

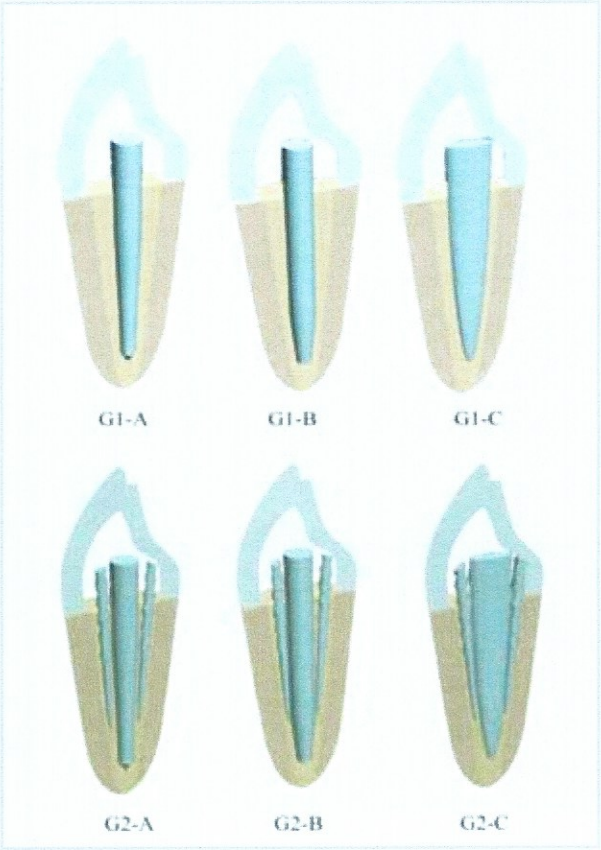

Figure 2 — Schematic representation of experimental groups.

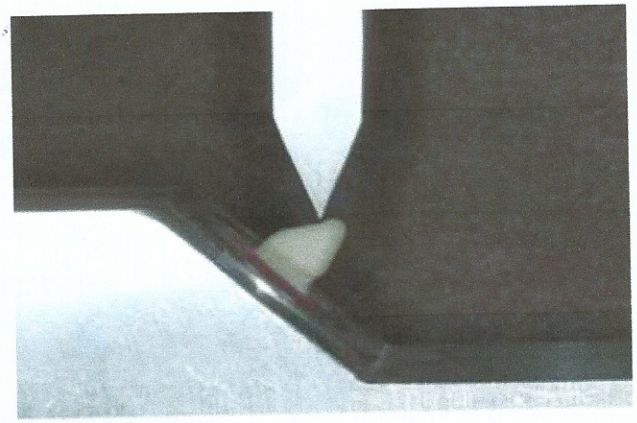

Figure 3 — Specimens were loaded lingually at 135 degrees to the long axis with a compressive force.

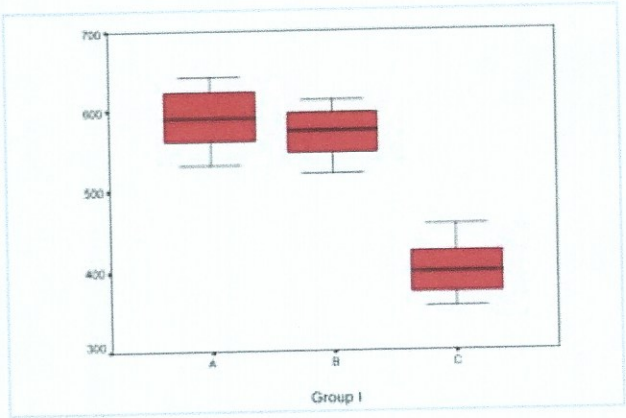

Figure 4 — Mean fracture strength values (N) and trust interval at 95% for Group1 specimens.

excess parts were cut using the special double sided diamond coated disc (Composidisc; Recherches techniques dentaires, St. Egreve, France).

A master core was prepared with the use of the adhesive system (Clearfil S3 Bond, Kuraray Co Ltd, Osaka, Japan). A light-polymerized composite core (Clearfil Photo Core, Kuraray Co Ltd, Osaka, Japan) was fabricated on one of the specimens, and a master core preparation was completed on the composite material with the use of water cooled diamond coated burs. The core portion of the post and core restoration was 6.0 mm in height. A special light transmitting matrix was fabricated from the epoxy resin and all other composite cores were produced using this matrix from the master core preparation according to the method described by Atalay.[23]

A crown was designed on the master composite core specimen in the form of a framework coping using a CAD/CAM device (Cercon Smart Ceramics, DeguDent GmbH, Hanau-Wolfgang, Germany). Sixty polyurethane copings (Cercon Base Cast, DeguDent GmbH, Hanau-Wolfgang, Germany) were milled and all were further pressed from all ceramic ingots (IPS e.max Press, Ivoclar Vivadent AG, Schaan, Liechtenstein). Crowns were cemented on the cores (Clearfil SA Cement; Kuraray Medical Inc, Tokyo, Japan) and were stored in water at 37°C for 48 hours.

Specimens were secured in a universal testing machine (Autograph AG-IS, Shimadzu, Tokyo, Japan) with the use of a device that allowed loading of the specimens lingually at 135 degrees to the long axis. The load head was placed on the specially formed palatal step of the crown (Figure 3). A compressive force was applied at a crosshead speed of 1mm / min until fracture occurred. The fracture loads (N) were determined and the obtained data were analyzed by 1-way ANOVA with interaction followed by Tukey HSD tests. Student's t test used for between group comparisons.

Two specimens from each group were randomly chosen upon the cementation of all the posts and processed for stereomicroscope (SM) evaluation of the fiber post-cemented interface. All 6 specimens for each group were embedded in auto polymerizing acrylic resin surrounded by specially designed two piece aluminum matrix in 30x40x60 mm dimensions. Upon completion of the polymerization process coronal post sections were cut horizontally by double sided diamond disc (Composidisc; Recherches techniques dentaires, St. Egreve, France). The blocks were serially cross-sectioned using a microtome (Isomet 1000; Buhler, IL, USA) with the use of a water-cooled precision cutter diamond blade (Buhler, IL, USA) at a speed of 975rpm. The thickness of each section was 2 mm. Each section was examined under a stereomicroscope (Leica MZ7,5; Leica Microsystems, Cambridge, UK). The cement thicknesses were measured on the perpendicular lines to the tangents as the minimum distance between the cement border and the post perimeter. Representative 1.0x, 2,0x and 3,2x zoom stereomicroscope images and cement thickness measurements were performed with the software (Image Manager; Leica Systems, UK) of the SM.

Results

The fracture strength values (Newtons) and standard deviation (SD) observed after application of compressive loads are presented in Table 2. Significant differences within Group 1 and Group 2 specimens were identified with Anova and Tukey HSD tests (α=.05) (Table 3).

Within-group comparisons for Group 1 specimens demonstrated statistically higher fracture strength values for groups cemented with G1-A, DT Light Post (590 N) and G1-B, Match Post (570,9 N) groups compared to G1-C, Ellipson Posts (400,83 N) ($p<.001$). Mean fracture strength values (N) and trust interval at 95% for Group 1 specimens are displayed in Figure 4.

Table 2 — The mean (SD± Standard deviations) fracture strength values (in Newtons) of the experimental groups and significant differences between groups as identified with Student's t test (α=.05)

	Group 1		Group 2		
	Mean	**SD**	**Mean**	**SD**	**P**
A (QFibDT)	590,00	35,44	764,18	28,57	,000***
B (QFibCir)	570,90	30,02	726,51	40,33	,000***
C (QFibOv)	400,83	33,35	574,96	47,13	,000***

The highest fracture resistance was recorded for G2-A (QFibDTAcces) at 764,18 N , followed by group G2-B (QFibCirAcces) at 726,51 N. Within-group comparisons of these two groups (G2-A, G2-B), in which master posts were used in combination with two accessory posts, resulted with statistically higher fracture resistance of teeth compared to G2-C (QFibOvAcces) at 574,96 (p<.001). Mean fracture strength values (N) and trust interval at 95% for Group 2 specimens are shown in Figure 5.

Table 3 —
Significant differences within groups
as identified with Anova and Tukey HSD test (α=.05)

Group 1		Group 2	
Group 1	**P**	**Group 2**	**P**
G1-A/G1-B	,207	G2-A/G2-B	,101
G1-A/G1-C	,000	G2-A/G2-C	,000
G1-B/G1-C	,000	G2-B/G2-C	,000

The mean (SD± Standard deviations) fracture strength values (Newtons) of the experimental groups and significant differences between groups were identified with Student's t test (α=.05) and are represented in Table 2. Fracture strength values of groups with accessory posts (Group 2 specimens) were statistically higher, irrespective of the post geometry tested, than those of only one master post cemented group (Group 1 specimens) (p<.001). Comparison of mean fracture strength values (N) and trust interval at 95% for all groups are shown in Figure 6.

Representative 1.0x, 2,0x and 3,2x zoom stereomicroscope images were performed with the software (Image Manager; Leica Systems, UK) of the SM. Representative stereomicroscope images of each experimental group can be seen in Figure 7. Representative cement thicknesses were also measured for basic comparisons on the perpendicular lines to the tangents as the minimum distance between the cement border and the post perimeter. Variations in the thickness of the cement with/without accessory posts were displayed distinctly (Figure 8).

Failures in all post groups were recorded as favorable and repairable. No catastrophic failures were present and there were no root fractures.

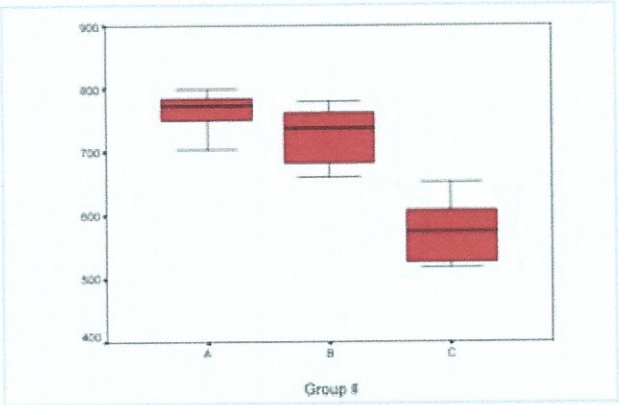

Figure 5 – Mean fracture strength values (N) and trust interval at 95% for Group 2 specimens.

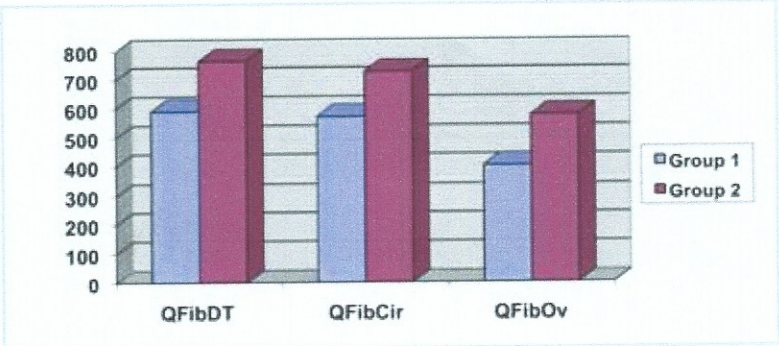

Figure 6 – Comparison of mean fracture strength values (N) and trust interval at 95% for all groups.

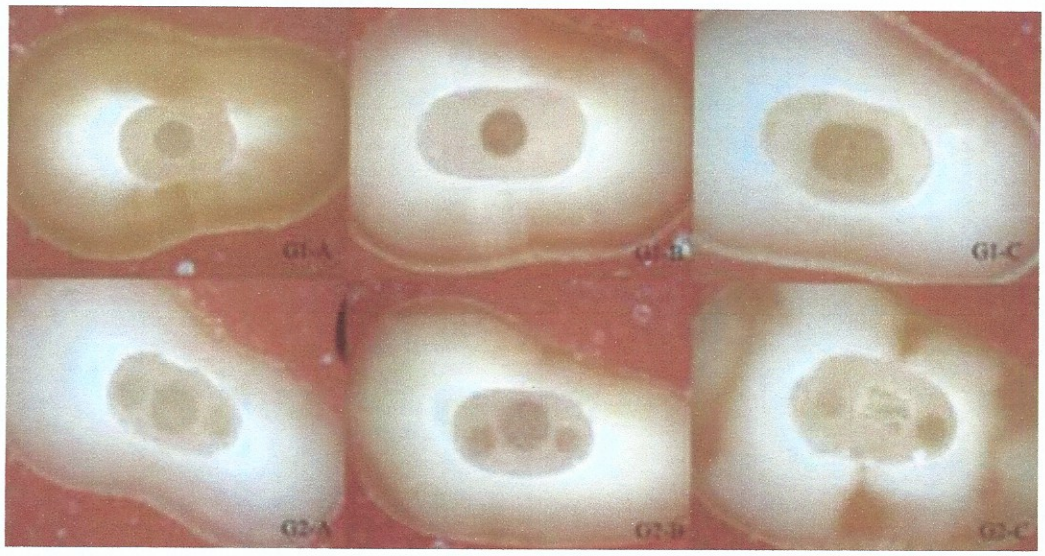

Figure 7 — Representative stereomicroscope images of experimental groups at 1.0x or 2.5x magnifications.

Discussion

Post cementation and bonding within the root is a complex concept due to several invariables: Root canal anatomy and influence of the endodontic procedure,[11,12,24-27] polymerization shrinkage and contraction because of an unfavorable C-factor,[28-30] poor control of moisture and polymerization difficulties in the apical regions.[28,31,32]

It has been reported in former studies that an excessively thick layer of resin cement around a fiber post was an unfavorable factor for long-term success of post supported restorations and this might have some correlation to higher frequencies of post debonding.[9,16,17,33] D'Arcangelo et al.[33] reported that the cement thickness is correlated to the post fitting into post space and has a direct influence on the pull-out strengths of fiber posts. He concluded that the least cement thickness will provide better post adaptation with the canal walls. However, when circular post drills and posts of larger diameter are used in wide oval-shaped root canals, sound dental tissue is sacrificed to adapt the canal shape to the post,[34] thus resulting in decreased root strength.

Grandini et al.[15] stated that if a post does not fit well, the resultant cement layer is too thick and bubbles are likely to be present within it, the post is more predisposed to debonding. Moreover, they reported that the polymerization stress, developing within a relatively thin film of cement, would be minimal and the formation of bubbles or voids, representing areas of weakness within the material, is less likely to occur in a thin layer of cement. Valandro et al.[35] also indicated that less microporosities and polymerization shrinkage will be present in the thinner cement layer. Perez et al.[36] evaluated the influence of cement thickness on the bond strength of a fiber-reinforced composite post system to the root dentin and concluded that increased cement thickness surrounding the post did not impair the bond strength.

Porciani et al.[14] supported the idea that a good post fitting can be achieved when the cement layer is thin and uniform on all canal walls and that the variations in the cement film thickness along the fiber post could result in a non-homogeneous stress distribution throughout the root that this might increase the failure rate of the post in the long term.[37]

In the present study, an attempt was made to restore a wide oval-shaped root canal with posts with minimal tooth structure removal. The effect of post geometry on the resistance to fracture of endodontically treated teeth restored with prefabricated quartz fiber reinforced esthetic post systems was also questioned. Highest fracture strength values with 590 N were obtained for G1-A, QFibDT followed by 570,90 N for G1-B, QFibCir specimes. Within group comparisons revealed no statistical differences ($p>.05$) for these two subgroups in Group 1. However G1-C, QFibOv, specimens with 400,83 N mean fracture strength value of N were found to be statistically different ($p<.001$) from the other 2 groups, G1-A and G1-B. Considering the fact that all post spaces were prepared with a standard set of drills in the present study, statistically different results could be related to the smaller dimensions of the oval post system used. Ellipson posts (G1-C) were manufactured only in one size to fit to the oval post space created by the special ultrasonic oval shaped tip of the system. In order to create a group of posts with the most similar surface areas, the smallest diameters of the post systems were chosen for the other two groups (G1-A, G1-B). Oval posts used in combination with the special ultrasonic tip will perfectly conserve the root configuration in narrow

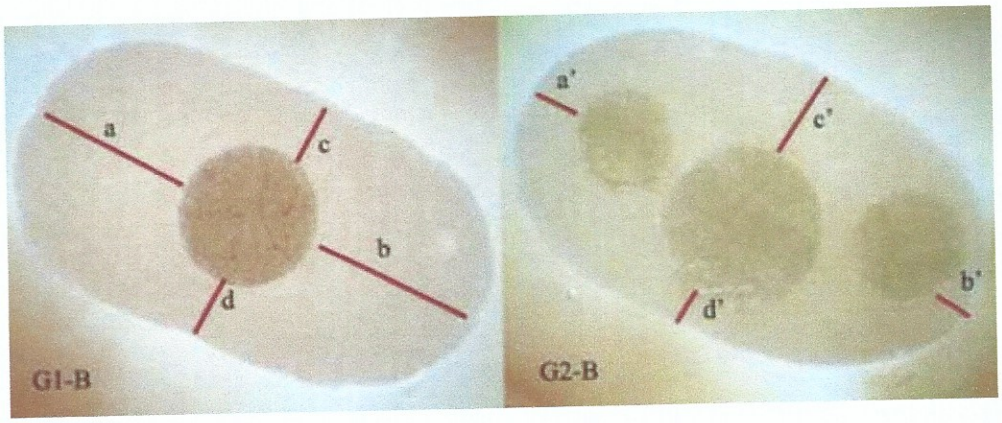

Figure 8 – Variations in the thickness of the cement with/without accessory posts in G1-B/G2-B experimental groups.

oval-shaped canals resulting in a desirable post-root adaptation and superior biomechanical performance.[9] According to the findings of the present study it can be speculated that the oval shaped posts might not provide enough fracture strength in wide oval-shaped root canals due to the increased cement thickness between the post's oval shape and root canal walls.

The mean fracture strength values of specimens in G1-A and G1-B with 590 N and 570,9 N are comparable with the results of the former studies.[4,8,9] No catastrophic root fractures were seen in any Group 1 specimens, supporting the findings that tooth fractures were favourable creating less damage to the root and being repairable due to their modulus of elasticity to dentin when restored with quartz fiber reinforced post systems.[8,24,38,39]

Maccari et al.[13] reported repairable mode of failure with quartz and glass fiber post specimens whereas mostly nonrepairable fractures were observed in cast metal post group specimens in the restoration of endodontically treated teeth with flared canals and no ferrule. Teeth restored with custom made cast posts had a fracture strength twice that of teeth restored with fiber posts according to the results of their study. This finding could be explained by the close root canal anatomy and post adaptation. Adhesive failures are more common in thick cement layer, because of the low mechanical properties of this layer, mainly due to the more stress concentration and polymerization shrinkage thus negatively affecting the longevity of the restorations.[29]

Circular shaped posts usually don't provide a good post fitting with the canal walls especially in wide and oval-shaped canals due to the discrepancies left between the post's circular shape and canal's anatomy when a smaller diameter post system is chosen in order to provide a conservative alternative. Different approaches have been suggested to solve this problem. Braz et al.[40] suggested using a main glass fiber post and three accessory fiber posts as the ideal method of restoration in roots with wide root canals. Newman et al.[41] reported a direct relationship between the proportion of fiber and tooth fracture strength. Bonfante et al.[3] tested an alternative technique where fiber strips were applied around the post to fill the empty spaces in the root canal and increase the amount of reinforcement fibers. The same technique was also proposed by Grandini et al.[22] as a method of relining the fiber posts in wide root canals with composite resins to reduce the thickness of the cement layer, preventing adhesive failures and increasing post retention. According to the results of the present study it can be speculated that in contemporary esthetic restorative dentistry, the use of accessory posts will provide a safe and rigid alternative in those cases by decreasing the cement thickness on mesial and distal sides of the master post cemented and creating a better root canal-post adaptation.

In narrow and oval-shaped root canals the use of circular shaped posts requires the removal of healthy dentin tissue by the use of preformed drills which alters the anatomy of oval canals. There have been different attempts to overcome this problem. To reduce this alteration, a more conservative drill suitable for all canals and a medium grit ultrasonic oval tip were proposed in recent years by the manufacturers.[16,17] Ayad et al.[7] proposed an alternative technique of relining thin-walled roots with composite resin prior to cementation of fiber posts. Porciani et al.[14] suggested the use of combinations of smaller posts when an endodontically treated tooth with a small or medium size root is restored or in oval root canals. They pointed out that this indication will serve to reduce the thickness of the cementation material. Several in vitro studies[42,43] have confirmed the presence of gaps in the interface between the luting composite resin of the fiber post and the root canal wall especially in cases where cement thickness is increased.

The use of accessory posts combined with the master post will provide a modulus of elasticity able to support occlusal loads with the increased fiber volume in the root canal and also create a thin layer of cement. The significant differences between two main groups of the present study (Group 1 and Group 2) validate these findings (p< .001). The results of our study support the use of accessory posts.

Figure 8 visualizes the representative changes in the cement thickness between Group G1-B, QFibCir and G2-B, QFibCirAcces specimens. The cement thickness measurements for G1-B specimen is recorded as a;1215,52 µm, b; 1281,57 µm, c; 470,9 µm and d; 416,97 µm whereas measurements for G2-B specimen displayed a'; 391,25 µm, b'; 202.7 µm, c'; 593,73 µm and d'; 230,59 µm thicknesses. The cross-section stereomicroscope images of the present study revealed a distinct increase in cement thicknesses when no accessory posts were used (Figure 7 and 8). Restoration of endodontically treated teeth with an appropriate post size providing minimal tooth structure removal combined with accessory posts resulted in more uniform and decreased cement thicknesses around the posts.

The fracture strength values supported by representative SM images observed in the present study suggest that the use of accessory posts reduces the cement thickness around the posts thus increasing the endodontically treated teeth resistance to fracture. The use of a prefabricated quartz fiber reinforced accessory post system, especially in wide oval-shaped canals, provides a viable technique for functional recovery and reinforcement of endodontically treated teeth.

Conclusions

1. G1-A, QFibDT and G1-B, QFibCir groups demonstrated higher fracture strength values compared to G1-C, QFibOv group in standardized post spaces restored with one master post (p< .001).
2. The within group differences of Group 2 specimens resulted in significantly higher fracture resistance values for G2-A, QFibDTAcces and G2-B, QFibCirAcces groups compared to G2-C, QFibOv group (p< .001).
3. Fracture strength values of groups with accessory posts (Group 2 specimens) were statistically higher, irrespective of the post geometry tested, than those of only one master post cemented group (Group 1 specimens) (p<.001).
4. The use of accessory posts combined with a master post can be proposed as an effective alternative treatment technique and ensure a better post-cement-root assembly, especially in wide oval-shaped root canals.
5. The use of accessory posts could be proposed as an efficient treatment alternative to reinforce endodontically treated teeth.

Author declaration

The authors declare no competing financial interest with any of the materials used in the present study.

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