Adaptation of Different Milled Post Materials with Flared Root Canals

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Abstract:

Objective: To evaluate the internal adaptation of different milled post materials using microcomputed tomography. **Materials and Methods:** Forty mandibular first premolar teeth were distributed into four equal groups (n=10). Three groups in which different milled post materials were used in widely flared root canals: group CV; Custom made Vita Enamic posts, group CP; Custom made PEKK posts, group CF; Custom made fiber posts and one group in which ready-made fiber posts were used in normal root canal (group RF). All teeth received root canal treatment and were sectioned 1.5 mm above the cemento-enamel junction. The gutta-percha was removed from the root canals to a total depth of 9 mm from the cutting site. Thirty milled post-and-core were milled after direct scanning of the flared root canals and ten prefabricated fiber posts were used for the normally flared root canals. Cementation was done using self-adhesive, self-cure multilink speed resin cement. Cement thickness and voids volume was measured using microcomputed tomography scanning. **Results**: There was a significant difference in cement distance between groups at the different sites and sections ($p<0.05$). The mean ± standard deviation of cement distance was 154 ± 67 µm. There was a significant increase in buccal cement distance in the cervical and middle sections in the group (RF). There was no significant difference in voids volume between groups. **Conclusions:** Different CAD/CAM milled post materials fabricated from fiber, Polyetherketoneketone, and Vita Enamic presented adequate internal adaptation to flared root canals. The voids increased in the apical-coronal direction.

Introduction:

Endodontically-treated teeth are often prone to crown fracture due to dehydration, loss of crown structure, and changes in the physical condition.[1] Root canal posts have been recommended for the anchorage of the core build-up and final coronal restoration when the remaining coronal tooth structure is insufficient.[2] Fiber posts are generally more esthetically pleasing than metal posts because they are more natural in color and more flexible than metal or ceramic posts, resulting in a more equal stress distribution on the canal.[3]

The use of computer-aided design and computer-aided manufacturing (CAD/CAM) in flared canals allows the fabrication of a post-and-core in a single piece, thus reducing the chances of structural failure in the material through more controlled milling of the material blocks.[4]

Polyetherketoneketone biomaterial has been introduced in the post-core systems because of its acceptable processing, suitable mechanical strength, shock-absorbing ability, good biomechanical behavior, and fracture resistance compared to metal and fiberglass post-core systems.[5] Manufacturers have also developed new CAD/CAM materials by combining ceramics with composite resin, to create a material that has the high mechanical property and the color stability of ceramics along with the low modulus of elasticity and higher resilience of resin composites. Examples of such hybrid materials include Enamic (VITA Zahnfabrik, Bad Säckingen, Germany).[6]

Adaptation is the degree of fitting between the prosthesis and supporting structures. Poorly fitting posts may result in levers inside the root canal, increasing the tooth's susceptibility to fracture and can produce a marginal void, which can lead to microleakage due to inadequate cementation.[7] One of the most recent and nondestructive methods used in dental research for measuring the accuracy of fit is computed microtomography (µCT), it has already been successfully used in dental research for measuring the microstructure of inner and outer tooth structures and restorative materials.[8]

The use of prefabricated fiber posts is difficult when endodontic treatment leaves a large and irregular root cavity or in badly destructed teeth with flared canals because it cannot achieve an optimum post fit.[9] CAD/CAM custom-made post and core show excellent biomechanical behavior because of their good adaptation to the prepared root canal walls, which promote increased frictional retention and a thin layer of cement, creating favorable conditions for post retention.[10]

The objective of the current study is the evaluation of the internal adaptation of different CAD/CAM post materials which are; fiber reinforced composite, Polyetherketoneketone, and Vita Enamic in flared root

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canals using microcomputed tomography scanning. The null hypothesis is that using different milled post materials would not have any effect on their internal adaptation.

Materials and Methods:

A total of forty extracted natural mandibular first premolars were collected from the clinic of the Oral and Maxillofacial Department, Faculty of Dentistry, Mansoura University suffering from grade III periodontitis. The current research project was ethically approved by the Dental Research Ethics Committee, Faculty of Dentistry, Mansoura University. The ethical approval number is (A20020822).

The sample size was calculated using Power Analysis and Sample Size software program (PASS) version 15.0.5 for windows (2017) using data from a pilot study conducted on 8 samples collected at Mansoura University with cement distance as the primary outcome. A sample size of at least 6 samples in each group is needed to achieve 90% power (1-β or the probability of rejecting the null hypothesis when it is false) in the proposed study using an F test with a significance level (α or the probability of rejecting the null hypothesis when it is true) of 5%. To account for dropouts 10 samples will be taken in each group.

The selection criteria of sample teeth were based on the teeth' condition and dimensions. All teeth were examined for any cracks, caries, old restorations, or any defects using x4 magnification loupes (Ergovision 4.0 x flip-up readymade, Ergovision loupes, China). All defective teeth were excluded. The teeth selected are 21 ±1 mm long with a single root with mature apices. Exclusion criteria were: a tooth with extra roots and root canals, open apices, calcified canal, root resorption, curved roots, immature apices, or any tooth with the presence of other cracks or craze lines at the cemento-enamel junction.

Root canal treatment of selected teeth was done. The root canals were prepared at the working length using F1, F2, and F3 ProTaper Universal files (Dentsply-Sirona, Germany). For irrigation, 2 mL of 2.5% NaOCl solution was used after each instrument change by using 30-gauge side-vented irrigation needles. A master gutta-percha cone with size F3 was coated with sealer (ADSEAL™, Meta Biomed, Inc., Chungbuk, Korea) and fully seated to the working length. Excess gutta-percha coronal to the canal orifice was removed with a warm plugger. An X-ray was taken for each tooth to confirm that each canal was fully obturated especially at the apical third of the canal.

The coronal portions of the teeth were marked 1.5 mm above the cemento-enamel junction with a red marker and then removed using a diamond disc mounted on a straight handpiece attached to a dental surveyor (BF 2, Bredent, Germany) perpendicular to the long axis of each tooth to produce a flat surface.

The gutta-percha was removed from the root canals of teeth using pesso drills to the depth of 9 mm measured from the coronal end of the root. Post-space preparation was done with a low-speed straight handpiece attached to the dental surveyor to obtain vertical preparation with a standard diameter.

Ready-made fiber post space preparation was done in a total number of ten teeth (Group RF) using Glassix plus post drill number #2 (Harald Nordin, Switzerland) of 1.2 mm in diameter to a total length of 9 mm measured from the coronal end of the root. Ten posts (size #2) with a diameter of 1.2 (Ø 1.2) were measured to a total length of 9 mm then the complete fitting of each post inside its corresponding root canal was done. A total number of thirty teeth (group CV, group CF, and group CP) was flared to a depth of 9 mm from the cutting site with a tapered diamond stone (Intensiv, Montagnola, Switzerland) of 10 mm length and 2.5 mm diameter (Blue coded, FG 8237/6).[11] An X-ray was taken for each tooth before and after canal flaring ,Figure 1.

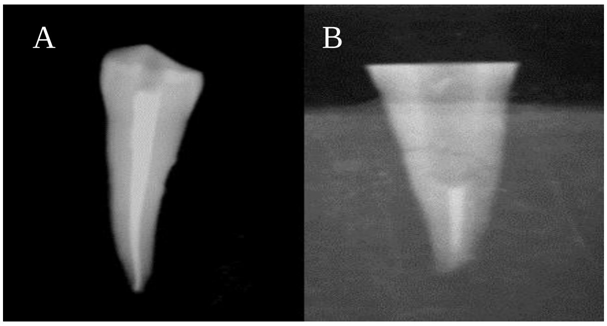

Figure 1. X-ray of a tooth A. After canal obturation and before flaring B. After canal flaring

Direct scanning of the previously flared root canals is done using a laboratory scanner (Identica I500, MEDIT corp, South Korea), and the post and core for all prepared specimens were designed using CAD software (exocad CAD software, version 2.2 Valletta, exocad GmbH, Germany). The cement gap thickness was determined to be 80 µm and the cement gap distance from the margin of the core was 1 mm. When all virtual posts and cores were completely designed, their detailed data was simply transferred into the 5-axis wet/dry milling machine (ED5X, EMAR, Egypt) then all posts from the different materials in the main groups (CV, CF, and CP) were milled.

Air abrasion of Vita Enamic and ployetherketoneketone was done using aluminum oxide particles of 50 µm under a pressure of 2 bar at a working distance of 10 mm for 10 seconds. All posts were cleaned for 10 minutes in distilled water and air-oil free was used to dry the specimen for 15 seconds.

A silane solution (Ultradent silane, ultradent products, Inc. South Jordan) was applied to the surface of the fiber posts for 60 seconds using a brush and air-dried

for 10 seconds.
All posts were cemented using self-adhesive, self-cure resin cement (Multilink speed) (Ivoclar, Vivadent). The cement was gently dispensed with help of a mixing tip inserted into the canal and along the sides of the post. All teeth were scanned using SkyScan 1173 micro-CT scanner (Bruker, Kontich, Belgium) to evaluate the internal adaptation of the posts. The resultant micro-CT Scan images were analyzed with the proprietary software that is available with the scanner.

Cement distance measured by micrometer (µm) was done between the post surface and prepared root canal wall at four sites (Buccal [B] at 0 degrees, the approximal right [AR] at 90 degrees, lingual [L] at 180 degrees and the approximal left [AL] at 270 degrees) and voids volume measured by mm^3. All measurements were done in three sections of the post (cervical, middle, and apical).

Data were transferred to the computer and analyzed using IBM SPSS Statistics for Windows (IBM SPSS Corp 2013, Version 22.0, IBM Corp, Armonk, NY). Normality was tested using Shapiro–Wilk test. Data were described as mean and standard deviation. One-way ANOVA test was used for normally distributed data to compare more than 2 independent groups followed by Post Hoc Tukey test. Kruskal-Wallis test was used for non-normally distributed variables. Significance values have been adjusted by the Bonferroni correction for multiple tests.
The significance of the obtained results was judged at the (0.05) level.

Results:

The mean and standard deviation values of all samples at different points of measurement of cement distance (thickness) and voids volume are listed in Table 1.

According to the one-way ANOVA test and Kruskal–Wallis test, there was a significant difference in cement distance between different groups at the sites and sections. There was a significant increase in buccal cement distance in the cervical and middle sections in the group (RF) while there was a significant decrease in cement distance in the group (RF) in the four sites of measurement at the apical area ($p<0.05$) ,Figure 2.
Analysis of voids volume was done between the post surface and prepared root canal wall in each of the three sections (cervical, middle, and apical). One-way ANOVA test and Kruskal–Wallis test revealed that there was no significant difference in voids volume between groups ($p>0.05$) ,Table 2, Figures 3 and 4.

Table 1. Descriptive statistics of cement distance and voids volume in groups

	Mean	Standard deviation
Cervical cement distance		
Buccal	188	115.02
Approximal right	125.2	28.3
Lingual	134.9	34.8
Approximal left	148.3	45.2
Middle cement distance		
Buccal	240.9	95.9
Approximal right	133.04	44.6
Lingual	148.5	27.8
Approximal left	137.4	44.9
Apical cement distance		
Buccal	142.3	48.4
Approximal right	141.9	55.1
Lingual	148.4	67.4
Approximal left	165.8	58

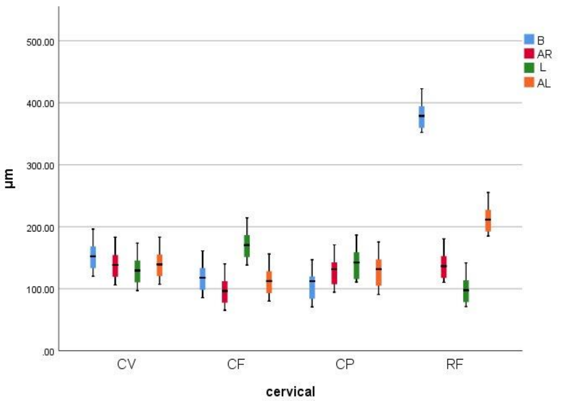

Figure 2. Diagrammatic chart representing the mean values of cement distance (µm) at the cervical area in groups
CV: Custom-made Vita Enamic .
CF: Custom-made fiber post .
CP: Custom-made Polyetherketoneketone .
RF: Ready-made fiber.
(B: Buccal AR: Approximal right L: Lingual AL: Approximal left).

Table 2: Cervical, middle, apical, and overall cement volume (mm^3) in groups

mm^3	CV	CF	CP	RF	Test	P value
Cervical voids volume	0.228 ± 0.26	0.1674 ± 0.17	0.298 ±0.296	0.2941 ±0.24	H:1.085	0.781
Middle voids volume	0.1899 ± 0.243	0.2261 ± 0.22	0.3477 ± 0.36	0.1304 ± 0.11	H: 0.522	0.914
Apical voids volume	0.2192 ± 0.17	0.1693 ± 0.09	0.2113 ± 0.22	0.1439 ± 0.065	F: 0.212	0.885

Data are expressed as mean ± standard deviation
H: The Kruskal–Wallis test
F: One-way ANOVA test
P value is significant if < 0.05
Similar letters donate a presence of significance in pairwise comparisons
CV: Custom-made Vita Enamic
CF: Custom-made fiber post
CP: Custom-made Polyetherketoneketone
RF: Ready-made fiber

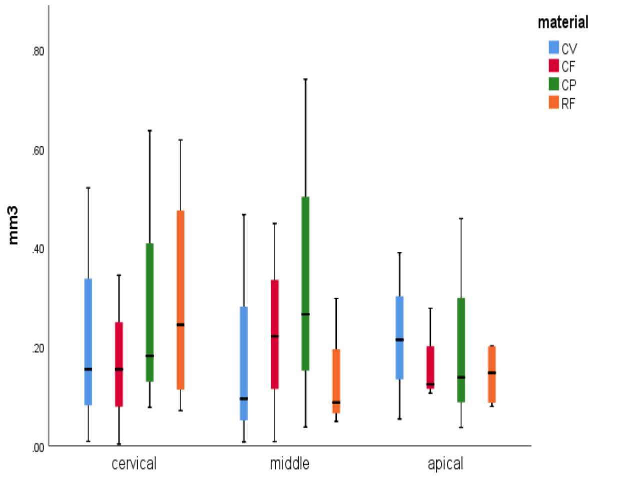

Figure 3. Diagrammatic chart representing the mean values of voids volume (mm^3) at the cervical, middle, and apical sections in groups

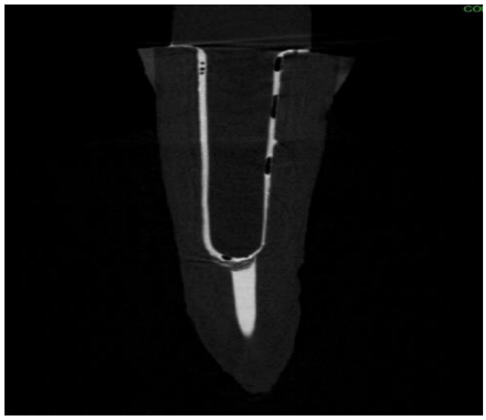

Figure 4. Representative micro-CT image of the CAD/CAM posts(V: Voids, C: Cement, P: Post, R: Root dentin, G: Gutta-percha)

Discussion:

The current study investigated using micro-computed tomography analysis, the influence of post-and-core material on cement distance and the presence and distribution of voids in the cement layer. Based on the results of the present study, the formulated null hypothesis has to be partially rejected, as there was a significant difference in cement distance, and cement volume in groups and no significant differences in the voids volume in groups.

Since prefabricated posts were used in this study, human lower first premolars have been used because they have round to slightly oval shape canals.[12] Post space was determined at the constant length of 9 mm. To maintain an adequate apical seal, a minimum of 4 mm to 5 mm of remaining gutta-percha is recommended. The intraoral scanner can precisely scan post-space lengths up to 10 mm.[13]

Using self-adhesive cement was intended to standardize and simplify the adhesive bonding of all post-and-core restorations, contributing to achieving high mechanical strength, and high bonding efficiency. Also, the choice of self-cure resin cement was intended to overcome the problems associated with improper cement polymerization in the most apical portion of the root canal.[14]

According to the measurements of the cement distance between the post and the prepared root canal, there was a significant difference in cement distance between different groups at the different sites and sections. The mean ± standard deviation of cement distance was 154 ± 67 µm. These results are within the previously reported results obtained by Tsintsadze et al [15] who studied the effects of scanning technique on the performance of CAD/CAM-fabricated fiber posts and found that the cement thickness was 162 ± 24 µm for posts fabricated by the direct scanning of the post space, also within the results of Vaddamanu et al [16] who assessed the layer of cement thickness and nano leakage of luted fiber posts which were fabricated with CAD/CAM technology and recorded 172 ± 39 µm cement thickness of the milled posts fabricated using the direct technique.

There was a marked increase in voids volume in the cervical and middle sections than in the apical section. These findings come in agreement with the results obtained from the study of Uzun et al [17] who analyzed the voids formed in resin cement used for the fiber-post cementation using micro-computed tomography scanning and concluded that there were certain amounts of voids that formed inside the tested resin cement and that the voids increased in the apical-coronal direction. Also in agreement with the results obtained from the study of Rengo et al [18] who evaluated using micro-computerized tomography (micro-CT) the voids in resin cement used for cementation of oval or circular posts in oval-shaped premolars and concluded that a higher amount of voids were present at the coronal third of the post.

The increase in cervical voids volume may be due to the movement of the voids, during post placement, into the root canal from the apical to the coronal third, and the voids that could not be eliminated accumulated in the coronal third region and generated larger voids. From a biological standpoint, void formations may act as a way for microorganisms to pass from the coronal to the peri-apical area. Void formations decrease the bonding strength by restricting the available area for cementation.[16]

The prefabricated posts (RF group) showed the least voids volume and voids area between groups in all sections. This result disagrees with the result obtained by Gama et al [10] who used microcomputed tomography scanning to compare the voids volume of CAD/CAM milled glass fiber posts and prefabricated fiber posts in flared root canals and concluded that CAD/CAM milled glass fiber posts presented lower voids volume when compared to prefabricated glass fiber posts. This difference may be related to the difference in the selected resin cement, cementation technique, and cement gap in CAD/CAM milled posts.

There were some limitations in the current in vitro study. Firstly, the intraoral environment is difficult to be completely replicated through both thermocycling and cyclic mechanical loading because of their complex procedures and individual differences. Further in vitro and in vivo studies are needed. Further research is needed to investigate and compare different drilling systems, and retention with different cementation techniques.

Conclusions:

Within the limitations of this in-vitro study, it was concluded that

Different CAD/CAM milled post materials fabricated from fiber, Polyetherketoneketone, and Vita Enamic presented adequate internal adaptation to flared root canals.

Recorded internal adaptation was within the clinical acceptability of the previously reported studies.

The voids increased in the apical-coronal direction.

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