ASSESSMENT OF INTERNAL FIT OF CUSTOM-MADE POSTS FABRICATED BY OPTICAL IMPRESSION

(AN IN-VITRO STUDY)

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ABSTRACT:

Aim: The aim of the study was to compare the internal fit of custom-made post fabricated by direct scanning of post space with indirect technique (Addition silicon).

Methodology: Twenty single rooted teeth were endodontically treated and prepared to depth 12 mm for receiving post and core restorations. The specimens were randomized into two equal groups: CAD/CAM PEEK post and core restorations for group I, were obtained by direct scanning intracanal. For group II polyvinylsiloxane impressions of the post space were scanned. Post and core restorations were milled and cemented on their respective teeth. All the twenty specimens were then sectioned horizontally, and the cement thickness was evaluated using a steromicroscope. **Results:** The CAD/CAM post and core restoration fabricated by the direct scan approach had the least cement thickness and attained higher adaptation in comparison with conventional impression scanning technique within non-significant range. **Conclusions:** Within the limitations of this study; CAD/CAM scanning methods to post fabricated from Polyetheretherketone, presented adequate internal adaptation to root canal within the accepted clinical range. Direct scanning is considered as an alternative tothe conventional impression in fabrication of PEEK post and core restorations.

Key Words: Post and core, PEEK, Intra-radicular impression, CAD/CAM, Internal fit.

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INTRODUCTION:

Custom made post and cores are still considered to be the gold standard for restoring extensively damaged endodontically treated teeth. It can provide excellent retentions by reducing cement volume, which improves the post's fitness to the root walls [1].

CAD/CAM technology employs two primary manufacturing approaches: additive and subtractive. Additive manufacturing constructs objects layer by layer, building them up from raw material. Conversely, subtractive manufacturing removes material from a solid block to create the desired shape, using techniques such as machining, milling, or laser ablation [2].

Digital technologies possess the potential to replace traditional methods in the creation of posts and cores. Nevertheless, the precision of restorations produced through digital processes remains a subject of extensive research.

Polyetheretherketone (PEEK), a high-performance polymer with confirmed biocompatibility, offers an aesthetically pleasing option for post and core restorations beneath ceramic crowns, it exhibits a low modulus of elasticity close to the dentin fabrication by (CAD-CAM) technology [3].

Polyetheretherketone (PEEK) is a synthetic, tooth-colored polymer widely used in medical and dental applications due to its biocompatibility. Its versatility is enhanced by its ability to incorporate materials like carbon, glass, or ceramic fibers. Known for its low density, lightweight properties, shock absorption, and biocompatibility, PEEK can be veneered with composite resin. As a framework material for both fixed and removable dental prostheses, PEEK can be fabricated using CAD/CAM milling techniques or pressed from granular or pellet forms [4].

The null hypothesis postulated no difference in the internal fit of direct scanning of post space and indirect scanning of conventional impression post system.

MATERIALS AND METHODS

Teeth Selection and storage

Twenty teeth were collected extracted for orthodontic purposes and selected with straight roots, with mean length of 23±1 mm measured by digital caliber (Hogetex, China).The collected teeth were sterilized and stored in accordance with the Occupational Safety and Health Administration (OSHA) regulations. After that all samples werede-coronated at the cement-enamel junction with low-speed sectioning discs leaving standardized 15 mm length of root samples then endodontic preparation was done.

Sample Preparation

Each tooth was stored in a separate container numbered from 1 to 20.All the samples were prepared byde-coronated at the cement-enamel junction with low-speed sectioning discs (CUTFLEX® diamond discs, Dental Future Systems DFS DIAMON, GERMANY). leaving standardized 15 mm length of root samples then endodontic preparation was done (Figure 1).

Figure 1: Tooth sectioning by using metal disk leaving 2 mm above the CEJ.

Endodontic treatment

Root canal instrumentation was performed using the MPro rotary system®.Gutta percha (Meta Biomed, KOREA) points were coated with resin sealer (ADSEAL, META Biomed CO., LTD.) and inserted into the root canal. The auxiliary Gutta-Percha points were chosen and compacted by lateral condensation.

Teeth mounting

The teeth were positioned upright and encased in epoxy resin (KEMAPOXY 150, manufactured by CMB Chemicals, Egypt). The teeth were centered within a plastic cylindrical container measuring 14 millimeters in diameter and 25 millimeters in height. One millimeter of the tooth was left exposed above the epoxy resin block.

Post space preparation

After one week from endodontic treatment, Gutta percha was removed from each root canal using a Gates Glidden drill (Mani, Japan) size (3, 4) to remove Gutta percha and achieve post length of 12 mm, leaving 3 mm Gutta percha in the apices, to maintain the apical seal. The drill stopper was adjusted to 12 mm post length, then post space preparation was done by using Piezo drills (Mani, Japan) size 3 to size 4 then finished by using parallel-meter device (Nouvag USA Inc., USA.) to standardize preparation (Figure 2). The canal was shaped and cleaned with copious amounts of saline solution between each drilling phase. After creating the post space, all samples underwent radiographic examination to verify the complete removal of sealer and gutta-percha from the canal walls.(Figure 3a and 3b).

Figure 2: post space preparation by Piezo drill.

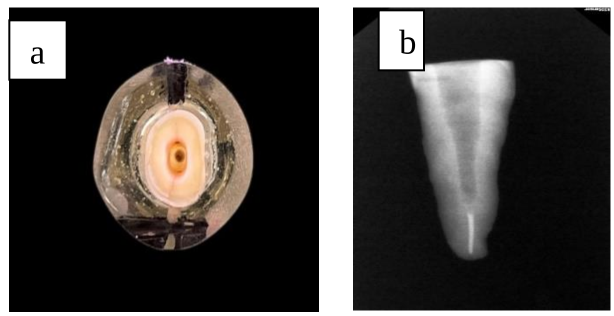


Figure 3: Showing (a) sample after post space preparation; and (b) Radiograph of extracted samples after root canal preparation

A total of twenty extracted single rooted teeth were randomly categorized into two primary groups, each containing 10 teeth:

Group I: Included samples subjected to direct intraoral scanning via Prime scan.

Group II: Included samples subjected to scanning of conventional impression (Addition silicone).

Post space scanning

Direct post space scanning was done by using an Intra-oral scanner (Prime scan, Dentsply Sirona, USA) by capturing digital impressions of the prepared post space directly. manufacturer's instructions were followed for scanning operation to ensure proper calibration for accurate imaging and taking multiple scans from various angles to ensure comprehensive coverage of the post space (Figure 4). This helps in obtaining accurate 3D representations of the tooth structure and post space morphology. After evaluating the digital impressions to assess the dimensions, depth, and angulation of the post space, post space was checked by software to measure these parameters accurately, ensuring compatibility with the intraoral scanning system.

Figure 4: Direct scanning for post space

Post space impressions

Before making direct impression to the root canal, dis-bonding agent (MULTI-SEP Separating Medium; GC America) introduced inside the root canal, then by using plastic post and extra flow addition silicone (PANASIL, GERMANY) the impression was made and impression assembly was carried by putty cap (Figure 5). Then the impressions were scanned by Intra-oral scanner (Prime scan, Dentsply Sirona, USA) (Figure 6).

Figure 5: Post space impression.

Figure 6: Scanning of impression.

Designing of PEEK Post

PEEK posts were designed by CAD software (EXOCAD) firstly, restoration material was selected then the type of restoration defined. After that, designing started with margin detection.

PEEK post Milling

After complete designing of posts and cores for all samples, the digital design of the custom post and core, saved as an STL file, was transferred to specialized dental CAM software. This software generated instructions for a five-axis milling machine to create the final product without using coolant (REDON Dental Milling Machine, ISTANBUL, TURKEY) then the custom-made post and core ready for milling from PMMA for try-in.
After that, the milling process of PEEK blank (BREDENT, breCAM.BIOHPP, GERMANY) with (diameter 98.5mm / thickness 20mm) was done by five-axis dry milling machine (REDON Dental Milling Machine, ISTANBUL, TURKEY).
After milling, the posts and cores were detached from the blank and the length of the post was checked. Then the post was placed in its corresponding root canal without any internal adjustment and seating was checked (Figure 7).

Figure7: PEEK post after separation from PEEK block

Post cementation

All posts and cores were cemented following the BioHPP manufacturer's protocol. The sandblasting procedures was done by 50 µm AL2O3 (Basic-eco sandblaster; Renfert GmbH, Hilzingen, GERMANY) with 4 bar air pressure for 14 s, The second step of surface treatment was applying a primer (Visio.link, Germany) on the post surface and light curing for a 90 sec. Dual-cure self-adhesive resin cement (Bisco Duo-link, Schaumburg, U.S.A) was used, each sample was placed on the lower compartment of the loading device, while a static load of 5 kg was applied directly on the upper compartment for 2 min. The excess cement was removed with a micro-brush before curing. The cement was subsequently polymerized using a Bluephase LED light curing device (iLED WOODPECKER, CHINA) at 1,200 mW/cm through the cervical portion of the root for 40 seconds.

Samples preparation for internal fit test

The initial one-millimeter segment of each sample below the CEJ was removed. Subsequently, a two-millimeter-thick coronal slice was prepared from each sample. The coronal, middle, and apical sections of each specimen were marked with red, blue, and yellow indelible markers, respectively.

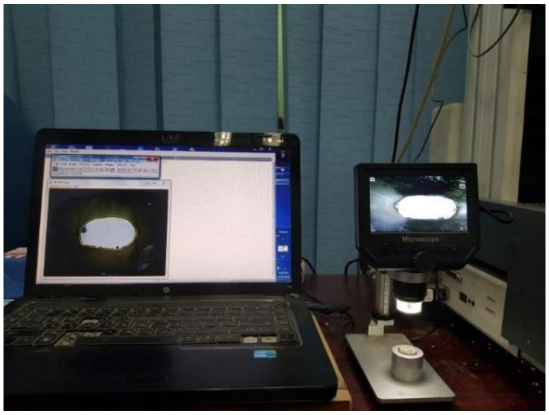
Internal fit of posts

The specimens were affixed to glass slides and examined exclusively on their coronal surfaces. Utilizing a USB digital microscope equipped with a camera, each section was observed at a magnification of ×50. The captured images were subsequently transferred to image analysis software for further evaluation.

Image acquisition was performed using a U500x Digital Microscope (Guangdong, China) equipped with a 3-megapixel camera positioned vertically at a distance of 2.5 cm from the samples. The camera angle was perpendicular to the light source. Illumination was provided by eight adjustable LED lamps with a high color index of approximately 95%.

High-resolution images were captured using an IBM-compatible personal computer and a fixed magnification of 50X. Each image was recorded at a resolution of 1280 x 1024 pixels.

Image J 1.43U software (National Institutes of Health, USA) was employed to quantify cement thickness. As Image J measurements are pixel-based, a calibration process was conducted using a ruler to convert pixel values into real-world units (micrometers). For each specimen, images were captured and analyzed. The software delineated and measured the total root canal area. Morphometric measurements were taken at four points around the root canal circumference for each image (Figure 8). The average of these measurements determined the thickness in micrometers.



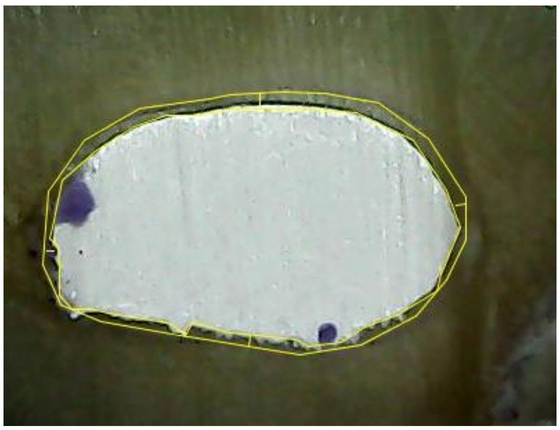


Figure 8: Section under microscope 50X revealing four measuring points

Statistical Analysis

Statistical analysis utilized SPSS 20®, Graph Pad Prism®, and Microsoft Excel 2016. Data normality was assessed with the Shapiro-Wilk and Kolmogorov-Smirnov tests. Quantitative data were presented as mean and standard deviation, analyzed with One-Way ANOVA and student t-test for group comparisons. Two Way ANOVA was employed for evaluating the effect of different variables on fracture resistance. Qualitative data were presented as frequency and percentages and analyzed using the Chi-square test. Significance was set at $P<0.05$.

RESULTS:

Descriptive statistics for sealer thickness (µm) measurements (Table 1).

The influence of various factors and their interactions on sealer thickness (µm) (Table 2). Only the root section had a significant effect on thickness ($p<0.001$).

Intergroup comparisons, mean and standard deviation values of thickness (µm) for different acquisition methods (Table 3). Scannedimpression samples had a higher thickness than intraoral scanner samples, yet the difference was not statistically significant ($p=0.633$).

There was a significant difference between different sections in intraoral sections and conventional impressions sections ($p<0.001$). Thickness measurements revealed the greatest values in the apical region, followed by a gradual decrease towards the middle and coronal sections. All post hoc pairwise comparisons were statistically significant difference ($p<0.001$) (Table 4).

Table 1: Descriptive statistics for the cement thickness (µm).

Root section	Acquisition method	Mean	95% Confidence interval		SD	Min.	Max.
			Lower	Upper			
Apical	**Intraoral section**	59.69	50.05	69.33	15.56	40.16	86.19
	Conventional impression	63.05	53.30	72.80	15.74	44.28	86.85
Middle	**Intraoral section**	43.35	36.99	49.71	10.26	32.25	65.87
	Conventional impression	47.11	37.88	56.34	14.90	30.12	80.79
Coronal	**Intraoral section**	31.82	25.69	37.96	9.90	19.13	47.99
	Conventional impression	29.82	25.42	34.22	7.10	18.24	42.12

Table 2: Effect of different variables and their interactions on sealer thickness (µm)

Source	Sum of Squares (II)	df	Mean Square	f-value	p-value
Acquisition method	43.56	1	43.56	**0.23**	**0.633ns**
Root section	9342.33	1	6442.99	**31.40**	**<0.001***
Acquisition method * root section	103.73	1	71.54	**0.35**	**0.640ns**

Table 3: Intergroup comparisons, mean and standard deviation values of sealer thickness (µm) for different acquisition methods.

Sealer thickness (µm) (Mean±SD)		p-value
Intraoral section	**Conventional impression**	
44.95±16.53	46.66±18.76	**0.633ns**

Table 4: Intergroup comparisons, mean and standard deviation values of sealer thickness (µm) for different acquisition methods and root sections.

Acquisition method Root section	Sealer thickness (µm) (Mean±SD)		p-value
	Intraoral section	**Conventional impression**	
Apical	59.69±15.56^{A}	63.05±15.74^{A}	**0.637ns**
Middle	43.35±10.26^{B}	47.11±14.90^{B}	**0.519ns**
Coronal	31.82±9.90^{C}	29.82±7.10^{C}	**0.609ns**
p-value	**<0.001***	**<0.001***	

DISCUSSION:

This study determined that, the generated CAD/CAM post and core restoration fabricated by the direct scan approach had the least cement thickness and attained higher adaptation in comparison with conventional impression scanning technique within non-significant range.

Customized PEEK post and core restorations produced by direct intraoral scanning offer least cement thickness control compared to those fabricated by scanning impressions. Direct intraoral scanning captures the precise geometry of the prepared tooth, including fine details and undercuts, thereby producing a more accurate digital model. This precision reduces discrepancies and distortions that can occur when using traditional impression materials, which can expand or shrink, leading to inaccurate models. As a result, restorations fabricated from direct intraoral scans fit more uniformly, ensuring a more consistent and optimal cement layer. A recent study by Kasem et al [5] found that direct intraoral scanning significantly improved the marginal fit and cement thickness of PEEK post and core restorations compared to those produced by conventional impression techniques. This could be affected by storage period of the impression and media that altered in dimensional stability. This improvement in cement thickness is crucial for the longevity and success of restorations, as it minimizes the risk of cement washout and secondary caries.

Vogler et al [6] compared the accuracy of fit between CAD/CAM and conventional cast post and core restorations, evaluating both digital and traditional impression methods. Their findings indicated a significantly superior fit for CAD/CAM restorations compared to conventional ones ($p = 0.022$).

And by agreement with the results of previous study examined the consequence of using two different intracanal impression techniques on the accuracy and adaptation of CAD/CAM restorations hybrid ceramic post and core restorations, they found that in the impression scanning technique, the overall space that was made between the canal walls and posts was less in comparison with the acrylic pattern scanning technique [7].

This was also supported by Kanduti et al [8] compared the accuracy of conventionally fabricated posts with those produced using a CAD/CAM digital workflow. Cement thickness measurements were taken on four cross-sections of each post. The results showed a thicker cement layer in the apical and middle sections compared to the coronal section for both groups. While CAD/CAM posts exhibited consistently thicker cement layers, both methods demonstrated comparable accuracy in the cervical region. However, the apical accuracy was significantly better for the conventionally fabricated posts.

Comparison between the three horizontal slices for each group was performed to evaluate the internal adaptation of the posts at each area of the root. Cement thickness measurements revealed the thinnest layer in the coronal section, followed by a thicker layer in the middle, with the thickest layer found apically. Statistically significant variations were found between the coronal and apical portions. This discrepancy may be attributed to the finishing step in the laboratory, the PEEK post may be subject to manual or machine-based finishing processes. These processes can introduce surface scratches and irregularities, especially in the more delicate and less accessible apical portion. Scratches and rough surfaces can create micro-spaces that require additional cement to fill [9].

Contrary to the findings of Naddar et al [10], the current study produced different results regarding cement thickness. While Naddar et al. reported the thickest cement in the coronal section for the CAD/CAM group and the middle section for the Press group, with a gradual decrease towards the apical region in both groups, this study revealed significantly greater internal gaps in all sections of the CAD/CAM group compared to the Press group (p=0.0001).

An important consideration for milling internal contours in the CAM process is that the milling instrument diameter and shape may reduce the machining accuracy and fit of the restorations. It is necessary for clinicians to prepare rounded internal angles for CAD-CAM post and cores because round-ended milling burs cannot accurately reproduce sharp angles. Moreover, during the milling process, factors such as diamond rotary cutting instrument wear and water quality can have an impact on the quality of the restorations [7].

The null hypothesis was supported, indicating no difference in internal fit between direct scanning post space and direct scanning impression post system by intra oral scanner was accepted.

The introduction of PEEK biomaterial in post and core systems is attributed to its favorable processing characteristics, superior internal fit, adequate mechanical strength, shock absorption capacity, and resistance to fracture. Additionally, manufacturers have developed CAD/CAM materials with a reduced modulus of elasticity that more closely resembles dentin [11].

The use of PEEK in post and core restorations has gained popularity due to its favorable mechanical properties and biocompatibility. Surface treatment by Sandblasting method involves high-velocity abrasive particles at the PEEK surface, effectively enhances its surface roughness and energy, thereby improving its bonding potential. This process creates micro-retentive features that facilitate better mechanical interlocking with dental adhesives and composites. Recent studies have highlighted the efficacy of sandblasting in enhancing the bond strength of PEEK in post and core applications [12].

To mimic clinical conditions, single-rooted teeth with similar root dimensions and canal configurations were selected. This choice was based on the prevalence of single, straight root canals in these teeth, which often renders them more susceptible to trauma and fracture, consequently increasing the need for endodontic treatment and restorative procedures. They were kept in a humid environment of saline until usage to avoid dehydration and occurrence of dentinal defects as cracks and fracture thought the work of study [13]

The direct scanning procedure by (Primescan Sirona) was done for the first CAD/CAM group which in turn has a great depth of scanning reach to 22 mm, full dental arch scan in a little as a minute, a high degree of accuracy, easy handling, and hygienic safety. Primescan enables high-precision digital impressions with outstanding imagery. As it acquires images with the aid of light and does not require surface coating with powder [14].

Using the same scanner used for the second group which was direct scanning to impression post, conventional impressions are taken for standardization. The use of elastomeric impression material (addition silicon) for its accuracy and biocompatibility of these materials. These semi-digital methods can be easily adapted into clinical practice and can also be used by clinicians not having access to an intraoral scanner. It could help eliminate many laboratory steps and thereby improve the ease, accuracy, and speed of manufacturing [15].

CONCLUSIONS:

Within the limitations of this study

1. CAD/CAM scanning methods of post presented adequate internal adaptation to root canal within the accepted clinical range.
2. Direct scanning by prim scan is considered as an alternative toimpression in fabrication of PEEK post and core restorations.

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