# ASSESSMENT OF PUSH-OUT BOND STRENGTH OF PEEK POSTS CONSTRUCTED USING OPTICAL IMPRESSION TECHNIQUE
# (AN IN VITRO STUDY)

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**ABSTRACT:**

**Aim:** Evaluation of push out bond strength of PEEK custom made post made with direct scanning of post space versus scanning of conventional impression (Addition silicon) of the post space. **Methods:** Twenty-Six single rooted teeth were chosen then endodontically treated and prepared at depth 12 mm for receiving post and core restorations. The samples were randomized into two equal groups: group I, CAD/CAM PEEK post and core restorations were obtained by direct scanning intracanal space. For group II, polyvinylsiloxane impressions (addition silicon) of the post space were scanned. Post and core restorations were milled and cemented on their respective teeth. All of the 26 specimens were then sectioned horizontally, and the post and core push-out bond strength were evaluated using a universal testing machine. **Results:** Push out bond strength values were non-significant between direct scanning post space and scanning conventional impression post. The bond strength was slightly higher for coronal third than middle and apical third within non-significant range. **Conclusion:** within the limitations of this study Direct scanning by prim scan offers a viable and clinically acceptable alternative to the conventional impression technique and can be used successfully for manufacturing custom post and core restorations.

**Key Words:** Post and core, PEEK, CAD/CAM, Scanning, Bond strength.

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## INTRODUCTION:

The risk of tooth fracture is an undesirable incident usually related to insufficient coronal tooth structure after endodontic treatment. Rebuilding of the tooth structure by a post and core prior to crown restoration is sometimes mandatory to provide a stable and solid restoration of the tooth. Treatment decisions and strategies should be based on the best and most-up-to-date materials and evidence available [1].

Post application is highly important for building up a core material in situations of a large loss of tooth Structure. Custom made post and core is highly successful and gives excellent results due to its approximating and adapting to the morphology of the prepared canal. It acts as corona-radicular stabilizers for single rooted teeth that becomes weak because of the combined impact of tooth structure reduction during tooth and access preparation. On the other hand, it has some drawbacks that make its use difficult and limited like. It is more expensive than prefabricated posts, many visits from the patient are needed because it needs to be sent to the laboratory. In cases where the post fails to adapt properly, it can create a gap or space within the canal, providing a breeding ground for bacterial infection and potentially leading to lever-like forces within the root canal. This, in turn, heightens the tooth's vulnerability to fracture and debonding [2].

The application of CAD/CAM technology in dentistry is no longer confined only to crowns, inlays, onlays, and fixed partial dentures. The growing success of using CAD/CAM fabricated post and cores provides various benefits, including enhanced precision and creating restorations better in quality control. Spreading of intra-oral scanners in dental clinics has provided a better experience for the patient and an easier way of creating an impression model in a more predictable and repeatable way to alleviate problems encountered in a conventional workflow using traditional methods with a tray-based impression. When digital intra-oral scanners were introduced, the fully digital work flow became a reality [3].

The increasing in patient demand for greater aesthetics led to the creation of new posts and cores of non-metallic materials as an alternative such as Polyetheretherketone (PEEK) which is a tooth-colored synthetic thermoplastic polymer, which exhibits appropriate mechanical and shock-absorbing properties and can be fabricated by (CAD-CAM) technology. It is a promising material providing less risk in root fracture if used in post and core systems [4].

Several methods have been used to assess the bond strength of fiber posts to root dentin; micro tensile, pull-out and push-out tests have been tried for this purpose. Thus, the objective of the current study was to evaluate push out bond strength of PEEK custom made post that is made with direct scanning of post space versus scanning for conventional impression (Addition silicon).

The null hypothesis stated that there would be no apparent variance in the bond strength between direct scanning of post space and indirect scanning of conventional impression post system.

## MATERIALS AND METHODS:

### Teeth Selection and preparation

A total of twenty-six extracted natural human teeth, were collected from the clinic of the Oral and Maxillofacial Department, Faculty of Dentistry, Cairo University, and were stored in saline. The selection criteria of sample teeth were based on the teeth condition and dimensions with intact clinical crowns. The teeth selected are 21 ±1 mm long with a single root with mature apices [5].

All the teeth were cleaned and de-coronated at the cement-enamel junction with low-speed sectioning disc (CUTFLEX® diamond discs, Germany) leaving standardized 15 mm length of root samples [6].

### Endodontic Treatment

The same operator performed standardized endodontic treatment on all teeth, using a carbide Round Burs (Dentsply Maillefer, Switzerland) for access cavity creation. Canal enlargement utilized an engine-driven rotary Nickel-Titanium (NiTi) system, extending up to a 2-degree taper and 0.4 mm diameter for apical preparation with the crown-down technique [5].

### Teeth Mounting

Teeth were embedded in epoxy resin (KEMAPOXY 150, CMB chemicals, Egypt) using a dental surveyor (KEMAPOXY 150, CMB chemicals, Egypt), ensuring each tooth was parallel to its long axis.

### Post space preparation:

The gutta-percha was removed from the root canals of teeth using Gates Glidden (size 2, 3, 4) to the depth of 12 mm measured from the coronal end of the root. Post-space preparation was done with Piezo drill (MANI, Japan) size 3 to size 4 and Radiographic x ray was done after preparation. The teeth were randomly divided into two equal groups (n=13) [6] (Figure 1a, 1b and 1c).

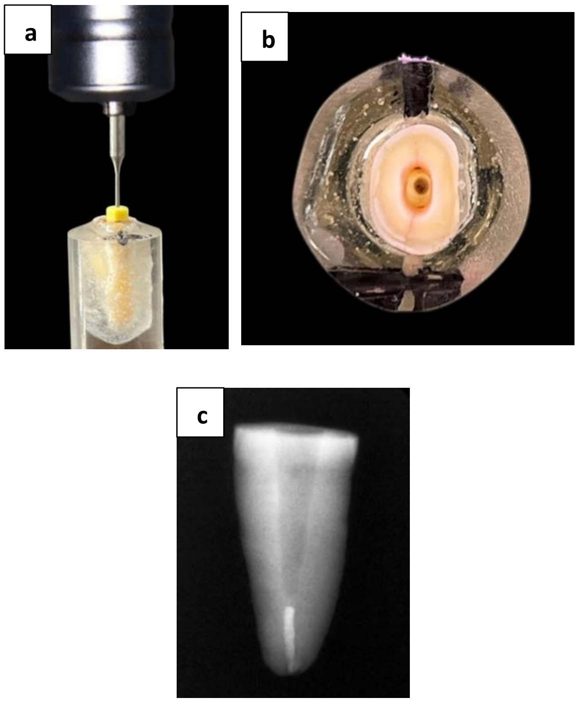



**Figure 1**: Showing (a) Post space preparation by Piezo drill (b) after post space preparation and (c) Radiographic x-ray after root canal preparation.

**Post space scanning:**

Direct scanning of the previously flared root canals of the first group was done using Intra-oral scanner (Prime scan, Dentsply Sirona, Gremany) following manufacturer's instructions for scanner operation and ensure proper calibration for accurate imaging [7] (figure 2)

**Figure 2**: Showing Direct scanning for post space

**Post space impression**

Using an indirect double-impression procedure, the prepared root canals were molded with addition silicone (polyvinylsiloxane) impression material (PANASIL,Germany) using prefabricated polycarbonate posts designed for root canal impression. Separating medium was applied inside the root canal before making the impression [8], finally, the impression assembly carried by putty cap. then, Direct Scanning of impression by Intra-oral scanner. Then the processed data was exported as STL files for further interpretation [9] (figure 3a, 3b and 3c).

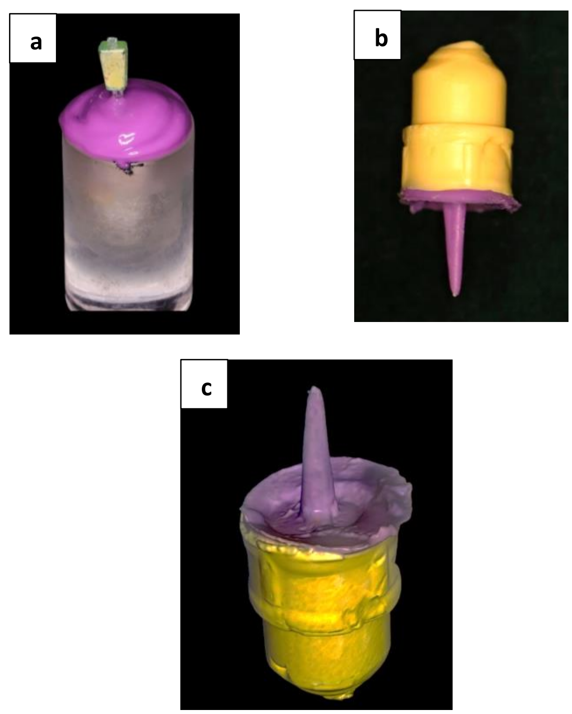



**Figure 3:** Showing (a) & (b) Post space impression; and (c) Scanning of impression.

**Fabrication and Surface treatment of PEEK posts:**

The post and core for all prepared specimens were designed using CAD software (Exocad, Darmstadt, Germany) and cement gap thickness was determined to be 20 μm [10] (figure 4).

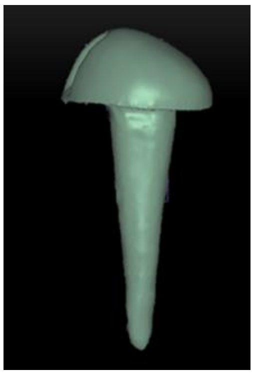


**Figure 4:** Showing PEEK post designing by using Exocad software.

After CAD processing, the STL file was transmitted to dental CAM software for programming and a five-axis dry milling machine (REDON Dental Milling Machine, Istanbul, Turkey) [11].

After milling, samples 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 [11] (figure 5).

**Figure 5:** Showing PEEK post after separation from PEEK blank.

The surface of specimens was air abraded with 110 μm Al2O3 particles (Basic eco, 110 μm, 230 V) with 2 bar pressure at a working distance of 10 mm for 15 s then air dried for 15s [12].

A uniform thin layer of the Visio.Link material (Bredent©, Germany) was applied onto the PEEK specimen as shown figure (29) and polymerized by light curing for a 90 sec [13].

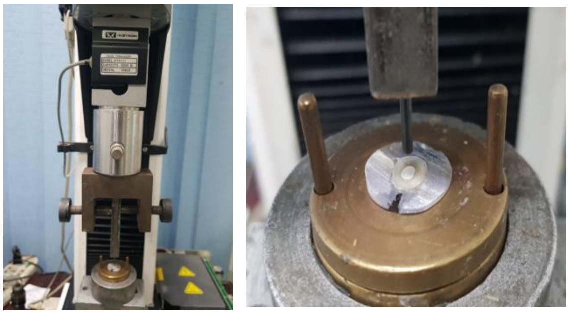
**Cementation**

Posts were bonded to corresponding samples using dual-cured resin cement (Bisco (Duo-link), Schaumburg, USA.) utilizing a loading device. Excess cement was removed, and adhesive resin was light-cured for 20 seconds on each surface [14].

**Samples preparation for push-out test**

Each epoxy resin block was mounted on the holding device of a low-speed saw and cut perpendicular to the long axis of the sample into 3 sections (coronal, middle and apical). Every slice was 2 mm thickness for each sample and push-out bond testing done by using universal testing machine (Model 3345; Instron Industrial Products, Norwood,MA, USA) [14] (figure 6a and 6b).

**Figure 6:** Showing (a) INSTRON® 2710-113
(b) Load was directed in apico-coronal direction.



**Statistical Analysis**

Numerical data were presented as mean with 95% confidence intervals (CI), standard deviation (SD), minimum (min.) and maximum (max.) values. They were explored for normality and variance homogeneity by checking the data distribution and using Shapiro-Wilk's and Levene's tests, respectively (Table 1). They were normally distributed with homogenous variances and were analyzed using mixed model two-way ANOVA. Main and simple effects comparisons were made utilizing the ANOVA error term with p-values adjustment using the False Discovery Rate (FDR) method. The significance level was set at $p<0.05$. Statistical analysis was performed with R statistical analysis software version 4.3.3 for Windows (Table 2).

## RESULTS:

The obtained P-values (>0.05) indicated insignificance, suggesting normal distribution of parametric data in all groups. Group comparisons revealed no significant differences. The comparison between conventional impression samples (1.76±0.36) (MPa) had a higher bond strength than intraoral scanner samples (1.60±0.44) (MPa), yet the difference was not statistically significant (p=0.083) (Table 3). For direct intraoral scanning group, there was no significant difference between bond strengths values measured at different sections (p=0.354). The highest bond strength was measured at coronal section (1.70±0.45) (MPa), followed by middle section (1.67±0.52) (MPa), while the lowest bond strength was found at apical section (1.44±0.31) (MPa). Upon conventional impression group, there was no significant difference between bond strengths values measured at different sections (p=0.088). The highest bond strength was measured at middle section (1.96±0.31) (MPa), followed by coronal section (1.72±0.32) (MPa), while the lowest bond strength was found at apical section (1.61±0.39) (MPa) (Table 4).

**Table 1:** Descriptive statistics for the push-out bond strength (MPa). Mean and standard deviation of both groups.

| Root section | Acquisition method | Mean | 95% Confidence interval | | SD | Min. | Max. |
|---|---|---|---|---|---|---|---|
| | | | Lower | Upper | | | |
| **Coronal** | **Intraoral section** | 1.70 | 1.35 | 1.99 | 0.52 | 0.78 | 2.65 |
| | **Conventional impression** | 1.96 | 1.77 | 2.15 | 0.31 | 1.48 | 2.46 |
| **Middle** | **Intraoral section** | 1.67 | 1.42 | 1.98 | 0.45 | 1.10 | 2.63 |
| | **Conventional impression** | 1.72 | 1.52 | 1.92 | 0.32 | 1.12 | 2.11 |
| **Apical** | **Intraoral section** | 1.44 | 1.25 | 1.63 | 0.31 | 1.00 | 1.95 |
| | **Conventional impression** | 1.61 | 1.37 | 1.85 | 0.39 | 1.14 | 2.21 |

**Table 2:** Effect of different variables and their interactions on push-out bond strength (MPa)

| Source | Sum of Squares (II) | Df | Mean Square | f-value | p-value |
|---|---|---|---|---|---|
| **Acquisition method** | 0.39 | 1 | 0.39 | **3.38** | **0.083ns** |
| **Root section** | 0.88 | 2 | 0.44 | **2.57** | **0.091ns** |
| **Acquisition method * root section** | 0.18 | 2 | 0.09 | **0.54** | **0.590ns** |

**Table 3:** Intergroup comparisons, mean and standard deviation values of push-out bond strength (MPa) for different acquisition methods.

| Push-out bond strength (MPa) (Mean±SD) | | p-value |
|---|---|---|
| **Intraoral section** | **Conventional impression** | |
| 1.60±0.44 | 1.76±0.36 | **0.083ns** |

**Table 4:** Intergroup comparisons, mean and standard deviation values of push-out bond strength (MPa) for different acquisition methods and root sections.

| Acquisition method / Root section | Push-out bond strength (MPa) (Mean±SD) | | p-value |
|---|---|---|---|
| | **Intraoral section** | **Conventional impression** | |
| **Coronal** | 1.70±0.45$^{A}$ | 1.96±0.31$^{A}$ | **0.147ns** |
| **Middle** | 1.67±0.52$^{A}$ | 1.72±0.32$^{A}$ | **0.147ns** |
| **Apical** | 1.44±0.31$^{A}$ | 1.61±0.39$^{A}$ | **0.284ns** |
| **p-value** | **0.354ns** | **0.088ns** | |

## DISCUSSION:

In regard to the results of this study; it was found that the custom post and core fabricated by both direct and indirect scanning techniques are considered comparable within non-significant range. As in a fully digital workflow, the IOS has hardware with a high depth of focus and an updated software version to facilitate good accuracy of fit.

Primescan IOS combines Structured Light-Confocal microscopy with Smart Pixel sensors, high frequency contrast analysis and dynamic depth scan. It is a video and photo-based scanner powered by artificial intelligence. It can achieve high levels of trueness. It does not require surface coating with powder, which is more accurate. It can record depths of a range of 12–21 mm. The scanning depth was assumed to affect both the feasibility of scanning and the accuracy of the scan data. An increasing amount of IOS light entering the post space during scanning, as a tapered post drill was used for creating post spaces, achieved wide entrance for scanning. Although, scanning the elastomeric impressions reported slightly higher in bond strength than those fabricated by direct scanning to the canal, due to better dimensional accuracy of addition silicone elastomeric impression materials could have led to better recording fine details of the post space anatomy, this agreed with Almalki et al, Sheth et al [15][16].

This results also supported by Dimitrova et al [3], who published a review of literature report on studies of post and core restorations that fabricated by CAD/CAM versus Conventional Methods in terms of their bond strength, fabrication techniques, and clinical performance. They concluded that, the CAD/CAM fabricated post and cores viewed as an alternative to traditional procedures. Both have comparable results with in non-significant range. Both techniques have excellent fracture resistance, bond strength, adaptability, and aesthetics, there have been few in vivo investigations reported so far. As the Capabilities of intraoral camera demonstrates impressive scanning abilities for post space average lengths up to 10 mm. Combining digital accuracy with tangible craftsmanship, resulting in precise restorations.

In contrast to our results, Tsintsadze et al [17], compared the push-out strength, cement layer thickness and interfacial nanoleakage of luted fiber posts fabricated with CAD-CAM technology following three different scanning techniques: direct scanning of the post space (DS); scanning of a polyether impression of the post space (IS) and scanning of a plaster model of the post space (MS). They found that Posts fabricated by DS achieved strongest retention, while IS and MS group fiber posts showed comparable results. As the direct acquisition systems are described as less invasive, quicker and more precise than the indirect methods as it can record fine details clearly.

The results obtained were consistent too with that of Hendi et al [18], who tested The effect of conventional (direct acrylic resin pattern), half-digital (scanning PVS impression), and full-digital fabrication (direct scanning) techniques on the retention and apical gap of post and core restorations by pull out test. They found that, the conventional technique was more accurate and resulted in higher retention than both the full- and half-digital techniques. These results suggest that the post space length preparation increases, the accuracy of IOS decreases as there was a noticeable decrease in accuracy in the apical third.

Regarding root canal regions, the findings of this study revealed a non-significant difference in bond strength for different root canal regions, with greater bond strength values in the coronal third in comparison to the other thirds.

These findings are consistent with those of previous investigations. This is due to increased cross sectional area in coronal part for better bonding, increased light curing penetration in the coronal third in comparison to the middle and apical thirds as improved photo-activation over chemical activation alone, differences in densities and mineral content between the coronal which is higher than the apical third of the root canal and restrictions in the flow of the resin cement toward the apical third of the root canal, which may cause more bubbles and voids in the luting cement agreed with this finding Attia et al [13].

These results confirm report by Kanzler Abdel Raouf et al [19], whom assessed the bond strength of different post materials at different root levels of endodontically treated teeth. All posts were sectioned at the coronal, middle, and apical root levels. Push-out tests were performed in the Universal Testing Machine (0.5 mm/min). The study showed that the bond strength was highest in the coronal root level for all tested post systems but did not differ significantly from the other two root levels. The bonding at the coronal level of the root canal seems to be more reliable than bonding at the apical level due to its higher cross section than others that’s in turn enhances bonding.

El-gawad et al [11] agreed with this finding, whom found that the values of the push-out bond strength for PEEK posts in the coronal sections was greater compared to the apical part. The dentinal tubules direction and their high density in the coronal portions, as well as improved photo- activation over chemical activation alone, may be the causes. Alternatively, the cervical segments may be more accessible.

The null hypothesis was accepted, as the study found no statistically significant difference between the two evaluated groups, regarding bond strength, direct intra canal scanning and conventional impression for PEEK posts.

## CONCLUSIONS:

Within the limitations of this study

1. Direct scanning by Prim scan offers a viable and clinically acceptable alternative to indirect scanning of the conventional impression technique.

2. Prim scan can be used successfully for manufacturing custom post and core restorations at post depth 12 mm when using digital methods of CAD CAM fabrication.

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