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INTRAORAL SCANNING TRUENESS OF POST SPACES: INFLUENCE OF DIAMETER AND DEPTH

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ABSTRACT

Background: Digital impressions using intraoral scanners have gained popularity as a favorable alternative to conventional techniques for capturing post space morphology. However, their performance can be influenced by the geometric complexity of the prepared canal.

Aim of the study: To investigate how variations in post space diameter and depth affect the trueness of digital impressions obtained with an intraoral scanner.

Materials and Methods: Twenty endodontically treated maxillary canines were allocated into two groups based on post space diameter: Group C (1.5 mm) and Group D (1.7 mm) (n = 10 each). Each group was subdivided by depth into Subgroup S (6 mm) and Subgroup D (10 mm) (n = 5), resulting in four subgroups: CS (1.5 mm, 6 mm), CD (1.5 mm, 10 mm), DS (1.7 mm, 6 mm), and DD (1.7 mm, 10 mm). Specimens were scanned using the Medit i700 intraoral scanner, and reference scans were obtained from conventional impressions digitized with the InEos X5 scanner. Trueness was assessed using 3D metrology software, and data were analysed using two-way ANOVA followed by Tukey's post-hoc test ($p < 0.05$).

Results: Both post space diameter and depth had a statistically significant effect on scan trueness ($p < 0.05$). Dilated diameter canals exhibited higher trueness values, while deeper preparations showed a notable reduction in trueness.

Conclusions: Within the limitations of this study, dilated post space diameter and shallow preparation depth were associated with improved scan trueness. All tested subgroups demonstrated clinically acceptable accuracy.

KEYWORDS: Dental Impression Technique, Post and Core Technique, Intraoral scanners, Trueness.

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INTRODUCTION

Root canals often present with diverse morphologies, including oval shapes, cavities, excessive preparation from previous restorations, over-instrumentation, incomplete root formation, internal resorption, and developmental anomalies. These variations can significantly impact the restoration process. When using prefabricated posts, root canal preparation must accommodate a standardized post design, which can weaken the tooth structure. Additionally, the mismatch between the shape of the prefabricated post and the post space creates an uneven gap between the post and dentin. This discrepancy increases the risk of fracture and debonding. While prefabricated posts may offer good outcomes when there is sufficient dentinal wall bulk, their main limitation lies in the inconsistency between the post shape and the canal morphology, compromising the overall fit and retention. [1–4].

Custom one-piece post-and-core restorations are widely recognized as the optimal choice for teeth exhibiting significantly flared root canals or insufficient ferrule designs. Their precise adaptation to the root canal anatomy improves mechanical retention, ensuring greater stability for crown restorations. Nevertheless, traditional lost-wax casting techniques used in these systems may result in fabrication inaccuracies, leading to suboptimal restoration fit. Additionally, the inherent metallic coloration of alloy materials can negatively influence the aesthetic outcomes of semi-translucent ceramic crowns[5, 6].

The advancement of digital technologies in dental practice has transformed patie nt care by elevating treatment precision and operational efficiency. Modern digital workflows streamline clinical procedures while conserving time and resources. Contemporary intraoral and extraoral scanning systems produce exceptionally accurate digital impressions, which research confirms as dependable for designing laboratory-fabricated prosthetic devices. Furthermore, digital manufacturing capabilities now enable the production of tailored glass fiber and zirconia post-and-core systems, effectively addressing aesthetic and functional limitations traditionally associated with metallic alternatives. [7–11].

The progress of computer-aided design and manufacturing (CAD/CAM) technology in dentistry, particularly with the latest generation of intraoral scanners (IOSs), has proven to be an effective alternative to conventional impressions. Coupled with the diverse array of materials now available, this technological advancement has significantly streamlined the production of custom-made posts, making the process more efficient and adaptable. [12–14].

Research on the accuracy of IOSs for post-space impressions is limited. Elter et al. [15] found that accuracy decreased as post-space depth exceeded 20 mm. Wahba and ElBasty [16] studied the Medit i700 and reported better trueness at larger preparation diameters (1.5 mm and 2 mm) at a 13 mm depth. Meshni et al. [17] observed that increasing the post-space diameter (1.4 mm, 1.6 mm, and 1.8 mm) improved the trueness of Medit i700 scans.

Recent developments in IOS technology have markedly improved their accuracy, efficiency, and ability to capture greater depths, solidifying their role in digital dentistry. The Medit i700 IOS is specifically engineered to capture deep preparations using advanced 3D-in-motion video technology. [18-22]

The aim of this in vitro study was to assess the trueness of scanned post spaces with different preparation widths (1.5 mm and 1.7 mm) and depths (6 mm and 10 mm) using an intraoral scanner. The null hypothesis posited that no significant differences in trueness would be observed based on variations in the post space preparation width and depth.

MATERIALS AND METHODS

Ethical approval for this study was granted by the Research Ethics Committee of the Faculty of Dentistry, Minia University, Egypt, under approval number Committee No. 95, Registration No. 736, dated 28/03/2023. Twenty human maxillary canines, extracted for periodontal reasons, were sourced from the Oral Surgery Department, Faculty of Dentistry, Minia University.

The inclusion criteria focused on teeth with straight roots, labio-palatal dimensions of 6-7 mm, mesio-distal dimensions of 5-6 mm, and an anatomical length of 22-23 mm. Visual and radiographic examinations confirmed the absence of exclusion criteria as endodontic treatment, restorations, caries, cracks, or internal resorption. Only teeth with straight, single root canals and fully matured apices were selected. The teeth were cleaned, immersed in 5.25% sodium hypochlorite for 7 days, and preserved in saline at room temperature to prevent desiccation. [23]

A power analysis was performed using G*Power software (version 3.1.9.7; Heinrich Heine University, Düsseldorf) to determine the sample size. The inputs were an alpha level of 0.05, statistical power of 80%, and an effect size of 1.21 derived from previous studies [17, 24]. The analysis indicated that 16 teeth were needed as a total sample size to achieve 80% power. To improve statistical robustness and ensure balanced representation, the sample size was increased to 20 teeth.

Specimens' Grouping

Twenty specimens were randomly assigned using Randomizer.org to two main width groups (C and D). Every group was subdivided into two subgroups according to preparation depth (S and D). Given four post space preparation subgroups as follows:

CS: Constricted and Shallow preparation (1.5 mm width, 6 mm depth).

DS: Dilated and Shallow preparation (1.7 mm width, 6 mm depth).

CD: Constricted and deep preparation (1.5 mm width, 10 mm depth).

DD: Dilated and Deep preparation (1.7 mm width, 10 mm depth).

Block randomization ensured balance, and allocation was concealed to prevent bias. (Fig. 1).

Specimens' Preparation

Teeth were sectioned 2 mm coronal to the cement-enamel junction using a diamond disk with coolant flow to prevent overheating. Endodontic treatment was performed using E-Flex files (Eighteeth, District, Changzhou City, China) ending by 35# taper4% master file. Irrigation of 5.25%

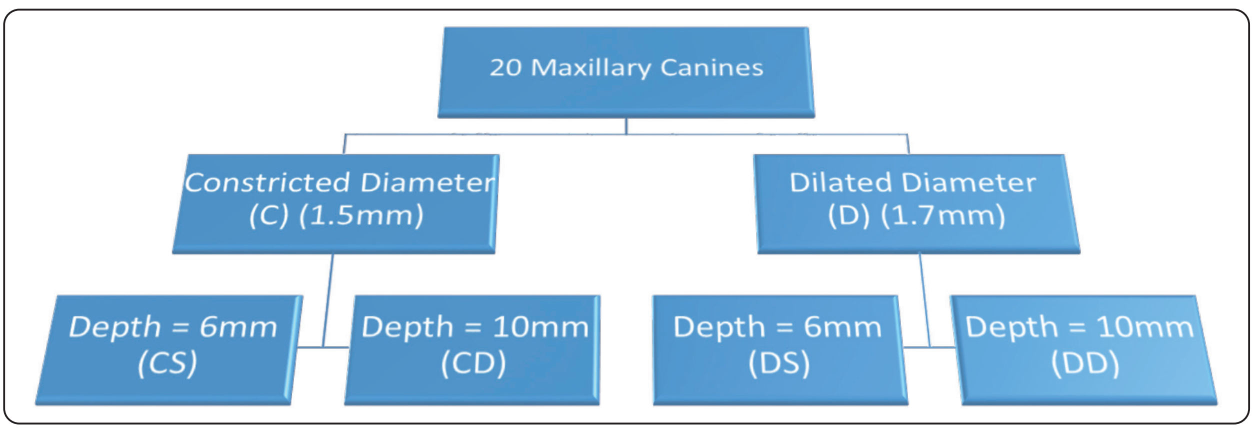

Fig. (1) Specimens' Grouping Diagram

sodium hypochlorite, 17% EDTA (Meta Biomed, Cheongju, Korea), and saline were used prior to obturation. The root canals were sealed with Well-Root bio-ceramic sealer (Well-Root ST, Vericom, Gangwon-Do, Korea), and obturation was done using a master cone and cold lateral condensation. Teeth were mounted in acrylic resin (Acrostone Acrylic Material-Cold Cure; ACROSTONE Co) 2 mm below the cement-enamel junction to simulate gingival color.

Water-cooled sequential drilling was conducted using Peeso reamers (NORDIN, Switzerland). For the Ø1.5 mm preparation width (Group C), reamers No. 1 to No. 5 were used. For the Ø1.7 mm preparation width (Group D), reamer No. 6 was used. The preparation depth was 6 mm for subgroups CS and DS, and 10 mm for subgroups CD and DD.

Specimens' Scanning

The Medit i700 intraoral scanner (Medit, Seoul, Korea) was used to scan post spaces. Calibration was performed before scanning each subgroup. Scanning was done in HD mode with the maximum scan depth selected. Scanning took place at room temperature under lighting of less than 1000 lux. An experienced operator scanned the samples in a clockwise motion from the occlusal notch to capture the post space depth. (Fig. 2). After scanning, models were rendered and data exported in a Standard tessellation language (STL) file format.

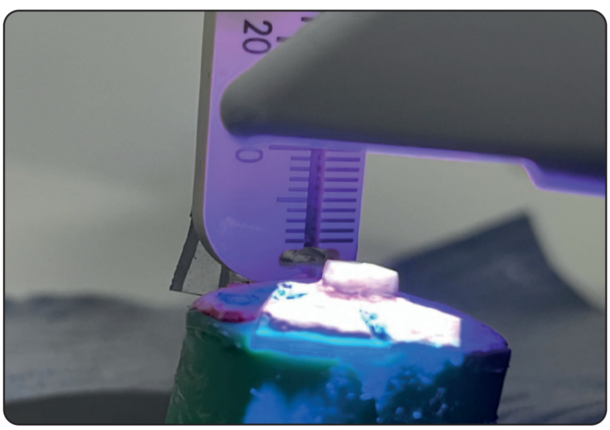

Fig. (2) Scanning of post spaces

Impression of Post Spaces and Reference Scanning

Conventional impressions of the post spaces were made using light-body polyvinyl siloxane material (Hydrorise Light Body, Zhermack, Italy). The material was directly injected into the root canal without the use of an impression tray, as only the post space was captured rather than the full arch. A wooden toothpick was used to support the material and minimize dimensional changes during setting and removal. Reference STL files were generated by scanning the impressions with the InEos X5 desktop scanner (Dentsply Sirona, Bensheim, Germany), and the data were exported in STL file format for analysis.

Trueness Measurement

Trueness measurements were performed using Geomagic Control X 2024 software. Reference STL files from the InEos X5 scanner were aligned with their corresponding STL files from the intraoral scanner using a best-fit algorithm. A 3D comparison was conducted with a 100% sampling ratio, and maximum deviations were automatically estimated. (Fig. 3). The square of the 3D phase difference between corresponding points was calculated after alignment applying the following equation:

$$\mathrm{RMS} = \frac{1}{\sqrt{n}} \times \sqrt{\sum_{i=1}^{n} (x_{1i} - x_{2i})^2}$$

RMS: Root mean square

x_{1i}: measurement of point i on the reference scan.

x_{2i}: measurement of point i on the test scan.

n: total number of points measured in each analysis.

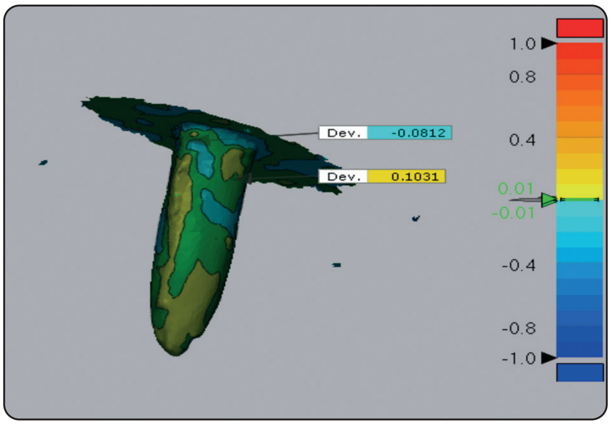

Fig. (3) 3D Trueness Assessment of Intraoral Scan

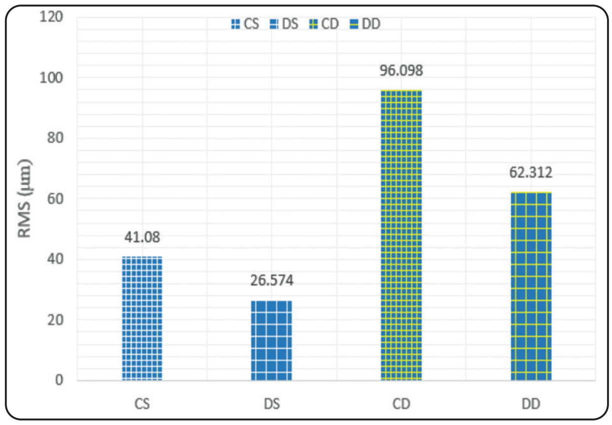

Fig. (4) RMS Deviation Across Study Groups.

STATISTICAL ANALYSIS

Descriptive statistics, including the mean and standard deviation, were calculated for all subgroups. The normality of the data was tested using the Shapiro-Wilk test. The data were normally distributed. The effects of post space preparation width and depth on trueness were analyzed using a two-way analysis of variance (ANOVA). Tukey's Honest Significant Difference (HSD) test was used for pairwise comparisons within the subgroups. A p-value of < 0.05 was considered statistically significant for all analyses.

RESULTS

Preparation width had a statistically significant effect on RMS values, where an increase in width was associated with enhanced trueness ($p < 0.05$). Specifically, subgroup (DS) exhibited superior trueness (26.57±3.01) compared to subgroup (CS) (41.08 ± 6.59). Similarly, within the deep preparation subgroups, subgroup (DD) demonstrated better trueness (62.31±6.87) than subgroup (CD) (96.10 ± 13.25). On the other hand, increasing preparation depth significantly compromised trueness ($p<0.05$) (Fig. 4). Additionally, the interaction between preparation width and depth was found to be statistically significant ($p = 0.034$), as shown in Table 1.

RMS: Root mean square; CS: Ø1.5mm, 6mm post space preparation depth; CD: Ø1.5mm, 10mm post space preparation depth; DS: Ø1.7mm, 6mm post space preparation depth; DD: Ø1.7mm, 10mm post space preparation depth.

TABLE (1) Two-way ANOVA results for the root mean square (RMS) values for trueness

	Factors	Sum of Squares	df	Mean Square	F	P-value	F crit
RMS	**Diameter**	2915.15	1	2915.15	33.89	***< 0.001****	4.49
	Depth	10295.81	1	10295.81	119.70	***< 0.001****	4.49
	Diameter * Depth	464.65	1	464.65	5.40	***0.034****	4.49

df – degrees of freedom; * statistically significant (p < 0.05).

DISCUSSION

The null hypothesis was entirely rejected, given that both preparation width and depth significantly affected trueness.

Due to their position within the dental arch, anterior restorations are subjected to considerable masticatory loads and lateral stresses, predisposing them to a higher incidence of fractures. The absence of sufficient mechanical retention in Class IV restorations further complicates adhesive bonding, resulting in failure rates that are approximately twice as high as those observed in Class III restorations[25].

Achieving a uniform thickness of the cement layer is critical for the success of post-and-core restorations. A thinner cement layer not only minimizes polymerization shrinkage stresses in custom-fabricated restorations but also promotes optimal adaptation. Additionally, the absence of voids during the cementation of CAD-CAM custom-made posts has been shown to improve bond strength in anatomically shaped post-and-core systems.[26–30] Although cement space was not directly assessed in this study, this background emphasizes the importance of accurate intraoral scanning for capturing post space anatomy, which is essential for the fabrication of well-adapted custom posts.

Digital impressions provide several advantages, preferable particularly for individuals with an exaggerated gag reflex. Intraoral scanners offer the capability of selectively rescan areas with deficient detail. Moreover, intraoral scanning contributes to a reduction in overall clinical time by decreasing the need for impression remakes and eliminating delays associated with material polymerization. [31–33]

Direct digital acquisition from prepared abutments using intraoral scanners streamlines clinical workflows by reducing both chair-side time and operator-dependent errors. The precision of digital impressions is critical for the fabrication of accurately fitting restorations. Advances in CAD/CAM technology now allow for the milling of fiber-reinforced composites and zirconia, enabling the fabrication of anatomically shaped post-and-core restorations with high fidelity to elliptical post space geometries. [34]

Hydrorise light-body polyvinyl siloxane (Zhermack, Italy) was employed for conventional impression making, chosen for its high elasticity properties, as reported by Re et al. [35], who recorded an ultimate strain at break of 90.39 mm. This mechanical behavior supports reliable recovery from intricate oral geometries without material tearing. To further ensure dimensional stability and reduce distortion during setting and removal, the technique was adapted from methods described by Elter et al. [15], and Wahba and Elbasty [16] incorporating the use of a customized wooden toothpick to reinforce the impression during polymerization.

In this study, 3D comparison analysis was performed by superimposing surfaces following best-fit alignment, a methodology extensively adopted in previous research [15, 36–45]. As defined by ISO 5725-1:2023 (Section 3.6), trueness represents the degree of agreement between a test result and the true reference value, thereby reflecting systematic error. The root mean square (RMS) value was selected as a more reliable indicator of deviation, as it accounts for both positive and negative errors without mutual cancellation, thus providing a more accurate representation of the overall deviation compared to the simple arithmetic mean. [46]

In the present study, increasing the post space preparation width resulted in a statistically significant improvement in the trueness of the Medit i700 intraoral scanner, as evidenced by reduced RMS values, irrespective of preparation depth. Specifically, at 6 mm depth, narrower preparations (CS) exhibited higher RMS values than wider ones (DS), and at 10 mm depth, a similar trend was observed (CD > DD). These findings are consistent with those reported by Taha et al. [47], who demonstrated that expanding the preparation diameter significantly enhanced scanning accuracy by lowering RMS deviations.

The superior trueness associated with wider post spaces may be attributed to enhanced optical accessibility; a larger diameter likely permits a greater amount of light to penetrate the post space, improving both illumination and reflection capture, as suggested by Hassan et al.[48]. Moreover, considering the geometric interaction between light and the prepared canal walls, a wider preparation reduces the incidence angle of incoming light, optimizing reflection angles for sensor detection. As described by Fu and Shi[49], increasing the base width of a triangular model (analogous to wider post spaces) results in a more favorable apical angle and near-perpendicular side angles, facilitating more efficient light reflection. Conversely, narrow and deep preparations may restrict light entry and increase the incidence of extreme-angle reflections, thereby limiting the amount of retrievable optical data.

The last phenomenon is further supported by Gerasimov et al. [50], who reported that increasing tunnel width decreases light attenuation and enhances internal reflections. Consequently, in narrower preparations, compromised light capture likely contributed to the increased surface deviations observed in this study.

In this study, a significant improvement in the trueness of Medit i700 intraoral scanning was observed with decreased post space preparation depth, as evidenced by lower RMS values. Specifically, at a 1.5 mm post space diameter, RMS values were higher for narrow preparations (CD > CS), and at a 1.7 mm diameter, wider preparations (DD > DS) exhibited better trueness. These results align with the findings of Hegazi et al. [51], who noted that increasing post space depth from 7 mm to 10 mm adversely affected the trueness of Primescan AC intraoral scanner readings. Furthermore, the results corroborate the work of Almalki et al. [52], who reported an increase in RMS values in the apical third of post space preparations with increased depth. Similarly, Elter et al. [15] observed that deeper preparations negatively impacted scanning trueness for mandibular canines using Primescan AC.

In contrast, the results of the present study diverge from those of Emam et al. [53], who found a reduction in RMS and improved trueness with increased post space depth in scanners like Primescan AC, Medit i500, and CS3600. The discrepancy between studies could be attributed to differences in scanning methodologies or post space geometry. The negative impact of increased preparation depth on scanning accuracy in this study can be explained by optical limitations. As the post space depth increases, the light beam from the scanner is less able to reach the deepest regions of the preparation, reducing reflection capture and leading to higher RMS values. This is in line with Rotar et al. [54], who highlighted the reduction in light intensity with increased scanning distance, thereby diminishing trueness.

Additionally, the increased depth of the post space likely increases the angle of light incidence, which can further decrease reflection quality. As the depth increases, the relationship between the light beam and the preparation wall changes, resulting in a greater angle of incidence. According to the law of cosines, this geometric adjustment causes the grazing angle to decrease, leading to less optimal light reflection and potential light grazing at the apical region. Such effects may exaggerate surface texture and shadowing, as noted by Sun [55], thus contributing to more pronounced deviations in deeper preparations.

The last explanations support the observations of Elter et al. [15], who reported significant deviations in the apical regions of post space preparations on color mapping software. Almalki et al. [52] also reported that RMS significantly increased at the apical third with deeper preparations, further confirming the detrimental effect of increased depth on scanning accuracy.

Chiu et al. [56] suggested that the clinically acceptable marginal gap for restorations produced using CAD/CAM technology falls within the range of 50 to 100 microns. Achieving this level of precision requires an exceptionally accurate initial digital scan, which is crucial for maintaining marginal discrepancies within the desired threshold of 100 microns. In this study, all RMS values for scanned post spaces, regardless of preparation parameters, fell within the clinically acceptable range of 50-100µm. These results indicate that CAD/CAM fabricated anatomical posts are likely to exhibit optimal adaptation and bond strength, ensuring clinical viability.

While this study provides valuable insights into the effect of post space preparation width and depth on the trueness of Medit i700 intraoral scanning, several limitations must be acknowledged. First, the study was conducted under controlled in vitro conditions, which may not fully replicate the complexities of clinical scenarios, such as patient-specific variations in anatomy or the presence of soft tissue. Additionally, only one intraoral scanner (Medit i700) was used in this study; therefore, the results may not apply to other brands or models of scanners, which could exhibit different scanning accuracies.

Future research should expand to include diverse tooth types, preparation geometries, and intraoral scanner models, along with long-term clinical studies to assess real-time performance across various patient conditions. Investigating the influence of operator experience on scanning accuracy.

From a technical perspective, intraoral scanner manufacturers should focus on enhancing light source technology and sensor sensitivity, particularly for deep or narrow post space preparations. Adjustable light intensity and optimized angle control could minimize issues related to light grazing and reflection loss. Additionally, the development of advanced software algorithms to correct for light distortion and improve scanning in challenging geometries, along with more user-friendly interfaces, would contribute to improved scanner performance and consistency in clinical practice.

CONCLUSIONS

This study demonstrated that both post space preparation width and depth significantly influence the trueness of the Medit i700 intraoral scanner. Increasing preparation width improved trueness, while deeper post space preparations negatively affected trueness, particularly at greater depths. However, all RMS values for the scanned post spaces fell within the clinically acceptable range of 50-100 microns.

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