International Journal of Applied Dental Sciences 2024; 10(1): 38-43

International Journal of Applied Dental Sciences

ISSN Print: 2394-7489
ISSN Online: 2394-7497
IJADS 2024; 10(1): 38-43

www.oraljournal.com
Received: 27-11-2023
Accepted: 02-01-2024

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Effect of different intraoral scanners on the trueness of custom post space scans with two different cervical diameters

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DOI: https://doi.org/10.22271/oral.2024.v10.i1a.1892

Abstract
Objective: This study aims to measure the trueness of post space scans using 3 intraoral scanners with 2 post cervical diameters.
Materials and Methods: A sample of 18 single-rooted mandibular second premolars, was collected for this study. These teeth exhibited root dimensions just below the CEJ, with mesiodistal and bucco-lingual ranges of 5-6 mm and 5-7 mm, respectively. Root-canal treatment was done for the 18 premolars. Subsequently, the crowns were reduced in height to remain 2 mm above the CEJ then preparation of the post space was done. After the preparation of each root, the corresponding teeth were allocated randomly to two groups (n=9/ group) according to the cervical diameter of the preparation. Group A: 2.5 mm and Group B: 3 mm. All teeth were scanned using (inEos X5 Sirona- Germany) to produce a reference scan, then scanning of post space directly using 3 intraoral scanners for all teeth.
Results: In Group A, the highest value was found in Trios (86.08±2.50), followed by Medit (85.35±5.46), while the lowest value was found at Prime Scan (36.21±4.36).
In Group B, the highest value was found in Trios (39.55±4.49), followed by Prime Scan (38.27±4.93), while the lowest value was found at Medit (37.48±10.37).
Conclusion: On the basis of the results and conditions of this study, the following conclusions can be drawn, Prime scanner is recommended for higher trueness value for direct post space scanning then followed by Medit. While trios have the lowest trueness value. Scanners that employ the confocal microscopy technology have the highest levels of trueness.

Keywords: Preparation, according, higher, trueness

1. Introduction

Rehabilitation of root-canal treated teeth, encompassing both functional and aesthetic considerations, is demonstrably challenging because of their inherent brittleness and often-significant loss in tooth structure. Studies indicates a higher prevalence of fractures in root-canal treated teeth in comparison with vital teeth. For those with weakened coronal structure, employing post procedures can significantly enhance their resistance to fracture and ensure long-term functionality. Post procedures are crucial for maintaining core retention and optimizing the long-term success of the fixed prosthetic restoration [1].

A diverse range of posts exists, each with different characteristics. These can be broadly categorized as ready-made prefabricated posts and custom-made designs.

Incompatibility between the prefabricated post geometry and the prepared post space results in uneven layer of cement, significantly raising the risk of structural discontinuities [2]

Incompatibility between prefabricated fiber post diameter and the anatomy of root canal can be rectified through several techniques. One approach involves filling the canal with composite resin to achieve a snug fit. Alternatively, the post itself can be modified by applying composite resin directly to its surface for an anatomically customized shape. Additionally, inserting an extra post can provide supplemental support and stability.

To prevent discrepancies between prefabricated fiber posts and the irregular shapes of wide root canals, the gold standard recommendation is anatomical posts customization. This approach yields superior adhesion, enhanced resistance to fracture, minimized stress from polymerization shrinkage, and reduced gaps and bubbles within the cement layer.

Digital/electronic advancements and innovative manufacturing techniques have paved the way for CAD/CAM to take root in dentistry, enabling faster and more accurate customized restorations with digital precision.

The recent surge in interest in CAD/CAM for post and core restorations can be attributed to its ability to quickly design and fabricate precise, well-fitting restorations.

Custom posts fabrication using CAD/CAM technology requires virtual models of the post space, obtainable through direct intraoral scanning, impression scanning, or model scanning [3]. New-generation intraoral scanners present an attractive alternative to traditional impressions.

Recent reports advocate for replacing damaged tooth structures with CAD/CAM fabricated custom post and core. Numerous studies have explored the performance of zirconia, a highly durable ceramic, as a material for CAD/CAM-produced post and cores [4–6]. Additionally, fiber-reinforced composite blocks have been employed to manufacture CAD/CAM-generated fiber posts, particularly suitable for large or irregularly shaped root canals [7, 8].

Null Hypothesis

Neither the scanning technique nor the post cervical diameter has an effect on the trueness of the post space scanning.

Materials and Methods

- This in vitro research was exempted by the faculty of dentistry Ain shams university research ethics committee (FDASU_RecEM121903 ethical committee number).
- A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that there is no difference would be found between different tested groups regarding measurement accuracy. By adopting an alpha (α) level of (0.05), a beta (β) of (0.2) (i.e., power=80%), and an effect size (f) of (0.524) calculated based on the results of a previous study [9]; the total required sample size (n) was found to be (54) samples. Sample size calculation was performed using G*Power version 3.1.9.7 [10].

1. Sample preparation

A sample of eighteen single-rooted mandibular second premolars, extracted for orthodontic treatment, was collected from the outpatients' clinic of endodontics. These teeth exhibited root dimensions just below the CEJ, with mesiodistal and bucco-lingual ranges of 5-6 mm and 5-7 mm, respectively. Root-canal treatment employed the Wave-One single file technique with a 6% taper and an ISO 25 apical preparation size. Subsequent obturation was done utilizing the technique of Continuous Wave Condensation with an ISO 25 taper 6% master cone then Obtura root canal filling system.

Using a dental surveyor, the teeth were positioned in acrylic blocks in alignment with their longitudinal axis, 2 mm below the cemento-enamel junction (CEJ). Subsequently, the crowns were reduced in height to remain 2mm above the CEJ.

Utilizing a dental surveyor for precise post-space drilling to depth 8 mm and two different cervical diameters:

A. Group (A): 2.5 millimeters
B. Group (B): 3 millimeter

The preparation of the post space was achieved through a sequential drilling technique employed with the Olident-Poland fiber post drills kit. Initially, a red-coded drill with a 1.2-millimeter tip diameter was utilized, afterward a blue-coded drill with a 1.4-millimeter diameter, and lastly, a green-coded drill with a 1.6-millimeter diameter. Throughout the drilling process, a dental surveyor and a coolant syringe were employed for precision and temperature control.

To ensure precise widths of 2.5 mm and 3 mm for samples in groups A and B, respectively, a dental surveyor employed two NTI Laboratory Diamond Burs with standardized diameters. Drilling proceeded to a depth of 8mm.

2. Reference Scanning

To generate reference STL files, we used a desktop scanner called InEos X5 to scan each individual sample. This scanning process was repeated for all 18 samples, resulting in 18 reference scans. The samples were identified using a numbering system ranging from A1 to A9 and B1 to B9.

3. Intraoral scanning

- **Primescan**

It 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.

- **Trios Scanner**

Trios3 employs a multifaceted approach to scanning, combining structured light projection with confocal microscopy, ultrafast optical scanning, and AI technology.

- **Medit Scanner**

Employing structured light and optical triangulation, the Medit 600 combines Smart Scan Filtering, Enhanced AI and color filtering for scanning. In addition, it utilizes both 3D-in-motion video and full-color streaming for detailed data capture.

4. Scanning workflow

The initial stage involved recording information about the restorations and their types. This was followed by the acquisition phase, where the recorded details were displayed in the page palette and scanning commenced upon foot control activation.

A meticulous scanning protocol started on the occlusal surface of the prepared tooth, with the scanner 0-5mm away. It swept mesially across the tooth, then tilted 45-90° on the buccal surface then the scanner head moved distally with 90° tilt over the lingual surface in a mesial direction. The process repeated on the proximal surface, using a "wave-like" motion with 15° on the occlusal, buccal & lingual surfaces.

Utilizing a digital stopwatch, a separate operator recorded scan times, resulting in an average scan duration of approximately 7-10 seconds.

Upon completion of the acquisition phase, the scan data was processed and rendered into a 3D model, which was subsequently exported in the widely-used STL format.

Each of the 18 samples underwent scanning, resulting in 18 numbered scans (D.S A1-A9 and D.S B1-B9).

5. The Trueness measurement

Using Geomagic Control X 2018, a reverse engineering software, the reference STL file from the InEos X5 scanner was superimposed to each file of 18 STL files from each scanner from each sub-division.

Import and align datasets

Here's how the data was prepared and aligned:

A. **Import and trim reference data:** The essential parts of the reference data were brought in, removing any irrelevant information.

B. **Import measurement data:** The STL file containing the measurement data from the corresponding scanner was imported.

C. **Align data sets:** An initial alignment was performed, followed by a more precise best-fit alignment. This ensured that both data sets shared a common coordinate system with the least possible mean deviation.

3D. Compare

The 3D comparison was limited to the region of interest defined by the lowest projection and automatic maximum deviation. A color map with a range of ±0.15mm was generated, where green represented perfect alignment, red indicated the test model being positively positioned relative to the reference, and blue denoted the test model being negatively positioned relative to the reference. To quantify the overall surface difference, the squared phase difference at each point in 3D space was averaged and the square root was taken to obtain the Root Mean Square (RMS). This RMS value provides a more accurate measure compared to a simple arithmetic mean, as it incorporates both positive and negative deviations (represented by red and blue in the color map) and mitigates the limitations of arithmetic means in situations with simple sums. Figure (1)

$$\text{RMS} = \sqrt{\frac{\sum_{m=1}^{n}(x_{1,m}-x_{2,m})^2}{n}}$$

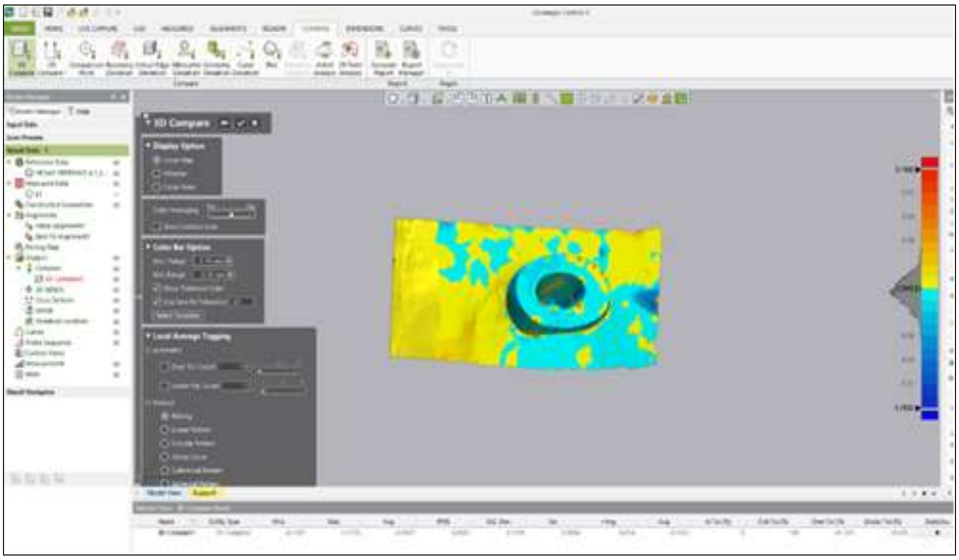

Fig 1: Showing the 3D comparison represented with a color map

Reports Generation

All calculated data from the superimposition process was presented in comprehensive reports (PDF and Excel).

Statistical analysis

Numerical data were presented as mean and standard deviation (SD) values. They were explored for normality by checking the data distribution and using Shapiro-Wilk's test. The data showed parametric distribution and were analyzed using two-way ANOVA followed by Tukey's post hoc test. Comparison of simple effects were done utilizing the pooled error term of the two-way model with p-values adjustment using Bonferroni correction. The significance level was set at $p<0.05$. Statistical analysis was performed with R statistical analysis software version 4.3.1 for Windows.

Results

Effect of scanner

Intergroup comparisons, mean and standard deviation values of trueness (RMS) (µm) for different scanners are presented in table (1) and in Fig (6).

- **2.5 mm**

There was a significant difference between different groups ($p<0.001$). The highest value was found in Trios (86.08±2.50), followed by Medit (85.35±5.46), while the lowest value was found at Prime Scan (36.21±4.36). Post hoc pairwise comparisons showed Prime Scan to have significantly lower value than other groups ($p<0.001$).

- **3.0 mm**

There was no significant difference between different groups ($p=0.899$). The highest value was found in Trios (39.55±4.49), followed by Prime Scan (38.27±4.93), while the lowest value was found at Medit (37.48±10.37).

Table 1: Intergroup comparisons, mean and standard deviation values of trueness (RMS) (µm) for different scanners

Scanner cervical diameter	Trueness (RMS) (µm) (Mean ± SD)			p-value
	Prime Scan	Trios	Medit	
2.5 mm	$36.21±4.36^B$	$86.08±2.50^A$	$85.35±5.46^A$	<0.001*
3.0 mm	$38.27±4.93^A$	$39.55±4.49^A$	$37.48±10.37^A$	0.899 NS

Means with different superscript letters within the same horizontal row are significantly different *; significant ($p<0.05$) ns; non-significant ($p>0.05$).

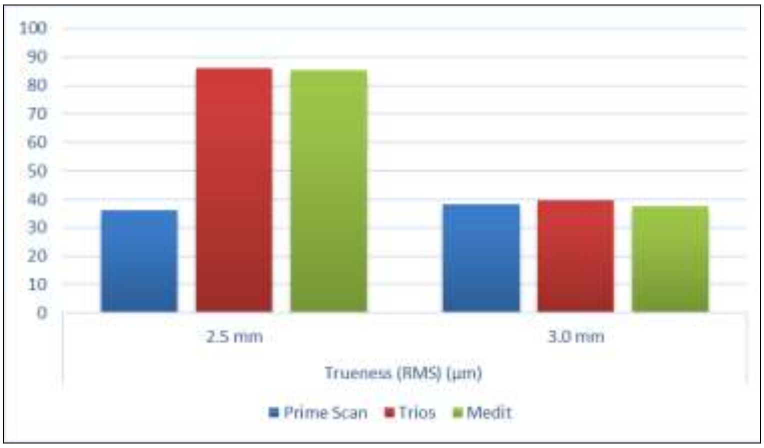

Fig 2: Bar chart showing average trueness (RMS) (µm) for different scanners.

Discussions

The dental field is increasingly embracing CAD/CAM technology for indirect restorations, as it streamlines lab workflows and avoids the downsides of traditional casting. However, a gap exists in custom-made post and core milling. Addressing this would greatly benefit dentists and patients alike [11].

The aim of this study was to evaluate the trueness of different scanning techniques of custom post space preparations with two cervical diameters. Considering the better features of an anatomic endodontic post, such as conservation of root dentin [12], reduction in cement layer thickness [13], enhancing the retention [14] and fracture resistance [15, 16] of the post.

This study compared various scanning technologies to see if they could produce anatomically-shaped post scans.

There are multiple steps in every CAD/CAM procedure, each step carries the risk of introducing inaccuracies. That's why every step in a CAD CAM workflow is crucial, impacting the final outcome. Understanding the effects of trueness is critical, as it ranks among the fundamental elements.

Our study was done *in-vitro* because the trueness parameters can't be evaluated in-vivo due to the missed reference structure [17].

This study used freshly extracted lower second premolars with single canal. The premolars were prepared through root canal treatment and crown removal before being embedded in acrylic blocks [18]. Drillings were made in two widths: 2.5 mm and 3 mm [18, 19].

The dental surveyor-mounted handpiece and its attached tapered drill enabled the operator to prepare standardized post spaces in all teeth [9, 20].

The InEos X5 scanner was chosen as the reference scanner because it is highly accurate, with deviations of less than 15 micrometers. This is considered as a minimum deviation according to literature and almost equivalent to PVS impression material accuracy [21, 22].

In a study by Nulty *et al.* [23] comparing full arch trueness of nine intraoral scanners and four lab digital scanners, a trueness value of 0.0±1.9 was reported.

Direct intraoral scanning technique was chosen due to its high usage in the market. During the process of scanning, no powder is needed since there is a lot of controversy about its effect on the trueness [9, 24, 25]

Previous studies have often expressed accuracy in terms of trueness and precision [26].

3D Compare Analysis, an adaptation of an engineering technique, superimposing two surfaces after aligning them precisely "Best fit alignment". This method has become popular in in vitro studies [27].

The superimposition of the STL files were imported to a reverse engineering 3D analysis software "Geomagic control X, 2018 (3D systems, Morsiville, NC)" in accordance with Renne *et al.* [27] in 2016, and Nedelcu *et al.* in 2017 [28].

The test and reference datasets were meticulously superimposed using a best-fit alignment. In the absence of reference shapes, we adopted this methodology to achieve our study goals [9].

Previous studies have employed best-fit alignments for comparing 3D datasets [29, 30].

For trueness calculation, STL files of each group were superimposed one by one on the imported reference STL file. To evaluate quantitative accuracy, the data of the root mean square of each superimposition was collected [31], since it shows a high estimate of the average error, and an average value was calculated.

In our study, tested null hypothesis was partially rejected. According to scanning techniques, in samples with cervical diameter 2.5 mm there was a significant difference between different groups ($p<0.001$). The highest value (86.08±2.50) was found in AI scan technology with structured light–confocal microscopy and ultrafast optical scanning technique (Trios), followed by optical triangulation technology (Medit) (85.35±5.46), while the lowest value (36.21±4.36) was found in structured light-confocal microscopy technology with smart pixel sensor (Prime Scan).

While in samples with cervical diameter 3mm there was no significant difference between different groups ($p=0.899$). The highest value (39.55±4.49) was found in AI scan technology with structured light–confocal microscopy and ultrafast optical scanning technique (Trios), followed by structured light-confocal microscopy technology with smart pixel sensor (Prime Scan) (38.27±4.93), while the lowest value (37.48±10.37) was found at optical triangulation technology (Medit).

This was in agreement with Zimmermann M *et al.* [32] As they reported trueness value 17.9±7.6 µm for Prime Scan, 21.2±6.7 µm for Trios followed by 21.6±6.9 µm for Medit.

Though past study didn't examine post space scanning, our findings in terms of trueness of direct intraoral scanning are in agreement with theirs.

In Study by Emam M *et al.* [20] Significant differences were found between the scanners in terms of RMS values ($p< 0.001$). Prime scan showed higher RMS value for trueness (0.26±0.09 mm) than Medit (0.18 ±0.05 mm). The Medit scanner showed higher post-space digital impression trueness as compared to Prime scan [20].

Michelinakis G *et al.* [33] reported that no significant difference in trueness was found between the Medit and the Trios3 scanners.

Nulty AB *et al.* [23] reported that Prime scan had the best overall trueness (17.3±4.9), followed by Medit (25.2±7.3),Trios 3 (27.7±6.8). Stating that scanners equipped with confocal microscopy technology achieve the highest levels of trueness.

Leven R *et al.* [34] found that Prime scan's accuracy was significantly lower than Trios, despite the current study using a larger sample size (Compared to previous studies). This suggests that sample size may be a factor in this disagreement.

Falih MY *et al.* [35] conducted in vitro study to compare the trueness and precision of eight intraoral scanners. For trueness, the least mean deviation (i.e., the highest trueness) was recorded by Medit followed by Trios then Prime scan.

Regarding the data capture principle, Park JM *et al.* [36] stated that Intraoral scanners (IOSs) employing active triangulation demonstrated substantially higher accuracy compared to those utilizing the confocal microscopy principle. Acquisition of video sequence data yielded greater trueness compared to individual image data acquisition.

The present study had the limitation inherent to an in vitro study. While this study focused on certain key factors influencing trueness, it's important to acknowledge that other elements, such as operator proficiency, powder application, software settings, and illumination levels, could also play a role and weren't addressed here. Fabrication and subsequent fit assessment of the final restorations were not undertaken, constituting a potential limitation of the study.

Many laboratories are embracing the advanced technology of extraoral scanners, which capture 3D digital impressions, significantly reducing the reliance on conventional workflow.

The future of digital scanning is bright, with continuous advancements in technology promising even more accurate scans and a wider range of applications. This ongoing progress keeps the door open for future research, ensuring their precision and accuracy.

Conclusion

Within the limitations of this *in-vitro* study the following conclusions could be drawn

1. Prime scanner is recommended for higher trueness value for direct post space scanning then followed by Medit. While trios have the lowest trueness value for direct post space scanning.
2. Scanners that employ the confocal microscopy technology have the highest levels of trueness.

Conflict of Interest

Not available

Financial Support

Not available

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How to Cite This Article
Taha NM, Zohdy MM, Abdel Fattah G. Effect of different intraoral scanners on the trueness of custom post space scans with two different cervical diameters. International Journal of Applied Dental Sciences. 2024;10(1):38-43.