AJDS AL-AZHAR
Al-Azhar Journal of Dental Science
Vol. 27- No. 1- 17:25- January 2024
Print ISSN 1110-6751 | online ISSN 2682 - 3314
https://ajdsm.journals.ekb.eg
Restorative Dentistry Issue *(Dental Biomaterials, Operative Dentistry, Endodontics, Removable & Fixed Prosthodontics)*

# INFLUENCE OF DIFFERENT ENDOCROWN PREPARATIONS ON THE ACCURACY OF MULTIPLE INTRAORAL SCANNERS-AN IN-VITRO STUDY

Ahmed Mohamed Samir Ahmed Wagdy[1], Ahmed Mohamed Yousri El-Kouedi[2], Hussien Ramadan Mohammed[3]

## *ABSTRACT*

**Objectives:** This study was made to determine the accuracy of 3 intraoral scanners (IOS) on different Endocrown preparations. **Methods:** Four Endocrown preparations with two internal angulations (6° & 10°) and two depths (3mm & 5 mm) were made on an acrylic typodont. Reference scans were taken with a reference scanner (InEos X5) and saved in a STL format then each IOS (Trios, Omnicam, and My crown) scanned each preparation 8 times. The STL files obtained were compared to the reference scans for measuring (trueness) and within each test group (precision). A reverse engineering software was employed to measure the accuracy of the IOS. **Results:** ***Trueness:*** the best scanner was the Trios scanner (25.13±3.89$\mu$) followed by My crown (37.24±6.8$\mu$) then Omnicam (39.31±6.08$\mu$). There was a statistically significant difference in total trueness of the Trios scanner compared to both My Crown and Omnicam. The 10° (30.87±6.74$\mu$) was significantly higher in trueness than 6° (36.9±8.98$\mu$). The 5mm depth (31.3±6.56$\mu$) was significantly higher in trueness than 3mm (36.48±9.37$\mu$). ***Precision:*** the best scanner was the Trios scanner (18.16±4.53$\mu$) followed by Omnicam (26.21±5.24$\mu$) then My crown (30.14±9.92$\mu$). No significant difference in precision between 6° (24.08±8.12$\mu$) and 10° (25.21±9.09$\mu$). Five mm depth (20.24±5.19$\mu$) was significantly higher in precision than 3mm (28.11±9.2$\mu$) **Conclusion:** Trios scanner shows better trueness and precision than Omnicam and My crown scanners. Endocrown scans with internal angulations 10° show more accurate results than those with 6° scans, and 5mm axial wall showed more accuracy than 3mm axial wall scans.

**KEYWORDS:** Intraoral Scanner, trueness, precision, CAD/CAM, Endocrown

## INTRODUCTION

Impression taking is one of the most important steps for the fabrication of fixed dental prosthesis. A dental impression is a negative reproduction or mold of dental and oral tissues [(1)]. Conventional impression taking has many disadvantages, it may cause anxiety, discomfort for patients especially those with sensitive gag reflexes, risk of retaking impressions, time-consuming, and the frequent disinfection of impression. Due to these problems of conventional impression, a digital impression is used widely nowadays. Many studies have shown that full-arch digital scans are as accurate as conventional impressions [(2,3)].

1. Masters Candidate, Dentist at Ministry of Health
2. Professor of Crown and Bridge, Crown and Bridge Department, Faculty of Dental Medicine for Boys, Al-Azhar University.
3. Assistant Professor of Crown and Bridge, Crown and Bridge Department, Faculty of Dental Medicine for Boys, Al-Azhar University.

• ***Corresponding author*:** ahmed084419@gmail.com

***DOI:*** *10.21608/AJDSM.2022.130896.1329*

Digital impression is the first step toward Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) for the production of the dental prosthesis.

Digital data capturing improves treatment planning, facilitates data storage, reproducibility, treatment documentation, time effectiveness, and easier communication between dental office and laboratory. The collected information by Intra Oral Scanner (IOS) can be transferred directly into the digital CAD/CAM production chain (4).

Data collected from (IOS) can be formed into Standard Triangle Language" or "Standard Tessellation Language" (STL) files. This format approximates the surfaces of a solid model with triangles. The more complex the surface, the more triangles are produced(5). Accuracy in a digital workflow will affects the quality of final restoration, it can be explained in terms of trueness and precision: Trueness is described as the closeness of the results between many test results and a reference value. Precision is described as the closeness of repeated results with each other (6).

Scanning errors may occur due to the image's superimposition during scanning and processing. This is due to the deviations of images which are more detected in the anterior region where teeth have steep inclines and less tooth surface. In addition, errors during computer processing are due to filter algorithms. Other factors that can affect the accuracy of IOS are operator factors (skill and scanning motion), intraoral factors (humidity, temperature, and illumination), scanner unit (capture box, light source, and receiver), computer software speed, and scanning area (axial wall angulation, preparation depth, and surface irregularities) (7).

Endodontically treated teeth usually need special techniques to restore them; a major amount of tooth structure was lost due to trauma or caries in addition to tooth destruction created by the endodontic access preparation. This usually makes the tooth with insufficient sound tooth structure. Conventional restoring endodontically treated tooth with post and core and crown results in more removal of sound tooth structure and this makes the tooth weaker. Endocrown can be made if the remaining tooth structure is sufficient enough instead of post and core for more preservation of sound tooth structure, Endocrowns provide many advantages over posts and cores and crowns, they need lesser clinical time and visits, and are easier to prepare (8,9).

The purpose of this study was to determine the effect of four Endocrown preparations on the accuracy of 3 intraoral scanners. The first null hypothesis of this study is that there will not be a difference in trueness and precision between the different IOS. The second null hypothesis is that there will not be a difference in trueness and precision between the different Endocrown preparations.

## MATERIALS AND METHODS

### Sample grouping

In this study, a total of 96 scans were made on 4 different Endocrown preparations as shown in Fig (1), classified into 3 groups according to the type of scanner with 32 scans per scanner **Group M**: My crown scanner (Fona, Italy), **Group O**: Omnicam scanner (Dentsply Sirona, Bensheim, Germany), **Group T**: Trios scanner (3 Shape, Copenhagen, Germany). Endocrown preparations were divided according to the divergence angle into 2 subgroups (16 scans). **Subgroup A**: internal divergence angle 6° and **Subgroup B**: internal divergence angle 10°. Each subgroup was divided into two designs according to the preparation depth with each subgroup (8 scans) **Design 1**: internal depth of 3mm and **Design 2**: internal depth of 5mm.

Each preparation was scanned one time with a reference extraoral scanner inEos X5 (Sirona Dental Systems Bensheim, Germany) with a total of 4 reference scans.

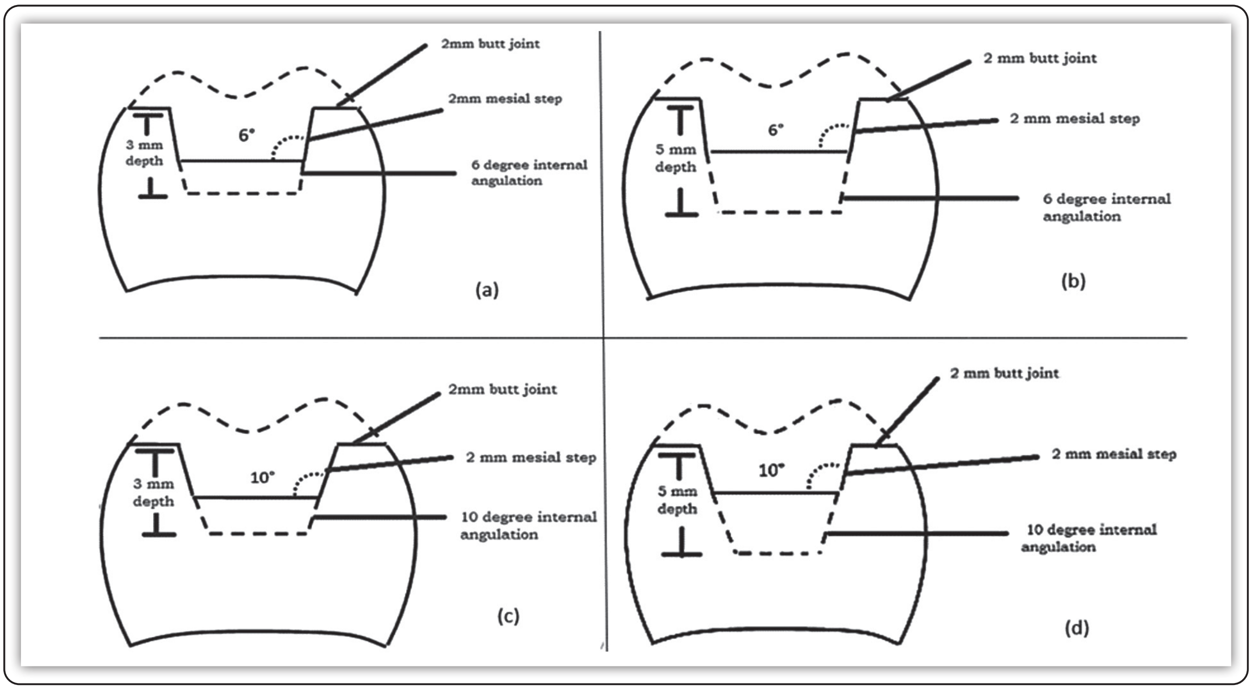


FIG (1) Diagram for Endocrown preparation Designs: a: Design A1 Endocrown preparation with 3mm depth and 6˚ internal angulation, b: Design A2 Endocrown preparation with 5mm depth and 6˚ internal angulation, c: Design B1 Endocrown preparation with 3mm depth and 10˚ internal angulation, d: Design B2 Endocrown preparation with 5mm depth and 10˚ internal angulation

**Endocrown preparations on typodont**

The selected acrylic tooth (Nissin Dental Product, Kyoto, Japan) was individually mounted in self-cure acrylic resin (Acrostone, Cairo, Egypt) block vertically along its long axis. A specially designed split brass mold was machine milled and used for the fabrication of acrylic blocks.

A paralleling device (Milling surveyor BEGO Paraskop M) was used to mount each acrylic tooth specimen up to the level 1mm above the cemento-enamel junction and to ensure centralization of the tooth within the blocks. After the complete setting of acrylic resin, the split mold was disassembled and the teeth within the acrylic block become ready for preparation.

**Acrylic tooth preparation**

CNC machine was used for the preparation of abutments. The CNC router with 1000x600mm machining area was used with a maximum cutting speed was 8000 RPM. The ball Screws/ spindles diameter was 12/12 mm. Easy preparation on the acrylic tooth and to confirm that the preparation angle is optimum when the tooth was placed at 90° to the floor and the drill of CNC is parallel to the long axis of the acrylic tooth. After milling, every acrylic tooth was fixed back to its place on the typodont model, and teeth were checked that the screws were tightly fit, each tooth was not removed and no external forces were applied to it.

**Digital scanning with reference scanner**

Reference scans were made by using an extra-oral scanner inEos x5 with an automatic jaw scan for evaluation of trueness. [10] The automatic jaw scans capture the model situation fully automatically in the "Capture Jaw" mode. It is used for all tasks, especially for large, complex tasks or tasks with especially high accuracy requirements. Each preparation was scanned one time with inEos x5 with a total of 4 scans.

## Digital scanning with intraoral scanners

Typodont jaw which contains Endocrown preparations was placed on a flat surface before scanning. The scanning motion that was done as recommended by each scanner's manufacturer was a sequential motion, starting from buccal, occlusal then lingual in S shape motion.

A file was created with the name of the scanned design then the tooth number was selected (for example tooth 36) and Endocrown preparation was selected as the design type to be scanned then scan acquisition started. All scans were captured in focus (out-of-focus captures were excluded). After scanning, an STL file was saved related to each design. During scanning with each scanner, a separate operator recorded the time taken with a digital stopwatch, and all times were averaged around 40±5 seconds for scanning 2nd lower premolar,1st lower molar, and 2nd lower molar.

## Processing of data for evaluation of trueness and precision

A reverse engineering software (control X 2018, Geomagic, 3D systems, NC) was developed to measure the accuracy of the IOS. All scanned STL files were trimmed to include lower 2nd premolar, lower 1st molar and lower 2nd molar and exclude other unnecessary data. For trueness measurements, each STL related to a certain design was imported and superimposed over a reference STL file related to the same design. The reference scan was chosen as reference data. For accurate alignment, the initial fit alignment function was chosen for 1ry alignment then best fit alignment function was chosen for more accurate alignment.

Once STL files were aligned, the 3D compare function allowed digital calculation of the difference between 2 STL files as shown in Fig (2). Color-coded images of the model showed the amount and type of the deviation of the 3D model where darker red highlights indicate an expansion or positive deviation of the superimposed files, darker blue highlights indicate a contraction or negative deviation of the superimposed files. For the precision measurements, the STL files of the same design and the same IOS were superimposed. Each scan for each design was considered as the reference model and the other 7 scans were superimposed on it. Trueness and precision were shown in the Root Mean Square (RMS). When two STL files were superimposed, the square of the difference between several points in 3-D space was calculated (x-, y-, and z-axis). The total sum of these squares was divided by the number of points, and RMS was calculated as the square root of this difference value.

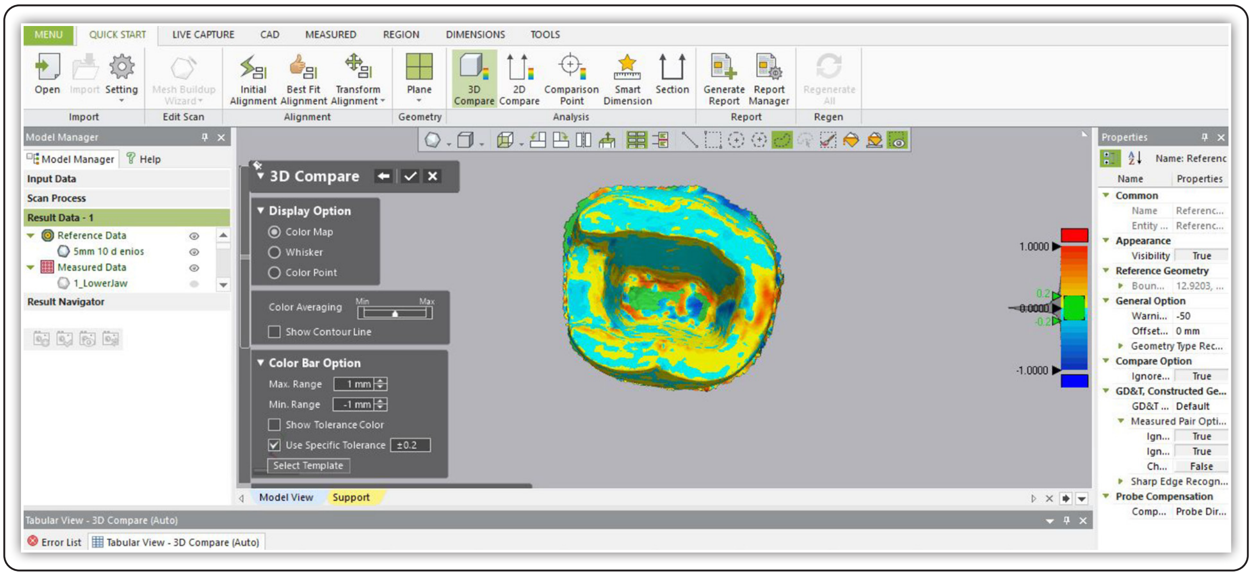


FIG (2) 3D compare of two superimposed STL files by Geomagic software

**Statistical Analysis**

Statistical analysis was performed with IBM® SPSS® Statistics Version 25. Numerical data were presented as mean, and standard deviation (SD). Data were explored for normality by checking the data distribution using Kolmogorov-Smirnov and Shapiro-Wilk tests. Parametric data were analyzed using multivariate analysis and independent t-test for comparisons between two groups, paired sample t-test was used to compare between the two angulations depth within the same scanner. The significance level was set at $P \leq 0.05$ within all tests.

## RESULTS

**Trueness results in microns**

**At 3mm depth and 6° divergence angle preparation:** The highest in trueness was group T(Trios) (29.51±2.84) followed by group M (My Crown) (45.83±4.86) followed by my group O (Omnicam) (47.56±3.96)

No statistically significant difference in the trueness of Omnicam scanner and My Crown scanner. A statistically significant difference in trueness of Trios scanner compared to both My Crown scanner and Omnicam.

**At 5mm depth and 6° divergence angle:** The highest in trueness was group T(Trios) (24.04±1.57) followed by my group O (Omnicam) (35.41±2.74) followed by group M (My Crown) (39.15±1.89)

A statistically significant difference in the trueness of the Omnicam scanner compared to the My Crown scanner. A statistically significant difference in the trueness of Trios scanner compared to both My Crown scanner and Omnicam.

**At 3mm depth and 10° divergence angle:** The highest in trueness was group T(Trios) (23.8±3.96) followed by group M (My Crown) (32.4±1.73) followed by my group O (Omnicam) (39.83±3.66)

A statistically significant difference in the trueness of the Omnicam scanner compared to the My Crown scanner. A statistically significant difference in the trueness of Trios scanner compared to both My Crown scanner and Omnicam.

**At 5mm depth and 10° divergence angle:** The highest in trueness was group T(Trios) (23.18±3.35) followed by group M (My Crown) (31.58±4.8) followed by my group O (Omnicam) (34.45±2.13)

No statistically significant difference in the trueness of the Omnicam scanner and My Crown scanner. A statistically significant difference in the trueness of Trios scanner compared to both My Crown scanner and Omnicam.

**TABLE (1)** Comparison of total trueness results in microns between the three studied scanners at depth 3mm & 5 mm and internal angulations 6˚ & 10˚

| | | Group M (My Crown) | | p value | Group O (Omnicam) | | p value | Group T (Trios) | | p value |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Internal Angulation | | | Internal Angulation | | | Internal Angulation | | |
| | | 6˚ | 10˚ | | 6˚ | 10˚ | | 6˚ | 10˚ | |
| Preparation Depth | 3mm | 45.83±4.84 | 32.4±1.73 | <0.001 | 47.56±3.96 | 39.83±3.66 | 0.004 | 29.51±2.84 | 23.8±3.96 | 0.006 |
| | 5mm | 39.15±1.89 | 31.58±4.8 | 0.007 | 35.41±2.74 | 34.45±2.13 | 0.46 | 24.04±1.57 | 23.18±3.35 | 0.5 |
| P value | | 0.003 | 0.6 | | <0.001 | 0. 003 | | <0.001 | 0.7 | |

- Total trueness results showed that the best scanner was group T (Trios scanner) followed by group M ( My crown) followed by Group O (Omnicam). There was no statistically significant difference in total trueness of Omnicam scanner (39.31±6.08) and My Crown scanner (37.24±6.8) (p-value = 0.32). A statistically significant difference was found in total trueness of Trios scanner (25.13±3.89) compared to both My Crown scanner and Omnicam (p-value <0.001, <0.001).
- For total trueness; 10° (30.87±6.74) is significantly higher in trueness than 6° (36.9±8.98) (p-value =0.001)
- For total trueness; 5mm (31.3±6.56) is significantly higher in trueness than 3mm (36.48±9.37) (p value =0.002)

**Precision results in microns**

**At 3mm depth and 6° divergence angle preparation**: The highest precision was group T(Trios) (22.31±5.11) followed by my group O (Omnicam) (26.34±2.62), followed by group M (My Crown) (38.12±9.23) a statistically significant difference in the precision of the My Crown scanner compared to the Omnicam scanner and Trios scanner. No statistically significant difference of precision of Trios scanner compared to Omnicam.

**At 5mm depth and 6° divergence angle**: The highest precision was group T(Trios) (17.2±2.84) followed by group M (My Crown) (20.27±3.72) followed by group O (Omnicam) (22.15±3.72) a statistically significant difference in the precision of the Omnicam scanner compared to the Trios scanner. No statistically significant difference in the precision of Trios scanner, Omnicam compared to My crown.

**At 3mm depth and 10˚ divergence angle**: The highest precision was group T(Trios) (16.19±3.22) followed by group O (Omnicam) (33.17±5.21) followed by my group M (My Crown) (35.26±8.1) a statistically significant difference in the precision of the Omnicam scanner My crown scanner compared to Trios scanner. No statistically significant difference in the precision of Omnicam and My crown.

**At 5mm depth and 10° divergence angle:** The highest precision was group T(Trios) (16.24±4.43) followed by group O (Omnicam) (23.26±2.83) followed by my group M (My Crown) (27.18±6.32) no statistically significant difference in the precision of the Omnicam scanner and My Crown scanner. A statistically significant difference in the precision of Trios scanner compared to both My Crown scanner and Omnicam.

**TABLE (2)** Comparison of total precision results in microns between the three studied scanners at depth 3mm & 5 mm and intemal angulations 6˚ & 10˚

| | | Group M (My Crown) | | p value | Group O (Omnicam) | | p value | Group T (Trios) | | p value |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Internal Angulation | | | In tern al Angulation | | | Internal Angulation | | |
| | | 60 | 100 | | 60 | 100 | | 60 | 100 | |
| Preparation Depth | 3mm | 38.12±9.23 | 35.26±8.1 | 0.24 | 26.34±2.62 | 33.17±5.21 | 0.004 | 22.31±5.11 | 16.19±3.22 | 0.013 |
| | 5mm | 20.27±3.72 | 27.18±6.32 | 0.005 | 22.15±3.72 | 23.26±2.83 | 0.73 | 17.2±2.84 | 16.24±4.43 | 0.8 |
| p value | | 0.001 | 0.035 | | 0.012 | < 0.001 | | 0.004 | 0.9 | |

- Total precision results showed the best scanner was group T(Trios) followed by group O (Omnicam group) followed by my group M (My Crown). no statistically significant difference in total precision of the Omnicam scanner (26.21±5.24) and my crown scanner (30.14±9.92) (p-value = 0.051) Statistically significant difference in total precision between both my crown and Omnicam scanners compared to Trios (18.16±4.53) (p-value <0.001) (p value<0.001).
- For total precision; no significant difference between 6° (24.08±8.12) and 10° (25.21±9.09) (p-value =0.5)
- For total precision; 5mm (20.24±5.19) is significantly higher in precision than 3mm (28.11±9.2) (p-value <0.001)

## DISCUSSION

The purpose of this study was to compare the trueness and precision of 3 IOS during scanning of 4 different Endocrown preparations with different internal angles and depths. The use of an artificial model was important as a replacement for natural teeth to exclude patient factors affecting the accuracy of scans[10]. NISSIN Acrylic typodont teeth was used in this study as they are close in shape and size to natural teeth and simulated to oral tissues. NISSIN typodont were used in several other studies[11,12].

This study was done in vitro due to a lack of standardization intraorally and determination of in vivo trueness parameters is very difficult due to lack of reference scan, moist environment, and limited space. There is a study found that these intraoral conditions might affect the accuracy of the scanner[13].

Teeth were prepared using a CNC machine to obtain standardized preparations and to avoid an arbitrary preparation by the operator [14]. Acrylic teeth were milled within acrylic blocks rather than typodont to ensure that internal angulations were accurate and related to the long axis of the tooth while in typodont; acrylic teeth may have some inclinations because of the curve of Spee and curve of Wilson.

Preparations were made on the lower 1st mandibular molars because it is the most frequent tooth treated by root canal therapy and it is the first permanent molar to erupt so it has the largest chance to be carious and decayed [15].

In this study Endocrown preparation was selected as Endocrowns have been introduced as alternative options for restoring endodontically treated teeth depending on the availability of remaining tooth structure. Endocrown can preserve tooth structure more than conventional post and core and crowns which need more tooth preparation and increase the susceptibility of tooth fracture [14].

Samples then were scanned with Trios, Omnicam, and My crown scanners. The same operator performed all the scans on 3 IOSs to exclude the effect of experience on the accuracy of the scans. According to manufacturer instructions, the powder was only used in My crown scanner and not recommended by the other scanners manufacturers [16]. Schaefer et al observed a significantly higher accuracy when no powder was used during digital scanning [17]. Ender et al concluded that regardless of the use of powder or scan spray, similar accuracy can be observed. [18] although powder is not very comfortable for patients, no clear difference was found in articles concerning the effect of powdering on scan accuracy [3].

According to the trueness results, the best scanner in trueness was group T (Trios scanner) followed by group M ( My crown) then Group O ( omnicam.). While Precision results: showed that the best scanner in precision is group T (Trios scanner) followed by Group O ( omnicam) followed by group M ( My crown). This is maybe due to the scanning technology of confocal microscopy of Trios is better than Stereo photogrammetry of My crown and Active triangulation of Omnicam [3].

Reme et al. [19] mentioned that scanning technologies may affect the accuracy of the scanner, such as the triangulation technique (used by Omnicam, Dentsply Sirona), and the confocal scanning technique (used by Trios, 3Shape). The confocal scanning technology is a faster scanning technology that captures images by focusing on an optical light beam with high-resolution visual images with improved accuracy and fewer distortions. our study found that confocal scanning was better than the triangulation technique and stereophotogrammetry.

The active triangulation strategy used in Omnicam IOS could have better trueness results if the scanning and oral conditions are ideal. In comparison, the confocal microscopic technology used in Trios doesn't need a certain distance for focusing, and therefore it's unnecessary to make the scanner tip attached to the teeth during the scanning procedure [20].

Ashraf Y et al [10] and Khaled M et al [21]. reported that the trueness and precision results of the Trios scanner were better than Omnicam results. They also reported a significant difference between Trios and Omnicam results, so the first null hypothesis was rejected as there was a difference in trueness and precision between the different IOS. This study showed that increasing divergence angle and wall-length will increase trueness values.

Jeon et al [22] mentioned that increasing wall divergence will lead to better trueness results. Attia M [20] et al concluded that inlay preparation with 12 degrees axial wall divergence is significantly better than the 6 degrees axial wall divergence, in terms of trueness. The second null hypothesis was rejected as there was a difference in trueness and precision between the different Endocrown preparations.

The limitations of this study were: that it was in vitro and there was no stimulation of the oral environment (saliva, darkness, fogging, and intraoral temperature). this study was related to the accuracy of only Endocrown preparation designs and not related to other types of preparations (crown, veneer, and onlay). The used intra-oral scanners have one scanner which needs powdering while the other two scanners don't need powdering (according to manufacturer instructions). more depth ranges needed to be evaluated.

## CONCLUSION

Within the limitation of this in vitro study, the following conclusions may be drawn:

1. Accuracy (Trueness & precision) of Trios IOS is better than Omnicam & My Crown scanners.
2. The more axial wall length (within limitation), the more accurate the digital scan.
3. The more axial wall divergence (within limitation), the more accurate the digital scan.

## REFERENCES

1. Perry R. Dental impression materials. Journal of Veterinary Dentistry. 2013 Jun;30(2):116-24.
2. Kravitz ND, Groth CH, Jones PE, Graham JW, Redmond WR. Intraoral digital scanners. Journal of Clinical Orthodontics. 2014 Jun 1;48(6):337-47.
3. Richert R, Goujat A, Venet L, Viguie G, Viennot S, Robinson P, Farges JC, Fages M, Ducret M. Intraoral scanner technologies: a review to make a successful impression. Journal of Healthcare Engineering. 2017 Jan 1;2017.
4. Patzelt SB, Vonau S, Stampf S, Att W. Assessing the feasibility and accuracy of digitizing edentulous jaws. The Journal of the American Dental Association. 2013 Aug 1;144(8):914-20.
5. Luthardt R, Weber A, Rudolph H, Schöne C, Quaas S, Walter M. Design and production of dental prosthetic restorations: basic research on dental CAD/CAM technology. International journal of computerized dentistry. 2002 Apr 1;5(2-3):165-76.
6. Braian M, Wennerberg A. Trueness and precision of 5 intraoral scanners for scanning edentulous and dentate complete-arch mandibular casts: A comparative in vitro study. The Journal of prosthetic dentistry. 2019 Aug 1;122(2):129-36.

7. Kim MK, Kim JM, Lee YM, Lim YJ, Lee SP. The effect of scanning distance on the accuracy of intraoral scanners used in dentistry. Clinical Anatomy. 2019 Apr; 32(3):430-8.

8. Debbabi I, Nouira Z, Saafi J, Harzallah B, Cherif M. ENDOCROWN": A Reliable Alternative to Restorate RCT Molar. Two Case Reports. Adv Dent & Oral Health. 2018;9(5):555774.

9. Rosenstiel SF, Land MF, editors. Contemporary fixed prosthodontics-e-book. Elsevier Health Sciences; 2015 Jul 28.

10. Ashraf Y, Sabet A, Hamdy A, Ebeid K. Influence of preparation type and tooth geometry on the accuracy of different intraoral scanners. Journal of Prosthodontics. 2020 Dec;29(9):800-4.

11. Oh KC, Lee B, Park YB, Moon HS. Accuracy of three digitization methods for the dental arch with various tooth preparation designs: An in vitro study. Journal of Prosthodontics. 2019 Feb;28(2):195-201.

12. Park JM, Kim RJ, Lee KW. Comparative reproducibility analysis of 6 intraoral scanners used on complex intracoronal preparations. The Journal of Prosthetic Dentistry. 2020 Jan 1;123(1):113-20.

13. Park HN, Lim YJ, Yi WJ, Han JS, Lee SP. A comparison of the accuracy of intraoral scanners using an intraoral environment simulator. The Journal of Advanced Prosthodontics. 2018 Feb 1;10(1):58-64.

14. Taha D, Spintzyk S, Schille C, Sabet A, Wahsh M, Salah T, Geis-Gerstorfer J. Fracture resistance and failure modes of polymer infiltrated ceramic endocrown restorations with variations in margin design and occlusal thickness. Journal of prosthodontic research. 2018;62(3):293-7.

15. Hull TE, Robertson PB, Steiner JC, del Aguila MA. Patterns of endodontic care for a Washington state population. Journal of endodontics. 2003 Sep 1;29(9):553-6.

16. Zaruba M, Mehl A. Chairside systems: A current review Chairside-Systeme: Eine aktuelle Übersicht. International Journal of Computerized Dentistry. 2017;20:123-49.

17. Schaefer O, Decker M, Wittstock F, Kuepper H, Guentsch A. Impact of digital impression techniques on the adaption of ceramic partial crowns in vitro. Journal of dentistry. 2014 Jun 1;42(6):677-83.

18. Ender A, Mehl A. Influence of scanning strategies on the accuracy of digital intraoral scanning systems. International Journal of Computerized Dentistry 2013;16:11-21

19. Renne W, Ludlow M, Fryml J, Schurch Z, Mennito A, Kessler R, Lauer A. Evaluation of the accuracy of 7 digital scanners: An in vitro analysis based on 3-dimensional comparisons. The Journal of prosthetic dentistry. 2017 Jul 1;118(1):36-42.

20. Attia, M., Ebeid, K. Influence of inlay preparation design on the trueness of different impression techniques. Egyptian Dental Journal, 2019; 65(Issue 3 - July (Fixed Prosthodontics, Dental Materials, Conservative Dentistry & Endodontics)): 2517-2526.

21. Khaled M, Sabet A, Ebeid K, Salah T. Effect of Different Preparation Depths for an Inlay-Retained Fixed Partial Denture on the Accuracy of Different Intraoral Scanners: An In Vitro Study. Journal of Prosthodontics. 2021 Nov 27.

22. Jeon JH, Kim HY, Kim JH, Kim WC. Accuracy of 3D white light scanning of abutment teeth impressions: evaluation of trueness and precision. The Journal of Advanced Prosthodontics. 2014 Dec 1;6(6):468-73.