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ACCURACY OF SCANNING STOCK ABUTMENTS VERSUS SCAN BODIES USING DIFFERENT INTRAORAL SCANNERS FOR SINGLE IMPLANTS. AN IN VITRO STUDY

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ABSTRACT

Aim: The aim of this in vitro study was to evaluate the accuracy of scanning stock abutment versus scan bodies on a single implant using two different intra-oral scanners.

Methodology: A printed cast model of a partially edentulous maxilla installed with a single implant at the second premolar area was fabricated to serve as reference cast. Two scannable components were used in this study; a scan body (control group) and a stock abutment (intervention group). For both groups, the cast was scanned once with an extra-oral scanner and five times with two different intraoral scanners; Medit i700 and Prime scan. Geomagic X- software was used to compare the trueness and precision in the two groups. Precision was recorded twice (with full model scans and after segmentation of the scannable components from their corresponding models). RMS values were recorded, tabulated and analyzed.

Results: There were no statistically significant differences in trueness between the 2 groups (scan body and stock abutment groups) for both intraoral scanners. There was no statistically significant difference in trueness between the two intraoral scanners within each group. Primescan IOS showed significantly lower precision than Medit i700 in the full model scans of the scan body group.

Conclusions: Trueness was significantly comparable for both groups and was not significantly affected by the type of IOS used. However, precision of Medit i700 was higher than that of Primescan IOS when scan bodies were used especially in the full model scans.

KEYWORDS: Trueness, stock abutments, scan bodies, intraoral scanners, precision

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INTRODUCTION

Partial edentulism, the condition of missing one or more natural teeth, significantly impacts individuals on biological, social, and psychological levels [1]. While it might seem that a single missing tooth has minor consequences, the loss of an anterior tooth can considerably affect appearance, speech, and overall oral health quality of life. Similarly, a missing posterior tooth can lead to impaired chewing ability, super-eruption of opposing teeth, tilting or drifting of adjacent teeth, malocclusion, premature wear on remaining teeth, temporomandibular joint disorders, and further tooth loss over time [2].

Various treatment options exist for replacing a single missing tooth, including no treatment, removable partial dentures, fixed partial dentures, and dental implants. Among these, dental implants supporting a single crown are often the preferred choice, as they avoid unnecessary preparation of adjacent teeth and eliminate the disadvantages associated with removable restorations, while demonstrating high survival rates [3-5].

Advancements in CAD/CAM technology have revolutionized dental implant prosthetics, utilizing digital workflows comprising scanners, software, and milling machines. Intraoral scanners enable digital impressions without the need for special trays or cast pouring, thereby reducing potential errors and fabrication time. They also mitigate issues related to gaps and voids from impression materials, which can lead to misfit prostheses[6, 7]. Furthermore, some patients have limited mouth opening, macroglossia, or a gag reflex. These situations complicate conventional (physical) impression procedures. Moreover, an inaccurate transfer of the implant position from a physical impression to a gypsum cast caused by shrinkage and distortion of the impression materials can lead to unstable repositioning of the analogue during the laboratory process. On the other hand, a digital workflow will avoid the use of impression materials, implant impression copings, and laboratory-analog abutments, thereby reducing the cost of consumable materials and overcoming the drawbacks of physical impressions [8, 9].

While scan bodies are essential for digital impressions, their straight-rod form can cause soft tissue collapse, altering the soft-tissue profile. Improper fastening of scan bodies may reduce prosthesis accuracy [10]. Additionally, using scan bodies requires two scans: one to record the implant position and another to capture the soft-tissue profile [11]. Considering these possible drawbacks, there was an idea of using the already present stock abutment instead of the scan bodies in making digital impressions. Because the implant crown could be manufactured on the already connected and scanned stock abutment, the restoration can be manufactured very simply and accurately; which consequently reduces the overall manufacturing time of the restoration, along with the cost, unlike wen customized abutments are used as in case of using the scan bodies [12]. However, there is lack of evidence about the accuracy of using such technique in making digital impressions.

Hence the aim of the current study was to evaluate the accuracy of scanning a stock abutment versus a scan body on a single implant using two different intra-oral scanners. The null hypothesis was that there will be no significant differences between the two scannable components and no significant differences between the two intraoral scanners used.

MATERIAL AND METHODS

1- Cast fabrication and implant drilling

A generic digital maxillary model, with a missing left second premolar, was designed and prepared with CAD software. The model was printed with an SLA 3D-printer with 50 µm layer thickness, then the post-printing instructions from the manufacturer were done including cleaning and curing of the object to finalize the polymerization process. Drilling was initially performed using drills of diameter size of 2.3 mm (pilot drill), followed by 2.8mm drill, 3.4 mm drill then finally 3.8 mm drill for the placement of the implant 4.1x10 mm (JDNow. JDentalCare., ITALY) in dimension. The drilling site was cleaned and the fixture was secured in place using cement (**Fig. 1**).

Fig. (1) Dental implant in the 3D Printed cast model.

2. **Preparing the casts for Digital Impressions:**

Group (A): Maxillary cast with a scan body (control group): A titanium scan body (JDNow. JDentalCare., ITALY) was tightened over the single implant in the cast **(Fig. 2A).**

Group (B): Maxillary cast with a stock abutment (intervention group): A torque wrench was used to tighten the stock abutment (JDNow. JDentalCare., ITALY) to the implant to 30Ncm **(Fig. 2B).**

3. **Scanning casts with Extra oral and intraoral scanners**

For both groups, a scan impression was taken with a digital high resolution extra-oral scanner (Dentsply Sirona lab scanner) (**Fig. 3A**) to act as the reference scan file. After scanning the models, the scans were exported as STL files and saved for comparison. Then the cast in both groups was scanned five times with two different intraoral scanners; Medit intraoral scanner (Medit I 700 Korea) and Primescan (Sirona Primescan, Dentsply LLC, Canda) intraoral scanner (**Fig. 3 B**). The scanning distance was standardized in both groups for all scans to be 10 mm and all scanning procedures were carried out by the same operator following the same scanning strategy (**Fig. 3C**). After the acquisition of five repeated digital impressions, the files were exported as STL files and saved for comparison.

4- **Accuracy assessment with digital scanning and superimposition:**

Using the Geomagic X-software (Geomagic control X, 3D systems, USA), the STL scan files of the intraoral scans were compared and superimposed on the extra-oral scan file to assess the accuracy (trueness) of each intraoral scanner (**Fig. 4**).

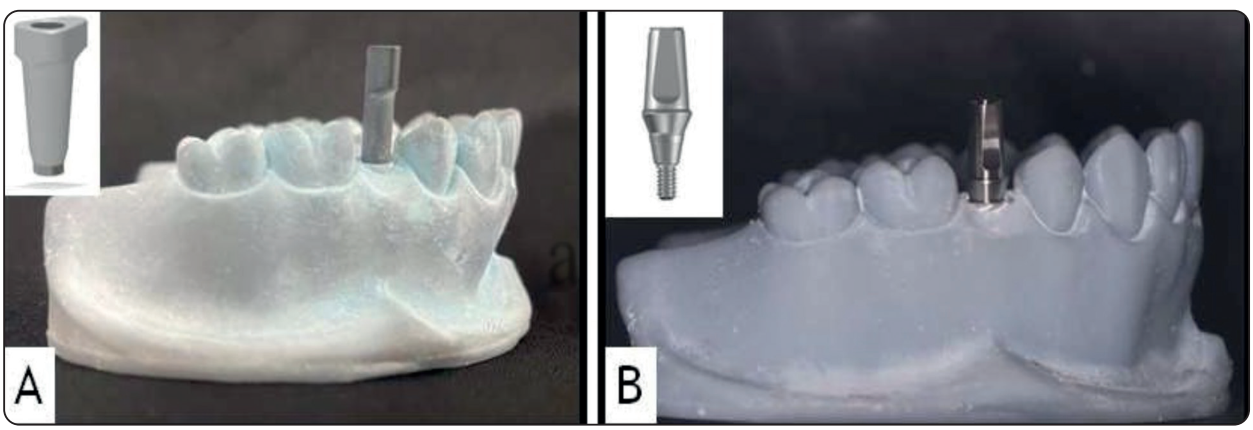

Fig. (2): (A) Scan body tightened over the implant (Group A); (B) Stock abutment tightened to the cast (Group B)

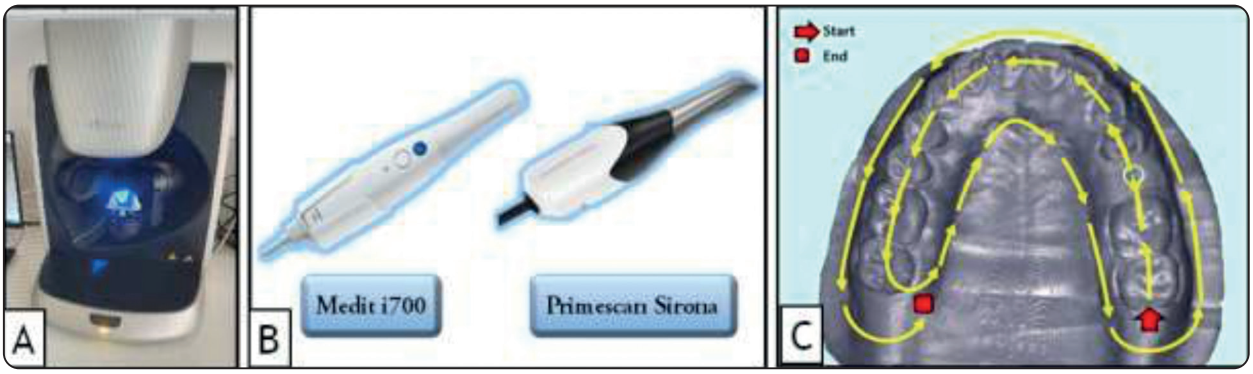

Fig. (3) (A) Extraoral Scanner; (B) Intraoral scanners used ; (C) Scanning Strategy

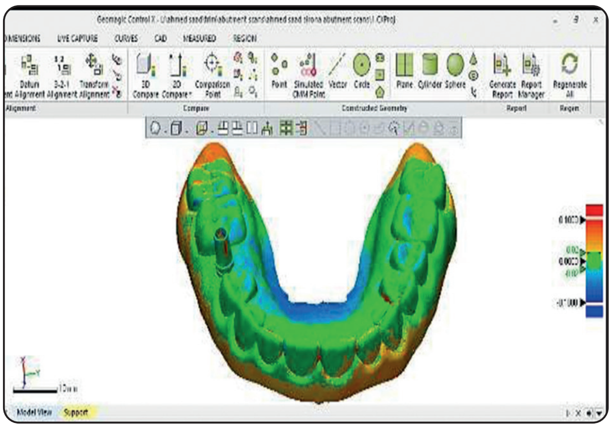

Fig. (4) Geomagic software screen showing the superimposition step.

On the software, the extra-oral scan file was considered as the reference scan while intraoral scan files were considered as the target scans. Virtual marks were made on fixed common points on all scans (control and targets) to facilitate the identification (**Fig.5 A and B**).

The target scans were being superimposed to the reference scan by using the best-fit algorithm. First, the scans were superimposed for initial alignment using the pre-alignment feature of the software. Then, the scans were further superimposed with "Local best-fit" feature of the software according to the predetermined virtual marks in order to minimize any errors. The software matched the points and

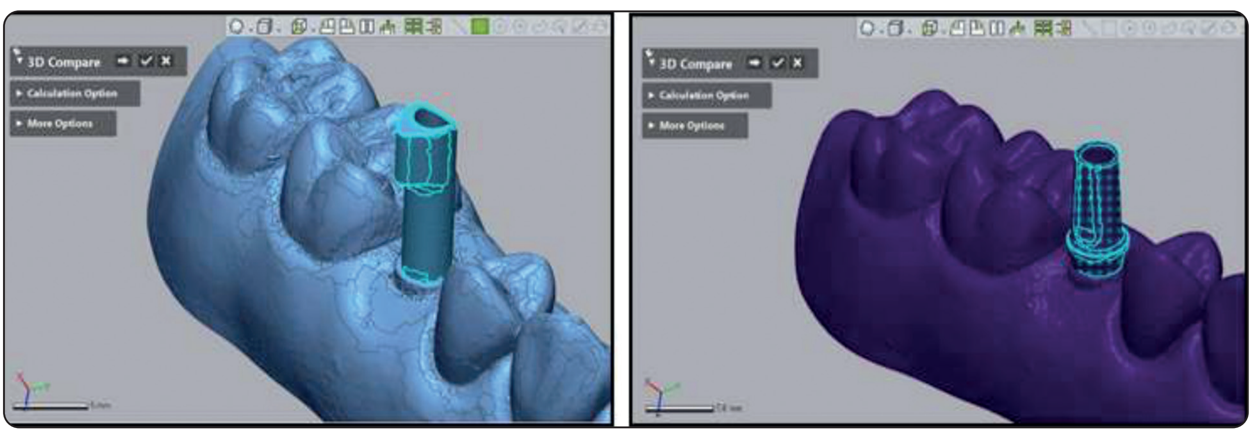

Fig. (5) Virtual marks were made on fixed common points, Virtual marks on scan body models (left), Virtual marks on stock abutment models (Right) made the superimposition. This was done for both the scan body (control) group and the stock abutment (intervention) group. The 3D linear deviations were then calculated by using the Geomagic control X superimposition software for data comparison. The software calculated the root mean square (RMS) through a programed equation. The software also provides a color map for the results with colors that represent positive and negative distances. The green color is the desired user-defined ideal deviation and the red and blue colors are deviations outside of the desired range; where blue represents inward and red represents outward displacement between overlaid structures.

To investigate the precision of each intraoral scanner, the 5 scans within each group were overlapped and superimposed on each other in pairs [(12)], by setting one scan as a reference scan and then superimposing the other scans on it separately. This led to a total of 10 pairs within each group for each IOS. Superimposition between each pair was performed using the initial alignment followed by the best-fit alignment (software tool) with a tolerance of ± 0.02 mm. The precision of each IOS was then obtained by calculating the average of the RMS values of all 10 scans of each IOS within each group. Precision was investigated twice; once with the full model scans (**Fig. 6**) and a second time after segmentation (**Fig. 7 and 8**). The reference scan was segmented into two parts [(13)]. The first segment consisted of either the scan body or the abutment (comparative aspect) used for 3D comparison, while the second segment consisted of all other areas of the model including teeth, gingiva and model base which were used for the superimposition. RMS values for the full model scans and for the segmented scans were recorded, tabulated and analyzed.

The SPSS statistical analysis software was used to analyze the RMS values obtained from the 3D analysis. The independent t-test was used to investigate the effect of group (scan body versus stock abutment) on trueness; while Paired t- test was used to test the effect of the type of intraoral scanner (trueness and precision) within each group. Significance cut-off was set at 0.05.

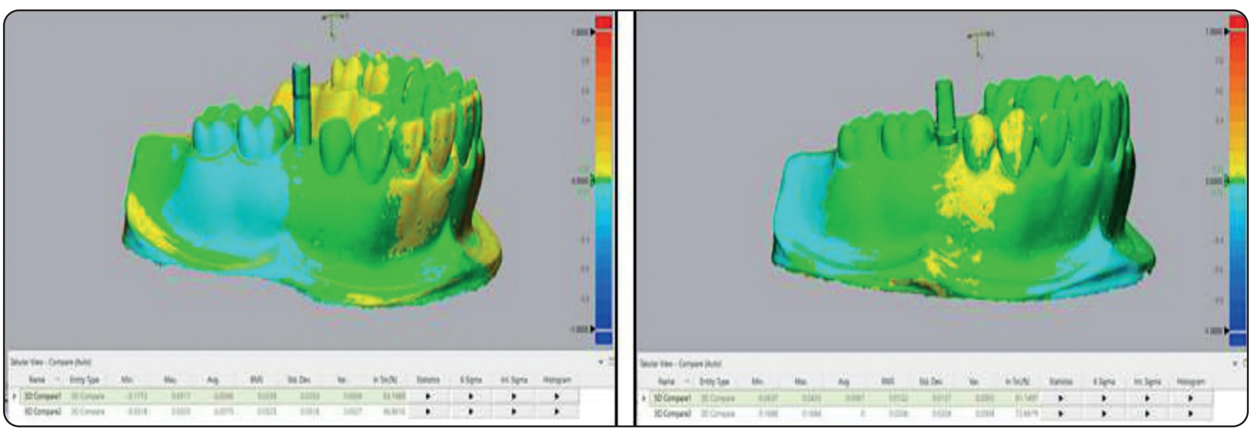

Fig. (6) A pair of 2 scans superimposed on each other in the scan body group (left) and in the stock abutment group (right)

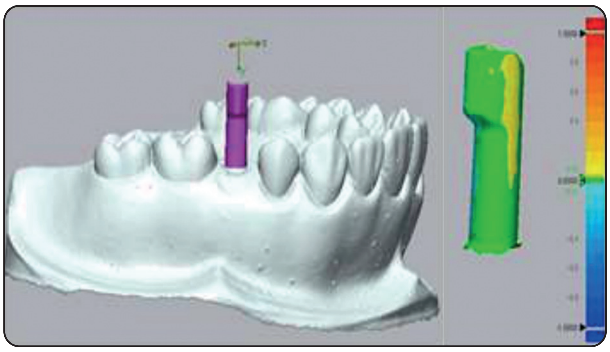

Fig. (7) Segmentation of the scan body (left); a pair of 2 scans in the scan body group (after segmentation) superimposed on each other (right)

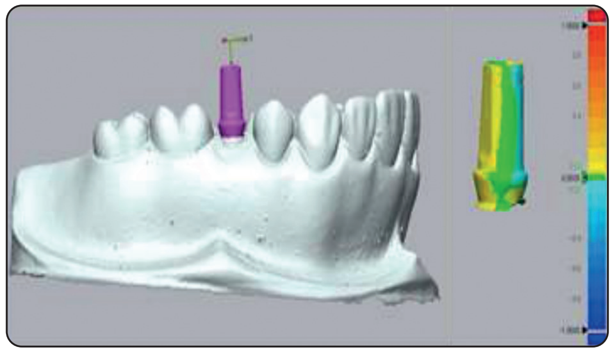

Fig. (8): Segmentation of the stock abutment (left); a pair of 2 scans in the stock abutment group (after segmentation) superimposed on each other (right)

RESULTS

A- Effect of Group (Scan body versus Stock Abutment) on Trueness

The mean RMS values in the scan body group were nearly the same as those of the stock abutment group for the Medit i700 intraoral scans. On the contrary, for the Primescan scans, the RMS values for stock abutment group were considerably lower (indicating superior trueness) than those of the scan body group. Statistical analysis however revealed insignificant differences between the two groups for both intraoral scanners **(Table 1).**

TABLE (1) The mean RMS values (in μm) for both groups using the two intraoral scanners.

Intra-oral Scanner	Group I Scan Body (n=5)	Group II Stock Abutment (n=5)	P-value
	Mean ± SD	Mean ± SD	
Medit i700	40.02 ± 3.42	40.46 ± 3.57	.847
Primescan	123.08 ± 119.20	39.84 ± 3.79	.157

B- Effect of Intraoral Scanner (Medit i700 versus Primescan) on Trueness

Mean RMS values for the Medit i700 IO were nearly the same for both scan body and stock abutment groups. The highest RMS values were recorded for the Primescan IOS in the scan body group. Despite that, statistical analysis revealed insignificant differences between the two intraoral scanners for both the scan body and the stock abutment groups **(Table 2)**

TABLE (2) The mean RMS values (in μm) for both intraoral scanners within each group

Group	Medit i700	Primescan	P-value
	Mean ± SD	Mean ± SD	
Scan body	40.02 ± 3.42	123.08 ± 119.20	.203
Stock abutment	40.46 ± 3.57	39.84 ± 3.79	.793

C- Precision of each Intraoral Scanner (Medit i700 versus Primescan) within each group (Full Model Scans)

Mean RMS values for both intraoral scanners were comparable in the stock abutment group with insignificant differences between the two intraoral scanners. However, in the scan body group, the Primescan IOS showed considerably higher RMS values (lesser precision) than the Medit i700 IOS with a statistically significant difference between both **(Table 3).**

TABLE (3) The mean RMS values (in μm) for both intraoral scanners within each group (Full model scans)

Group	Medit i700 (n= 10 scans)	Primescan (n=10 scans)	P-value
	Mean ± SD	Mean ± SD	
Scan body	40.42 ± 13.61	239.1± 171.86	.005
Stock abutment	35.63 ± 9.01	37.99 ± 8.05	.413

D- Precision of each Intraoral Scanner (Medit i700 versus Primescan) within each group (Segmented Scans)

Similarly, the mean RMS values for both intraoral scanners were comparable in the stock abutment group. In the scan body group, the Primescan IOS still showed higher RMS values (lesser precision) than the Medit i700 IOS. However, for the segmented scans, statistical analysis revealed insignificant differences between the two intraoral scanners for both the scan body and the stock abutment groups **(Table 4).**

TABLE (4) The mean RMS values (in μm) for both intraoral scanners within each group (Segmented scans)

Group	Medit i700 (n= 10 scans)	Primescan (n=10 scans)	P-value
	Mean ± SD	Mean ± SD	
Scan body	27.16 ± 9.77	96.21± 71.86	.103
Stock abutment	32.27 ± 14.51	59.66 ± 38.94	.193

DISCUSSION

The current study was meant to answer whether there would be potential differences when scanning with a scan body versus scanning with a stock abutment or not, and this was done using two different intraoral scanners. The two main evaluated parameters were trueness and precision. Trueness is a crucial aspect of digital impression accuracy and precision is also essentially important for understanding the consistency of intraoral scanners[14]. Trueness was investigated by superimposing the scans obtained by the intraoral scanners and comparing them to the scans obtained by an extra-oral scanner which has been advocated by some as a gold standard reference [15]. However, this has been a point of controversy recently. Although several studies reported that desktop scanners are more accurate than intraoral scanners [16, 17], other researchers reported insignificant differences in the trueness between intraoral and extraoral scanners [18]. In fact, a recent systematic review [19] reported that intraoral scanners may even be more accurate than extraoral scanners in partially edentulous situations. Yet it was necessary to include the extraoral scanner in the current study to obtain a reference scan for the purpose of superimposition and comparison.

Results of the current study revealed that the highest RMS value was recorded for the scan body when scanned with the Primescan IOS, yet interestingly enough statistical analysis revealed insignificant differences between the two approaches. This suggests that the choice of either a scan body or a stock abutment did not significantly impact the accuracy of the implant position registration with either Medit i700 or Primescan intraoral scanners. Hence, the first hypothesis suggesting insignificant differences between the two scannable components could be accepted. This could be attributed to a number of factors. Firstly, most of the factors that could influence scanning accuracy (trueness), including the scanning distance and the scanning pattern were standardized for both groups as mentioned earlier. Secondly, the area of interest was a short span bounded edentulous area with only one implant replacing a single missing tooth. The presence of teeth anterior and posterior to the area of interest may have contributed to the comparable trueness. It has been reported that teeth act as fixed reference points that facilitate stitching during image acquisition [20]. Moreover, both the scan body and the stock abutment were made of the same material, namely titanium. It has been reported that the material of the scan body can affect the trueness of the obtained digital impression [21]. Hence, the comparable trueness obtained in both groups could be partly due to the fact that they were both made of the same scannable material. In their study, Lee et al 2021 [21] compared between two different scan body materials (PEEK versus Titanium) and their effect on the trueness of digital implant impressions. Their results revealed that the titanium scan body produced significantly better trueness of the acquired scan data compared to the PEEK scan body.

As regards the effect of the intraoral scanner on trueness, results of the current study revealed that trueness was similar for both scanners with the Medit i700, but the Primescan IOS showed inferior performance with the scan body group, though this was not statistically significant. This indicates that both scanners are generally comparable in reproducing implant positions. However, for optimal safety, Medit i700 may be preferable when using scan bodies. Direct comparison with other published research was not possible, as to the best of our knowledge; there were no articles that compared between the trueness of Medit i700 and Primescan specifically in maxillary single implant cases. However, the results of the current study are somehow consistent with those reported by **Vag et al 2023** [22], who investigated the trueness of five intraoral scanners including Emerald S, iTero, Element 5D, Trios 4 as well as Medit i700 and Primescan in fully dentate maxillary and mandibular cadaver specimens and compared them to scans obtained from an extra-oral and an industrial scanner. Their results revealed insignificant differences among all 5 intraoral scanners as regards trueness.

It is worth mentioning that, in the current study, the trueness RMS values for the Medit i700 did not exceed 50 μm, while the highest value was 123 μm for the Primescan with scan bodies. Considering 120 μm as an acceptable margin gap for single crowns [23], our results suggest that digital impressions from both scanners should yield clinically acceptable restorations.

Precision, reflecting the consistency and repeatability of measurements, was also evaluated. For the full arch scans, there were insignificant differences between the two intraoral scanners in the stock abutment group. On the contrary, the Primescan IOS exhibited substantially lower precision (higher RMS values) in the scan body group when compared to the Medit i700 IOS with an explicit significant difference between both scanners. Hence, the second hypothesis suggesting insignificant differences between the two intraoral scanners could not be fully accepted. Direct comparison with other published research was not possible as mentioned earlier, however considering that most of the factors that have an influential role on precision were standardized as much as possible in the current study, then this difference may be attributed to a factor that cannot be standardized and is not in the hands of the operator, which is the scanning technology of the intraoral scanner itself. The scanning technology of Primescan involves high-resolution sensors and short-wave light with optical high-frequency contrast analysis for dynamic deep scan (20 mm). On the other hand, the scanning technology of for Medit i700 involves a 3D in motion video technology with a scanning frame of 70 FPS (frames per second) [24]. The scan body and the stock abutment used in the current study may be of the same material nevertheless they differ both in length and in geometry. The scan body is longer and has a projecting head with a resultant undercut beneath it, while the stock abutment is shorter with straighter surfaces all around. The results may suggest that there could be a correlation between the scanning technology and the geometry and length of the scannable component. To clarify further, the 3D in motion video technology of the Medit i700 might have been capable of capturing all hidden and unhidden (undercut areas) of the scannable component more accurately. This justification, however, needs further research to be confirmed.

It is noteworthy however that this significant difference in precision between the two intraoral scanners in the scan body group disappeared in the segmented scans when the scannable components were segmented from their corresponding models. This suggests that the precision of the Primescan IOS increases when the extension (span) of the scanning area decreases. This suggestion could be supported by the conclusions reached in a systematic review conducted by **Abduo and Elseyoufi 2018** [25], who reported that full-arch scanning showed a potential for more deviations compared to partial-arch scanning.

To conclude, the results of the current study suggest and imply that, in bounded single implant cases, both the stock abutment and the scan body can result in acceptable digital impressions from which we can obtain accurate final restorations with clinically acceptable fit. In which case, the clinician is free to choose any of the two scannable components based on availability and/or expenses, keeping in mind the extra benefit of using the latter as its use will reduce the overall manufacturing time as mentioned earlier, hence reducing the overall treatment cost. Moreover, if scan bodies are to be used, then Medit i700 IOS is preferred than Primescan IOS. And if the Primescan IOS will be used with the scan bodies, it could be assumed that partial arch scanning is preferred than full arch scanning to achieve more true and precise scans.

There are several limitations to the current study. First, it is an in vitro study; hence patient-related factors such as saliva, tongue movement, humidity and mouth opening were eliminated. Although this may have benefited the study in allowing the standardization of many factors, it could be considered a study limitation as it does not simulate the clinical situation. Additionally, results are specific to the tested scenario (maxillary bounded edentulous area with a missing second premolar replaced by a single implant) and cannot be generalized to all clinical situations.

CONCLUSIONS

Within the limitations of this in-vitro study it could be concluded that in maxillary cases with single implants:

1. Trueness of digital scans using scan bodies or stock abutments is comparable regardless of the type of intraoral scanner used.
2. Trueness of both tested intraoral scanners (Medit i700 and Primescan) seems comparable regardless of the scannable component used (scan body or stock abutment). However, using the Medit i700 IOS with scan bodies is preferable.
3. Precision of Medit i700 was higher than that of Primescan IOS when scan bodies were used especially in the full model scans.

There are no conflicts of interest. We confirm that the manuscript has been read and approved by all named authors and the order of authors listed in the manuscript has been approved by all of authors.

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