ISSN Print: 2394-7489
ISSN Online: 2394-7497
IJADS 2023; 9(3): 93-97

www.oraljournal.com
Received: 21-05-2023
Accepted: 23-06-2023

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Accuracy of digital scan body impression for implant supported fixed partial denture by using intra and extra-oral scanners (comparative *in vitro* study)

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DOI: https://doi.org/10.22271/oral.2023.v9.i3b.1791

Abstract
Purpose: To determine the accuracy of digital scan body impression for implant supported fixed partial denture using an intra-oral and extra-oral digital scanner
Material and Methods: A typodont cast with acrylic teeth was used, afterwards cast duplication and surgical guide were fabricated for drilling 0f implant fixture placement. The scan bodies were fixed on the implant fixture. Samples were divided into two groups. Group 1 intra-oral scanning (IOS) 10 samples using Medit i500 and for Group 2 extra-oral scanner (EOS) 10 samples using Medit T500. The reference model scanned using extra-oral scanner to be transferred as an STL file. That was used as a control group for comparison. The STL files from both groups with the reference model were analyzed by the metrology software Geomagic. For trueness comparison, the IOS and EOS group were supper imposed into the reference cast with scan bodies. For precision comparison the IOS group was over-imposed on one another, and the EOS group technique was also over-imposed on each other.
Results: It was found that the precision of both IOS and EOS was clinically accepted with no significant difference between both groups.
Conclusion: Through this study, it can be evidenced that the IOS and scan body are a valid alternative to conventional techniques of impressions with elastomeric materials for obtaining accurate restorations of the short-span implant fixed prosthodontics.

Keywords: Fixed partial denture, scanner, scan body, medit

Introduction
The digital scanning of the dentition is a critical step on the digital journey, for CAD/CAM manufacture of the dental implant, which is assisted by restoration, a virtual model is necessary. The translation of the intraoral condition to a virtual model is the first step in the digital workflow (Vecsei *et al*., 2021) [24].
Digitization of the dentition was first introduced by an indirect scan of the stone model, and more recently, direct intra-oral scanning, also known as digital imprint, has entered the dental field in conjunction with CAD/CAM technology. Intra-oral scanners (IOSs) have transformed both dentists and technicians (Lin *et al*., 2019) [12].
IOS digital implant impressions do not involve the use of impression material or trays, as well as impression taking, which enables patients to prevent having their mouths open wide during the imprint (Parize *et al*., 2022) [19]. In implant dentistry, intra-oral scan bodies (ISBs) are directly linked to implants and used as the scan object. It is useful for digital implant impressions since the ISB's dimensions and unique properties have already been loaded into the application. Furthermore, ISBs' smooth, dull and opaque surfaces may help in scanning. IOSs are suitable for implant impressions because they try to capture the implant position rather than the fine finish lines of the preparation (Sawase & Kuroshima, 2020) [22].
As a result, the use of an ISB is important for transferring implant position and inclination with great accuracy (Arcuri *et al*., 2022) [1]. More research is required to investigate the relationships between ISB and digital scanning accuracy.
The intraoral scanner has superior satisfaction over the extra-oral scanner because there is no need for imprint material.

This means an elimination of expansion and waiting time for the impression material to dry. Further no mess and no patient-gagging (Elmoutawakkil & Hacib, 2021) [3]. Furthermore, the possibility that displacement of the impression materials and expansion of the stone cast may result in prosthesis mismatch in routine implant impressions employing open or closed tray methods, good results have been achieved in clinical practice (Kurdi, 2022) [9].

The accuracy and trueness of an optical image transfer establish its validity. While precision evaluates how close repeated scans are to one another. The trueness describes how much it deviates from the real dimensions of the object (Mizumoto *et al*., 2020) [17].

As a result, the current study was intended to evaluate the trueness and precision of digital scan body imprints for implant-supported fixed partial dentures made with extra-oral and intra-oral scanners.

Materials and Methods

A total of 20 digital scans were taken for a partially edentulous mandibular model, based on the digital impression technique used.

The sample size for the present study was determined based on data obtained from a previous study (F. G. Mangano *et al*., 2019) [14] and calculated by using the statistical software PS[1], with a power of 80% and a 5% alpha level of significance. The calculated sample size was 10 samples per group. Samples were divided into two groups. Group 1 intra-oral scanning (IOS) 10 samples and Group 2 extra-oral scanner (EOS) 10 samples.

A prefabricated mandibular partially edentulous master model (Nissin cast) [2] consists of a 2-layered construction duplicating Type II hardness with wider bone width allowing basic implant techniques to be used in the present study to serve as the reference model. A typodont cast with missing lower left second premolar, and first and second left molars was used. Then acrylic teeth were added to the cast in the missing tooth area, afterward cast duplication and surgical guide were fabricated for drilling 0f implant fixture placement.

The scan bodies were fixed on the implant fixture. Figure (1) Samples were divided into two groups. The reference model scanned using extra-oral scanner to be transferred as an STL file that was used as the control group for comparison with the two groups.

Fig 1: The scan bodies were fixed on the implant fixture

The IOS group was scanned using Medit I500 10 times and transferred to STL files. For the EOS group, the impression of the master model was taken and poured. Procedures for the open impression technique were done, then implant analogue was fixed to the transfer coping and the impression was poured then scan body was inserted over the implant analogue. Figure (2) Then the model was scanned using an extra-oral scanner T500. The STL files from both groups with the reference model were analyzed by metrology software Geomagic.

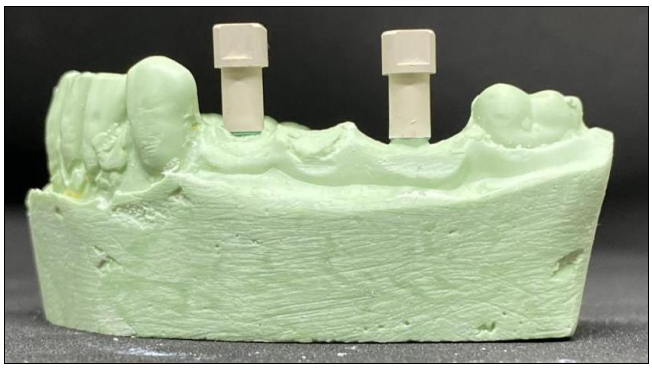

Fig 2: IOS group and EOS group impression

For trueness comparison the IOS and EOS group were supper imposed into the reference cast with scan bodies. For precision comparison the IOS group was over imposed on one another, and the EOS group technique was also over imposed each other. Figure (3)

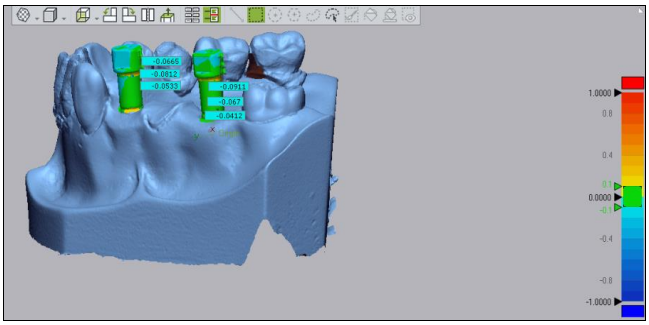

Fig 3: IOS group and EOS group technique

Statistical methods

Data were statistically analyzed and explored for normality, by checking the data distribution and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Data were then tested using Student t-test to compare values.

Results

Exploration of normality of the quantitative data, performed using the Shapiro-Wilk test and Kolmogorov-Smirnov test, revealed that the P-value was insignificant as it exceeded the predetermined level of significance (P-value > 0.05). Data of all outcomes (trueness and precision) were found to be parametric.ie. normally distributed as presented in Figure (4).

[1] IBM SPSS software New york United States

[2] JAPAN Nissin Dental Products INC. Karahashi Hiragakichō, Minami-ku

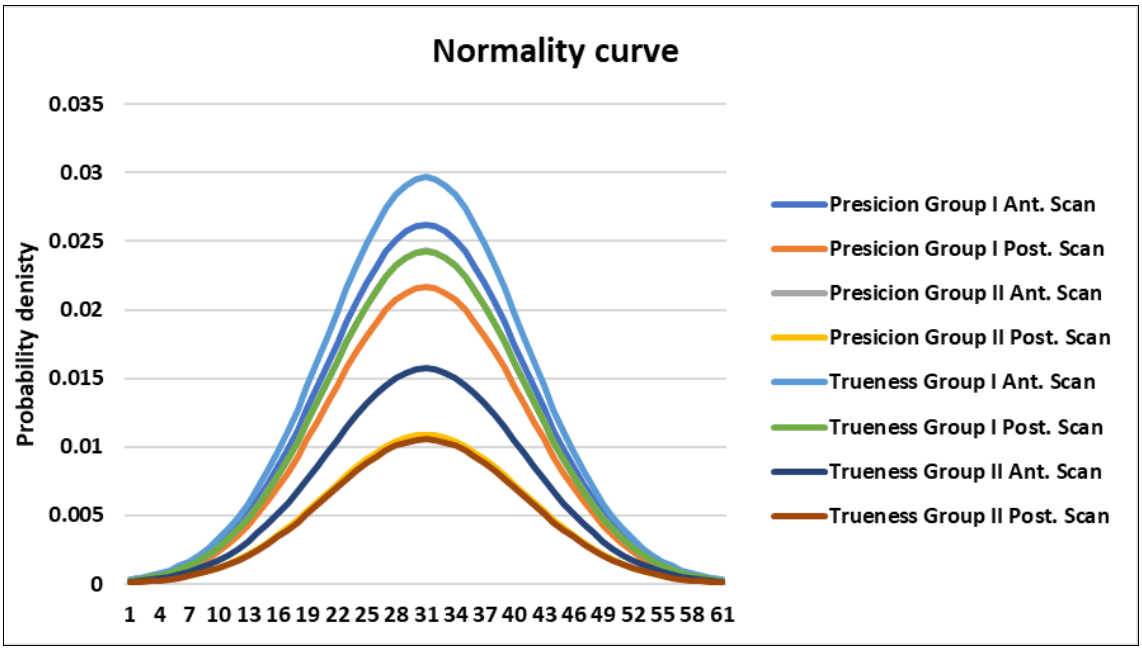

Fig 4: Curve of normality of both groups regarding precision and trueness.

Comparing the trueness of Group IOS and Group EOS using an independent t-test, reveled an insignificant difference between the intra-oral scanner (72.93±10.59) and the extra-oral scanner (78.06±21.99) in terms of the overall mean distance deviation (p>0.05), with the EOS being higher. Comparing the mean distance deviation of scan bodies individually, using an independent t-test, also revealed an insignificant difference between both groups at p>0.05, with the mean distance deviation of SB-Premolar being lower in Group IOS whereas that of SB-Molar was higher in the same group compared to Group EOS, as shown in Table (1).

Table 1: Results of comparing the effect of scanner type (IOS versus EOS) on trueness

Trueness	Group IOS		Group EOS		P value (Independent t test)
	M	SD	M	SD	
SB-Premolar	44.82 um	13.44 um	61.43 um	25.38	0.08 (ns)
SB-molar	101.04 um	16.44 um	94.69 um	37.82	0.63 (ns)
Overall trueness	72.93 um	10.59 um	78.06 um	21.99	0.52 (ns)

M: mean, SD: standard deviation, Ns: non-significant difference as p>0.05. P: Probability Level which is significant at $p\leq 0.05$`

Comparing the trueness of Group IOS and Group EOS using an independent t-test, reveled an insignificant difference between the intra-oral scanner (71.39±11.45) and the extra-oral scanner (85.82±12.80) in terms of the overall mean distance deviation (p>0.05), with the EOS being higher. Comparing the mean distance deviation of scan bodies individually, using an independent t-test, also revealed an insignificant difference between both groups at p>0.05, with the mean distance deviation of SB-Premolar being lower in Group IOS whereas that of SB-Molar was higher in the same group compared to Group EOS, as shown in Figure (5).

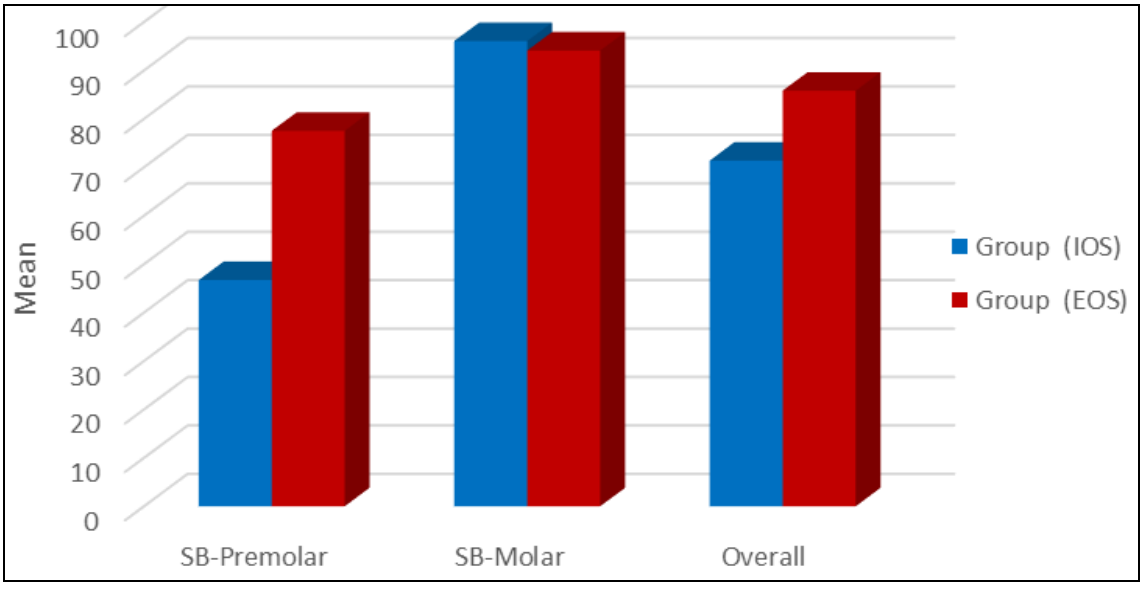

Fig 5: Bar chart showing mean of precision in both anterior and posterior in both groups

Discussion

The present study was an invitro study, which add advantages of removing additional factors that can degrade the quality of a scan such as saliva, blood, limited mouth opening and movements of the patient. (Imburgia *et al*., 2017) [8]. Intra-oral scanner and extra-oral scanners were tested to assess their accuracy. Medit I500 intra-oral scanner from Medit was used during this study because, Medit I500 considered as one of the most accurate newly designed IOS (Revell *et al*., 2022) [20] (F. Mangano *et al*., 2020) [15].

Regarding the results of overall trueness, the results failed to reject the null hypotheses, as there was no statistically significant difference between the tested scanners, with IOS group showing better trueness. Intra oral scanners advanced very fast in the past years starting from technology in fabrication to the software. Intra oral scanners uses less steps than extra oral scanner as distortion during impression taking and dimensional changes during cast fabrication as the result of the present study came in agreement with (Michelinakis *et al*., 2020) [16], (F. Mangano *et al*., 2020) [15].

The results of the present study came in agreement with Schmidt *et al*., (2020) [23] who tested trueness using Trios4Pod, and Primescan intraoral scanners. Also the results of (Falih & Majeed, 2022) [6] who tested trueness using Medit i700 and Primescan extra oral scanners.

Further, our results disagreed with (Lo Giudice *et al*., 2022) [13] who claimed that since *in vivo* may generate more errors than an *in vitro* one because clinical variables are eliminated in the *in vitro* process removing external factors as the patient mouth environment starting from saliva, limited mouth opening, movement of the patient, tongue and check. However, our results disagreed with J.-H. Lee *et al*., (2019) [11] who found that such disagreement might be due the scanning technique which was not discussed nor mentioned

Also our results disagreed with Ender, Attin, *et al*., (2016) [4-5] such disagreement might be due to full arch scanning not quadrant,since the most dominant factor affecting the performance of any intraoral scanner is stitching in large edentulous area.

Regarding the results of overall precision, the results accepted the null hypotheses, as there was statistically significant difference between the tested scanners, with IOS group showing better precision. As the result of the present study came in agreement with (Sanda *et al*., 2021) [21], (Braian & Wennerberg, 2019) [2]. It is also came in agreement with (Gimenez-Gonzalez - 2016.Pdf, n.d.) [7] who tested precision of TrueDef scanners. In accordance came in agreement with (Ender, Zimmermann, *et al*., 2016) [5] who tested precision of CEREC Omicam,Itero, and 3shape scanners

However, our results disagreed with (Kwon *et al*., 2021) [10] such disagreement might be due to the study was *in vivo* which is difficult to have an accurate reference model to compare with. The humid environment of the patient mouth plays a huge factor. Also scanning the anterior area with curvature in the premolar to the central area. On the contrary, our results disagreed with (Osnes *et al*., 2020) [18] this might be due the different intra oral scanner used in the study (Planmeca, Dentalwings,3Shape, and CEREC).

So, the results of the present study demonstrated that, for short distances up to a quadrant, current IOS systems yield less deviation compared with conventional impressions. Even our study reported impressive results on accuracy (much less than 100 µm) of scanning partial dental arches, it is important to underline that in clinical situation it is different due to oral environment.

Conclusion

Based on the findings of this *in vitro* study, with the use of scan body for intra-oral scanner and extraoral scanner the following conclusions were drawn:

1. The accuracy in all groups was within the clinically acceptable range.
2. The EOS group had lower accuracy values than those of the IOS group.
3. The highest level of precision was observed in IOS group anterior scan body. While the lowest precision was found in the posterior scan body of IOS group
4. The trueness of posterior abutment for IOS groups showed lower values compared with other groups.
5. Regarding trueness and precision no statistical differences were found among the scanners (extra-oral and intraoral) tested.

Authors' contributions

Conceptualization, motivation, writing-original review, editing manuscript. All authors approved the final draft of the manuscript. All authors participated in the study design, performed the experiments, collected and analyzed the data, drafted the manuscript, and confirmed the authenticity of all the raw data. All authors read and approved the final manuscript.

Conflict of Interest

Not available

Financial Support

Not available

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How to Cite This Article
Naguib YA, Ansary HA, Youssef EE. Accuracy of digital scan body impression for implant supported fixed partial denture by using intra and extra-oral scanners (comparative *in vitro* study). International Journal of Applied Dental Sciences. 2023;9(3):93-97.