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ACCURACY OF IMPLANT POSITIONS RECORDED BY INTRA- AND EXTRA-ORAL IMPLANT SCANNING PROTOCOLS IN PARTIALLY EDENTULOUS MODELS. (AN IN VITRO STUDY)

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and Amal Mahmoud Ibrahim***

ABSTRACT

Aim: The aim of this study was to compare the accuracy of implants' positions between intra- and extra-oral scanning protocols in mandibular bilateral free end saddle partially edentulous models in terms of angular deviation.

Methodology: This in vitro study included 5 class I Kennedy classification mandibular models with 3 implants on both sides that were placed fully guided using a computer guided surgical stent. Scan bodies (SB) were then screwed using hand torque to these implants. Then an extra-oral scan was taken to these models using a desktop scanner to generate a digital reference model. After that direct digital impressions were obtained by an intra-oral scanner (IOS) then an open-tray (OT) followed by closed-tray (CT) impression techniques were made for conventional impressions (CI). Stone casts from these conventional impressions were then digitized using the same desktop scanner. Each digital STL file of digital and conventional impressions was superimposed over the reference STL file to enable comparison and finally the accuracy was assessed by calculating the angular deviations by using planning software (Bluesky Bio-4.0, Bluesky Bio, USA). Statistical comparisons were carried out between the studied groups using a one-way analysis of variance (ANOVA) test.

Results: The results showed that the angular deviation mean for the (CT) was the highest (2.1197° ±0.790°) while the (IOS) was the lowest (0.792 °±0.0835 °).

Conclusion: Within the limitations of this current study, the results showed that there was a statistically significant difference in angular deviations among superimposed scan bodies between conventional and digital implant impression techniques, where the intra-oral scans showed the least deviation values.

KEYWORDS: Digital impressions, accuracy, open-tray impression technique, closed-tray impression technique, partially edentulous models.

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INTRODUCTION

Distal extension removable partial dentures (DERPDs) are commonly used for Kennedy-Applegate class I or II partially edentulous patients. However, they can lead to unfavorable consequences like alveolar bone loss, tooth caries and biomechanical problems, affecting chewing efficiency and patient acceptance [1]. Hence, there was a need for clinicians to consider other successful treatment options that can become an alternative to traditional dentures and provide long-term durability and comfort for patients which are dental implants.

Taking into consideration that the most critical step for an implant-supported prosthesis manufacturing with long-lasting success is to accurately transfer the 3D implant position from the patient's mouth to the master cast or prosthesis design software [2]. Therefore, requiring a passive fit occurrence for an implant supported prosthesis is mostly dependent on implant impressions which can be fabricated according to a conventional or digital workflow [3].

Many aspects can affect negatively the accuracy of the conventional impression as physical properties of the impression materials which can create a disadvantage in workflow management, as well as the applied impression technique and the type of dental stone. So, the digital impression technique has been regarded as a clinical substitute especially for single implant supported restorations and short-span fixed dentures [4].

Alternatively, the traditional workflow, involving impressions, gypsum pouring, and subsequent digital scanning indirectly—remains prevalent in many dental practices. This is because intra-oral scanning may not always be suitable, particularly in cases involving highly reflective surfaces, excessive moisture, or bleeding, which can compromise the accuracy of the scan [5].

Therefore, the purpose of this in vitro study was to compare the accuracy between the three-dimensional datasets acquired from digital impression by intra-oral scanning and extra-oral scanning protocols of the obtained casts with 3 implants placed bilaterally. The null hypothesis was that the extra-oral scans of the casts obtained by conventional closed-tray and open-tray implant impression techniques have similar accuracy to digital intra-oral scans in partially edentulous models in terms of angular deviation.

MATERIALS AND METHODS

Thirty J dental implants (3.7 mm x10 mm) (J Dental Care Srl, Italy) were placed in 5 partially edentulous Kenndey classification class I models. In each model, six implants were placed parallel to each other in second premolar, first and second molars segments bilaterally using computer guided surgical stent. The stent was designed on implant planning software (RealGuide, Italy) after a dual scan protocol for a 3D printed solid bilateral free end saddle mandibular working model, using intra-oral scanner (Medit i700 Wireless, Seoul, Republic of Korea) and was radiographed using CBCT (Planmeca, Helsinki, Finland) then printed using LCD 3D printer (Any cubic Mono SE, Guandong, China). The anterior area included all teeth from the first premolar on the right side to the first premolar on the left side. (Fig:1)

In this study, extra-oral scan data of resin models served as the control group, whereas intra-oral scan data of digital impressions and extra-oral scan data of casts from conventional impressions served as the intervention groups.

Six J dental scan bodies (J Dental Care Srl, Italy) were then screwed to the implants of each model directing the scan body's region (pointed edge) buccally to allow registering the orientation and angulation of the implant in the digital impression in the same manner for standardization.

Scanning was then done with the desktop scanner (DOF Freedom HD scanner, Seoul, Korea) to obtain the digital reference model and export the resultant scan as STL file to act as the control group for each model. (Fig:2)

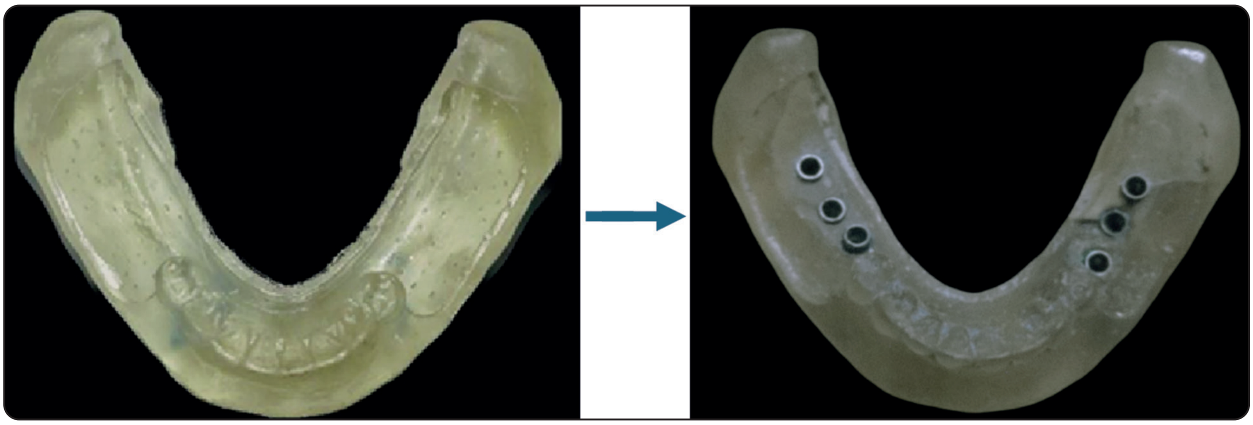

Fig. (1) 3D Printed solid mandibular working model before implant placement (left) and after implant placement (right)

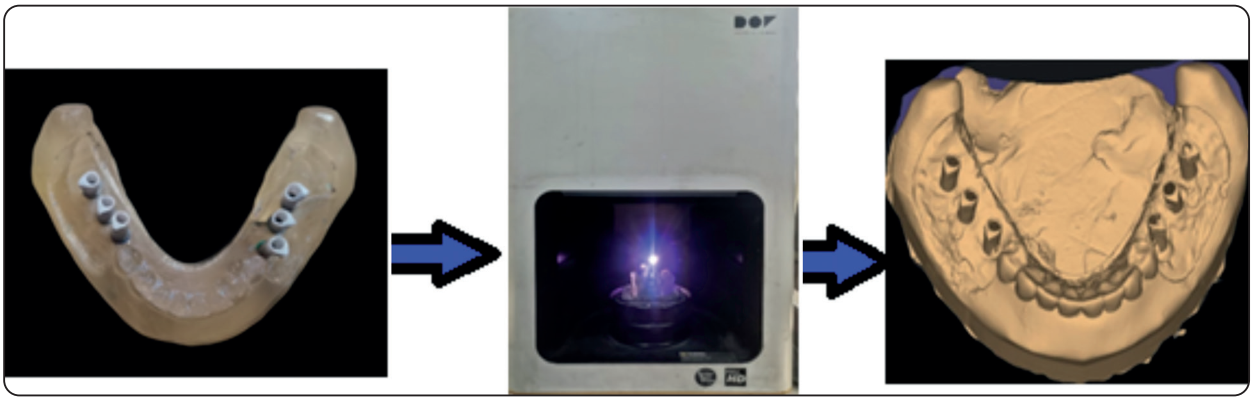

Fig. (2) Extra-oral scanning of the model using DOF lab scanner with the produced STL file.

Moreover, the same scan bodies were kept in place and same orientation and were then scanned using the intra-oral scanner. For all five models, the scanning protocol was performed in a continuous pattern, starting from the scan bodies on the left side posteriorly, passing through the anterior teeth and ending at the scan bodies on the other side. The scan was done over the occlusal surface at first, followed by the lingual surface and ended with the labial and vestibular sides of the scan bodies and teeth. (Fig:3) In cases of missing data, the scanner head was smoothly rotated vertically over the incomplete section of the scan. The scans were done by the same operator in around 5 min for each scan and then the scans were exported as an STL file representing intervention group (A).

Then two perforated custom trays for both open and closed-tray impression techniques were prepared on the model by a self-cured acrylic resin (Acrostone cold cure, Egypt) following the manufacturer's instructions with windows cut over implants area in the open tray impression technique to allow access for the open-tray transfer copings. To prevent variations in the thickness of the impression materials, the same custom tray was used during the impression making for each model.

The impression copings were screwed and a polyvinyl siloxane medium body impression material (Zhermack Elite P&P, Italy) was mixed on a glass slap (base and catalyst) and was syringed around the impression copings on the model then the rest of the mix was loaded into the custom tray and applied on the model.

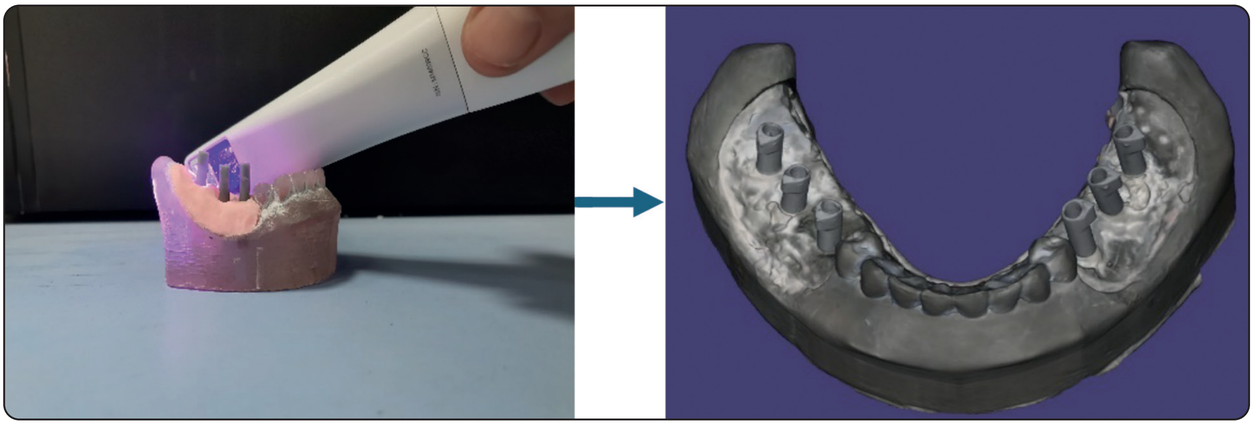

Fig. (3) Intra-oral scanning of the model using Medit i700 Wireless scanner (Left) with the produced STL file (Right).

After hardening the impression material in the open tray method, impression copings were unscrewed through the tray windows, and all the impressions were removed. Implant analogues were then screwed to the impression and ready for the step of pouring the cast. While for the closed tray method, the tray was removed, and all transfer copings were unscrewed and separated from the implants. Then the implant analogues were screwed into the impression coping. The impression coping-analog assembly was repositioned back into the impression. (Fig:4)

All the impressions from both techniques were poured with a low-expansion type IV extra hard dental stone and then the six scan bodies were then screwed to the model to their respective implant analogues for each cast and then scanned with the DOF Freedom HD scanner (desktop scanner) to obtain the digital scans and imported as STL file and served as the intervention groups (B) & (C). (Fig:5)

Measurements:

The implants' positions were recorded once by intra-oral scanning (intervention Group (A) and then by extra-oral scanning of poured casts obtained once by traditional impression using open-tray impression method (intervention Group (B) and another by closed-tray impression method (intervention Group (C)). The STL file for each technique was superimposed to the extra-oral scan of the working

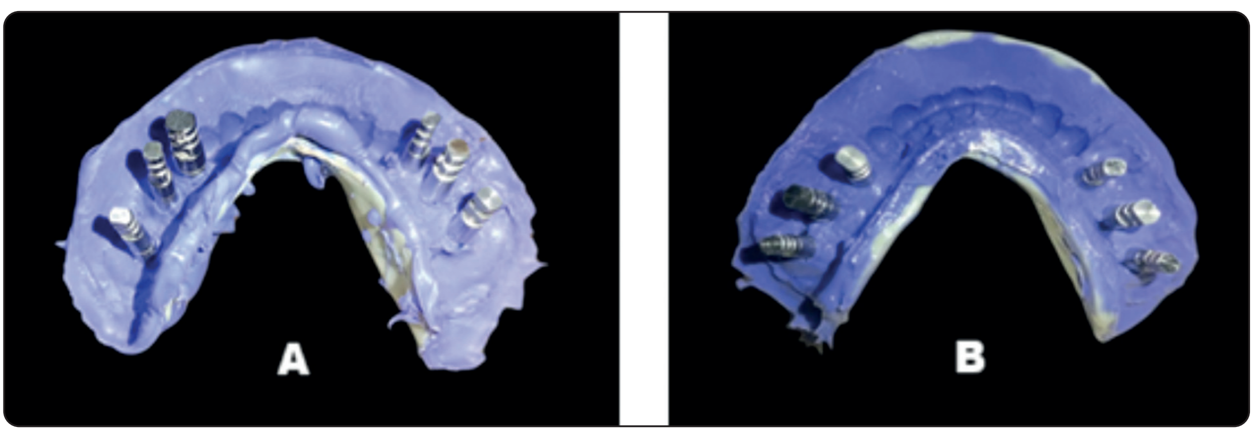

Fig. (4) The two impressions (open (A) and closed tray (B) impression techniques) with the transfer copings/ implant analogue assembly in place.

model (control group) using planning software (Bluesky Bio-4.0, Bluesky Bio, USA) beginning by manual matching points selection then the software superimposed the files automatically using voxel to voxel detection to allow the comparison between them. (Fig:6&7)

The central axis for each scanned scan body for the control scan and test scan was determined automatically using the scan body function of the software (Fig:8), and the global angle deviation between the control and test scan body long axes was calculated automatically by the angle measure in the software. (Fig:9)

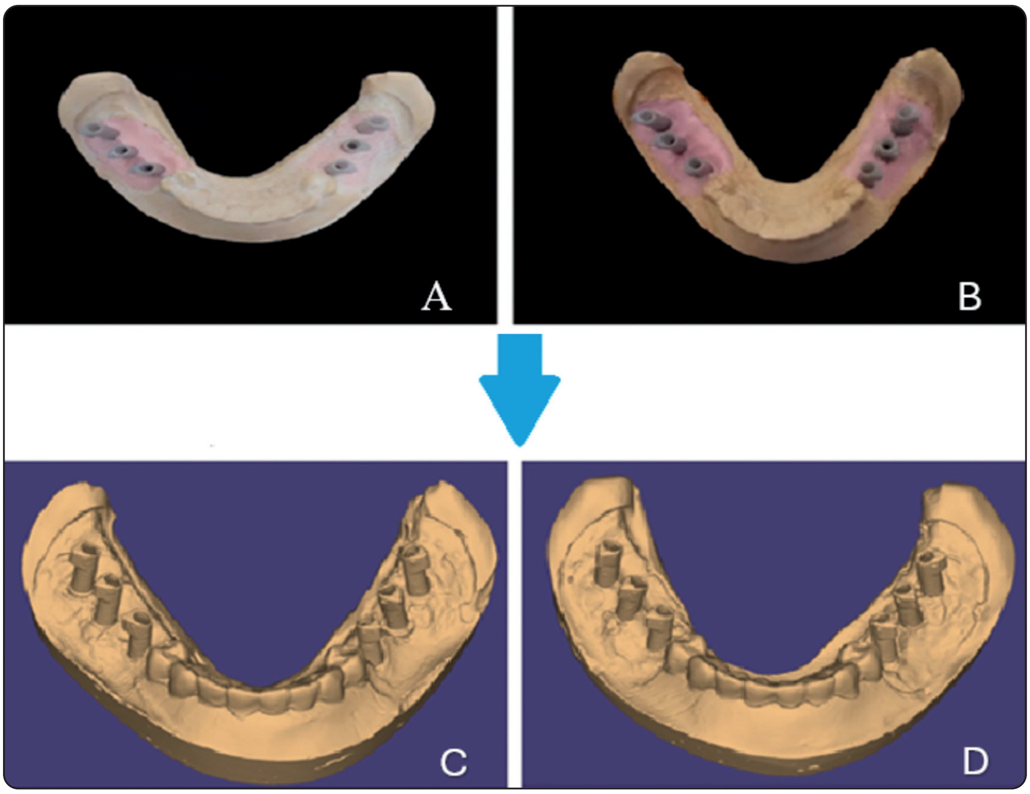

Fig. (5) Stone casts prepared from both techniques then their scanning with the extra-oral scanner to produce the digital STL files for them.

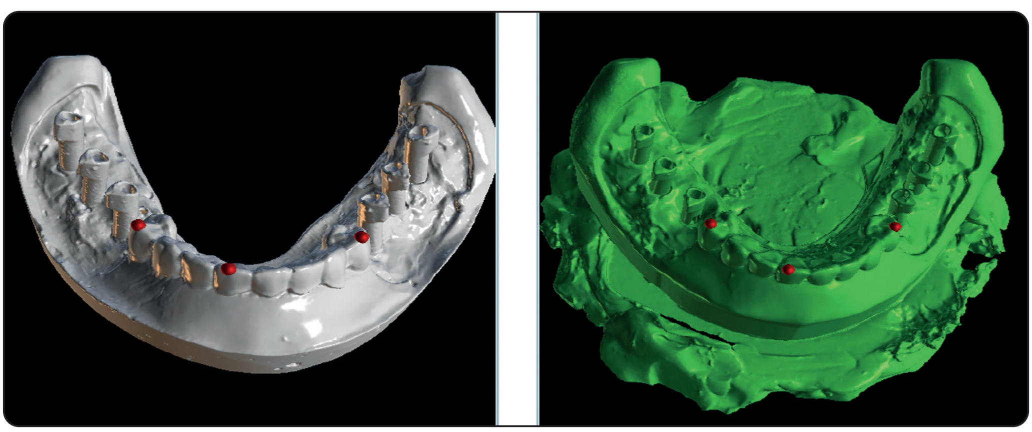

Fig. (6) The beginning of STL file superimposition by matching point selection.

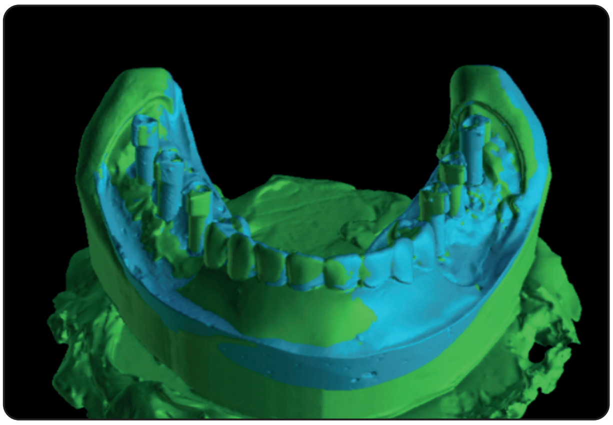

Fig. (7) The superimposed scanned files.

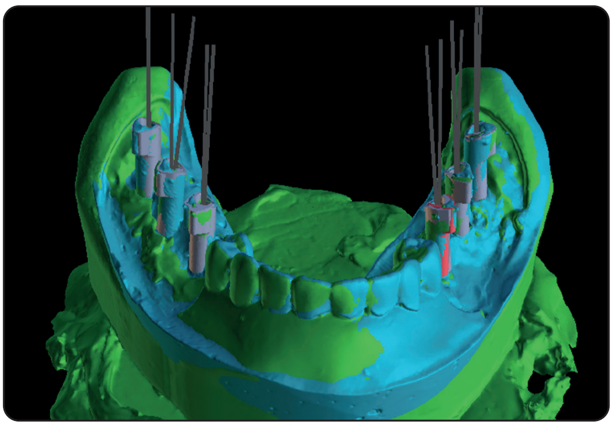

Fig. (8) The virtual long axis of each scan body to help in angular deviation measurement.

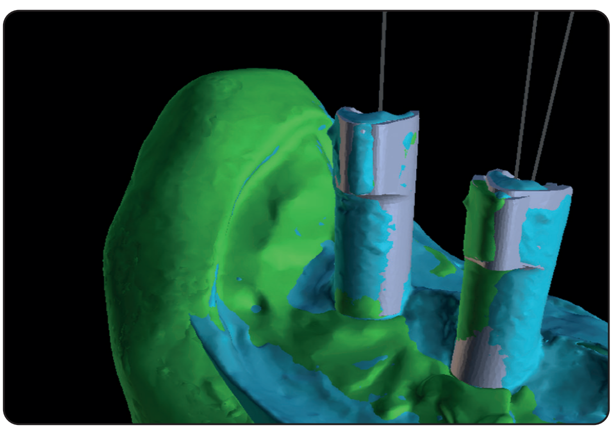

Fig. (9) The angular deviation between the test file and control file scan bodies.

RESULTS

Data of this study were presented as mean, standard deviation (SD) range (Minimum – Maximum) for values. Shapiro-Wilk tests were employed to check the data distribution and assess normality which showed normal distribution of data among three groups for angular deviation measurement.

For the angular deviation values which were described using mean and standard deviation as shown in (Table1) and (Fig:10) showed the angular deviation mean for group C (closed-tray impression method) being the highest (2.119°±0.790°) followed by group B (open-tray impression method) (1.759° ± 0.691°) with the lowest value for group A (intra-oral scanning) (1.055°±0.466°). The angular deviation of implant impression group A was highly statistically different from that of implant impressions group B and group C.

A one-way ANOVA test was then used to compare deviation means between groups, LSD multiple comparison Post hoc test was performed to compare each group and the other to detect significant difference between groups (Table 2 &3). The significance level was set at $P \leq 0.05$ and 95% Confidence interval. Statistical analysis was performed using software Spss version 26, IBM, USA.

Regarding angular deviation between groups (A, B and C) there was a high statistically significant difference between groups with a p-value of (0.00) while by comparing between each group and the other, a highly statistically significant difference was observed between group A (intra-oral scanning) against B (open-tray impression technique) and C (closed-tray impression technique) and there was a statistically significant difference when comparing group B against group C A highly statistically significant difference was observed between group A (intra-oral scanning) against B (open-tray impression technique) and C (closed-tray impression technique) and there was a statistically significant difference when comparing group B against group C.

TABLE (1) Angular deviation mean for each group (A =intra-oral group, B =open-tray impression group and C =closed-tray impression group).

Descriptives								
Angular deviation in degrees								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
A	30	1.0553	.46668	.08520	.8811	1.2296	.01	1.90
B	30	1.7597	.69129	.12621	1.5015	2.0178	.80	3.50
C	30	2.1197	.79059	.14434	1.8245	2.4149	1.21	3.80
Total	90	1.6449	.79242	.08353	1.4789	1.8109	.01	3.80

TABLE (2) Comparison of angular deviation means between group (A =intra-oral group, B =open-tray impression group and

ANOVA					
Angular deviation					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	17.585	2	8.792	19.972	.000
Within Groups	38.300	87	.440		
Total	55.885	89			

C =closed-tray impression group).

TABLE (3) Comparison of angular deviation mean between each group (A =intra-oral group, B =open-tray impression group and C =closed-tray impression group).

Multiple Comparisons						
Dependent Variable: Angular deviation						
LSD						
(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A	B	-.70433*	.17132	.000	-1.0448	-.3638
	C	-1.06433*	.17132	.000	-1.4048	-.7238
B	A	.70433*	.17132	.000	.3638	1.0448
	C	-.36000*	.17132	.038	-.7005	-.0195
C	A	1.06433*	.17132	.000	.7238	1.4048
	B	.36000*	.17132	.038	.0195	.7005

. The mean difference is significant at the 0.05 level.

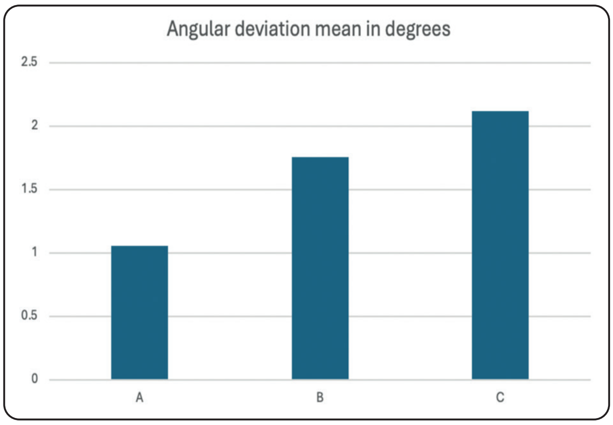

Fig. (10) Angular deviation means among groups (A =intra-oral group, B =open-tray impression group and C =closed-tray impression group).

DISCUSSION

It is indisputable that it is important to reproduce the implants position with the highest precision in all three dimensions when obtaining an impression of them (6), especially when impression required for multi-implant restorations, the accuracy of the impression will be even more critical (7). So, it is important to keep in mind that our procedure's goal is that the prostheses in any rehabilitation case involving several implants should fit on their implants passively and should not cause any tension between them (8).

It has generally been established that ensuring the longevity of the construction and preventing complications requires a well-fitting prosthesis. However, this is not always easy to achieve by means of the known conventional impression techniques (open-tray and closed-tray impression technique). The application of CAD/CAM in dentistry has improved the accuracy of implant impression compared to the traditional ones making digital implant impression a third promising option (9).

This in-vitro study has been conducted to evaluate the accuracy of different impression techniques, as it has been reported that the precision of the intra-oral scan of the dental arches scanned under in vivo situation has considerably decreased accuracy as compared with in-vitro scanning (10). The study was done for partially bilateral free end saddle edentulous mandibular models, where this classification being more commonly prevalent in Egypt (11), with more occurrence in the mandible more than the maxilla (12). The models and the surgical guide were prepared according to a previous in vitro study (13).

For the extra-oral scanning of the models and the conventional impression poured casts, the laboratory reference scanner (DOF) was considered as an acceptable reference scanner and as stated by the manufacturer, the accuracy was confirmed to be 7 µm, aligning with the precision levels observed in comparable reference scanners from prior research (14-19).

The results of our study corelated with another in vitro study which concluded that direct digital workflow was more accurate and efficient than indirect digital workflow in tested partial edentulism situations with two implants at right first premolar and right first molar sites in comparison to a conventional non splinted open-tray impression (20). The preliminary procedures involving screwing implant analogues into impression transfer copings, pouring impressions, and manually mounting scan bodies to the implant analogues prior to digitization of implant models may also be the cause. These procedures are subject to operator negligence.

Another study compared the accuracy of digital implant scans using 2 different intra-oral scanners with that of conventional impressions for partially edentulous arches and preferred the intra-oral impression technique (21). Also, a recent study that used three implants bilaterally in free end saddle maxillary models concluded that the digital scanning with intra-oral scanner was more accurate than conventional open-tray impression technique (22) suggesting that the same pattern of partial edentulism and the presence of the same remaining teeth used may enhance the results of the intra-oral scanning as in our study.

Briefly the findings of this study values are within accepted ranges with intra-oral scanning having the lowest angular deviation mean (1.055o ± 0.46o) and closed-tray impression technique having the highest mean angular deviations (2.1197 o ± 0.790o) and so, these results are consistent with other researches showing that digital scans obtained from IOS are considered as a valid alternative to traditional impressions for partial edentulous arches (22)(23).

On the other hand, some studies concluded that the precision of digital scanning did not reach to be an alternative to conventional impressions as follows: An invitro study used two posterior mandibular implant analogues, stated that the digital method produced less accurate definitive casts than the conventional method when using two implants at different angulations at 0 and 15 degrees of divergence. These inconsistent results of this study could be explained by these variations in angulation as well as the use of many IOS systems with different techniques for gathering data (24). A clinical study showed that the open tray technique produced less mean deviation values compared to the other two techniques (closed-tray and digital), which is in contrast to this study, but this may be due to the difference between the in vivo environment from in-vitro conditions which could be represented by the presence of saliva, patient movement during scanning, mobile area of mucosa, or challenges in evaluating specific oral cavity regions for correct digitization (25).

Moreover, from the suggested reasons regarding the lower accuracy of intra-oral scanners in these studies is the fact that intra-oral scanners are negatively affected by the presence of long span edentulous areas particularly in the posterior region. Also, the absence of clear anatomic areas makes digitizing them more delicate with the presence of non-attached mucosa and saliva makes the process more complex clinically (26-28).

Future clinical research may be needed to confirm the results gained from this in vitro investigation by comparing digital and conventional impression techniques in a clinical setting to validate and verify our findings.

CONCLUSION

Within the limitations of this research, it is possible to conclude that:

1. Intra-oral scanning recorded the least angular deviations followed by extra-oral scanning of open-tray impression technique poured cast while the closed-tray one exhibited the highest deviations in a bilateral free end saddle partially edentulous case.
2. These findings suggest that intra-oral scanners could be a trustworthy instrument for producing implant-supported prostheses in cases of free-end saddle partial edentulism.
3. This could enhance efficiency, facilitate work-flow, and decrease discomfort for the patient such as gagging, pain, and slightly uncomfort-able flavor related to traditional impressions.

CONFLICTS OF INTEREST

The present study was self-funded, and the authors report no conflict of interest.

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