Comparison of the accuracy of implant impression by conventional open-tray and digital techniques

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Background and objective: Precision of the impression taken from implants significantly determines the accurate fit of implant-supported prostheses. An imprecise impression may produce prosthesis misfit. This study aimed to evaluate the accuracy of the digital implant impression technique as compared to the conventional technique.
Method: A definitive maxillary edentulous model with four implants, two of them 10° anterior-posteriorly angulated, and the other two were parallel implants served as the standard reference for making all the impressions and later for accuracy evaluation. Two groups of ten samples were evaluated, first: open-tray implant impression technique, second; digital implant impression technique. All the models have been saved as standard tessellation language files and converted from 3- Dimensional to 2-Dimensional to calculate the distances between the center of the implants, and the implant angulations measurements by both design programs sketch up, and Auto CAD. Corresponding means for each technique and the definitive reference model were compared by using the t-test test.
Results: There was a statistically significant difference between the digital impression technique models and the reference model concerning the distances between the center of the four implants (A, B, C, and D) with *p*-value 0.027 and 0.000, respectively. Regarding the angular distortion, there was also a statistical significant difference between the digital and conventional implant impression models with the reference model.
Conclusion: It has been concluded that the digital implant impression models in a single angulated implant were more accurate than the traditional open tray models, whereby for a long span, a conventional open tray impression technique is preferable.
Keywords: Digital implant impression, Open-tray impression technique, Intra-oral scanner, Abutment level impression.

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Introduction

There are mainly three leading causes of tooth loss: caries, periodontal disease, and trauma. Considering many advancements in dental care over the past few decades, a remarkably high number of patients still experience edentulous. Teeth loss in an edentulous jaw can be restored in different ways: complete dentures, removable implant-retained prostheses, and fixed implant-supported prosthesis.[1]

Previously, people who lost their entire teeth were restored them with a complete, or partial removable denture. In the 1950-1960s, Branemark and colleagues developed and introduced the titanium endosseous dental implant.[2] Later, dental implants were accepted as a treatment option and have become widely used in dentistry. Nowadays, with the dental evolution, prosthetic implant rehabilitation is the preferred treatment option for replacing missing teeth.[3] High precision in the transfer of clinical conditions to the dental laboratory is one of the most critical factors in the fabrication of the prosthesis with an excellent fit for either natural teeth or implants. Hence, the crucial first step for fabrication of a successful implant-supported prosthesis is accurate transfer of three-dimensional implant position from the mouth to the laboratory cast through the impression.[4] Inaccurate position of the implant in the master cast makes it impossible to fabricate a well-fitting prosthesis, and the resultant misfit can lead to biomechanical complications such as screw loosening, bone loss, and prosthesis breakage as a result of increasing stress inside the prosthesis or at the interface of the implant and bone.[5] Accuracy of the cast is influenced by several factors, including the impression technique, type of the tray,[6] manipulations of the dental stone cast, and its compatibility with the impression material.[7]

Each step could have a potential error related to the nature of the materials or operators, which is expected. One of the most important factor involved in the success of the implant is the impression techniques. Which is related by the number and angle of implants, and the depth of implants.[8,9] Multiple implants with different angulations can distort the impression material on removal.[10]

In a review by Lee et al. (2008), it has been reported that when the number of the implants are more than three their angulation of implants may affect the accuracy.[11] However, when the implants are reduced to two or three, no effect was stated on the impression accuracy.[12] The start of intraoral scanners (IOS) has led to a noticeable change in prosthodontic dentistry. However the first IOSs became commercially available two decades ago, their recognition in recent years has grown noticeably, which results from an increase in precision and efficiency.[13] Digital impression can improve patient acceptance, reduce possible distortion of impression materials and dental model, and provide a 3-Dimensional (3D) image of preparation.[10] Although some articles reported distortion and lower accuracy of digital impression,[6,14] there are also some defensive evidence that show digital impression comparable to or even better than conventional impression.[15,16] The current study aimed to compare the accuracy of the conventional open tray (Con), and intraoral scanner digital implant impression techniques of the maxillary fully edentulous arch with parallel and tilted implants. The null hypothesis stated that there is no difference between digital and conventional techniques.

Methods

Study design: A total of twenty impressions were made for the edentulous maxillary model; which contains four implants in the canine and second premolar areas. The impression models were grouped into two categories according to the techniques used to make the impression. Ten for the conventional method using polyether impression material, and other ten for IOS.

Implant placement and reference model preparation:

One model of an edentulous maxilla designed for implant training has been used to place four dental implants (BTK-BT –nano-safe-ISY kone) type from BTK company. For standardizing the procedure, all of the implants have a diameter of 3.7mm and length 10 mm. Two of them have been placed in the right and left canine areas (B&C) parallel to each other perpendicular to the base of the model.

The other two implants placed in the second premolar areas (A&D) in angel 100° (10° diverted from the 90°) in the anterior-posterior direction (AP), with 90° in labio-palatal direction (LP) by using of the dental lab visualizer surveyor (Figure 1).

Impression techniques:

1. Conventional (open tray technique) impression procedure:

For the conventional impression technique, a total of Ten custom trays from light-cured acrylic resin plates (Vertex) were fabricated, with 4mm underlying wax thickness visible (Cavex regular pink) adapted over the reference model. Acrylic sheet with a uniform thickness of 2 mm adapted over the

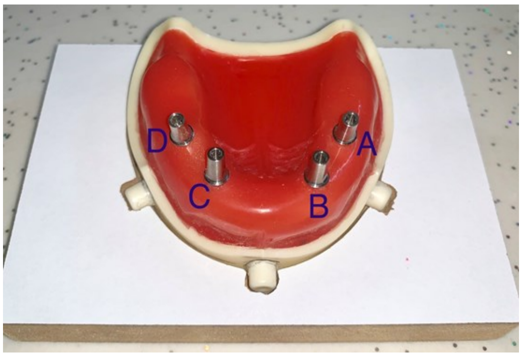

Figure 1. The reference model with the positions of the implants (A, B, C, and D).

model, and the spacer. Four holes were drilled through each tray to accommodate for the impression post guide screw in an open tray approach. Later, the trays were cured in the light cure unit (Silver crest).

The implant level impression posts (impression post-pro-pick-up KR, HU-ful21,5mm long screw) connected to the reference model with the help of their screwdrivers; lastly, the custom tray was coated with uniform layer of polyether tray adhesive (Impregum Penta; 3M ESPE, U.S.A.) and allowed to dry for fifteen minutes according to the manufacturers' recommendation.

Finally, hydrophilic Medium body polyether (Impregum Penta; 3M ESPE, U.S.A.) was machine mixed by automatic mixing unit (Pentamix lite, 3M ESPE, Seinfeld, Germany) and loaded into the custom tray. A small amount of the impression material was also syringed around the impression posts by the Penta-syringe.

The tray was then positioned over the reference model immediately.[17] The excess material that flew over the top of the coping screw was removed to expose the coping screw through the window in the custom tray. The impression was allowed to set undisturbed for 6 minutes as per the manufacturers' recommendation. After ensuring the complete set of impression material, the post screw of the impression post was unscrewed, and the custom tray was retrieved from the reference model.

This procedure was repeated nine more times to obtain ten impressions**.**

Impression pouring and die stone casts preparation:

The implant analogs have been fixed into the impression posts before pouring the impression. Ten stone casts have been gained from ten impressions by using die stone (Syna rock type 4), using vacuum mixer to get rid of the bubbles and gaining homogenous mixing of the stone, and the casts have been carried out to the dental lab for digital scanning.

Converting the physical models to 3D virtual model:

To obtain standard scanning, four implant abutments (BTK, Monocone Estetico KR) type with 1.5 height mm and 5.5 diameter have been screwed by the screwdriver to the implant fixtures of the reference model, and on the implant analogs of each die-cast. After that, the abutments have been sprayed by one layer and one motion with barium sulfate (zenotic) scan spray. Then, they have been scanned by a high-resolution reference lab scanner (S 600 ARTI, Zirkonzahn GmbH), as shown in Figure 2. Finally, the 3D images of the reference model and the ten stone casts have been obtained and saved as eleven Standard Tessellation Language (STL) files for later analysis, as shown in Figure 3.

2. Digital impression procedure:

Ten repeated digital scans were taken with IOS, utilizing confocal microscopy (TRIOS 3 pod 3shape) to the reference model.

Following the manufacturer recommended the scanning path, three swaps; occlusal, palatal, and buccal was made to ensure proper scanning. The scanning started from the maxillary right quadrant. Changing the scanning angle was about 35-55 degrees during scanning to allow the surfaces to overlap because if the overlap is small, the alignment would be loos.

The scanner head has been kept from the abutments at 0-5mm for gaining optimal capture, with slowly, and smoothly moving the scanner with hearing a more radical clicking sound that indicate good scanning image.[18] All the scans were timed from start to finish, and a scan was considered complete once the implants abutment surfaces were captured entirely. Any major holes in the reference model level present any deficiency was re-scanned.

Accuracy measurement method:

After creating the cast files of 3D scans as STL files. The STL files have accomplished in an architectural modeling software (Trimble sketch up, version 2019) to breakdown the 3D model into 2-Dimensional (2D) section (one horizontal for distance measurements between the centers of the implant, and four longitudinal sections for the angulation measurements). The 2D sections were then exposed as separate drawings files to calculate the data in the computer-aided design CAD (AutoCAD) software that architects, engineers, and construction professionals rely on to create precise 2D and 3D drawings. Draft and edit 2D geometry and 3D models with solids, surfaces, and mesh objects. In this study, AutoCAD software has been used for precise measuring of the distances between the implant centers, and the angulation of each implant.

Distance measurement:

One horizontal section has been done for the 3D model of each cast from definitive point in sketch up software then exposed to AutoCAD. The center of each implant has been determined. Then the distance between the centers of the implants has been measured one of the (right second premolar A) as reference point, and by ruler tool, the distance between the center of this implant to the center of the other implants B, C, and D have been measured. Finally, three distances were obtained for each model (AB, AC, and AD) as it showed in Figure 4, a.

Angulation measurement:

Six longitudinal sections have been done in the sketch up software then exposed to AutoCAD to make the angulation and inclination measurements. Two sections showed the Labio-Palatal (LP) angulation of the implants. The other four sections showed the Anterio-Posterior (AP) angulation of the implants. To calculate the angle, a horizontal line of 0 degrees was drawn at the center of the central axis. From which the command of Angular Dimension is applied to calculate the exact angulation or inclination (Figure 4, b).

The Statistical analyses:

T-test has performed to analyze the differences for accuracy of the distance and angle between the implants in the reference model (control group), and the mean of the ten modules of each impression technique.

The results were compared between the control group with the digital and conventional impression methods.

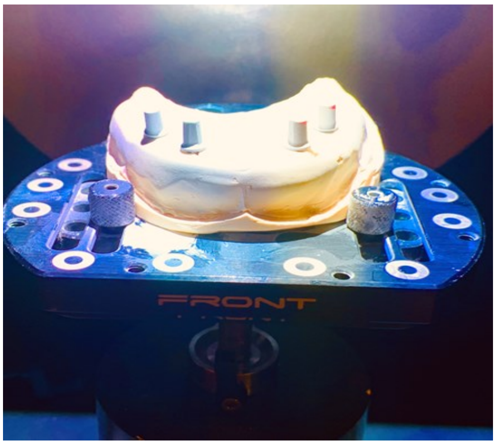

Figure 2. The physical die stone

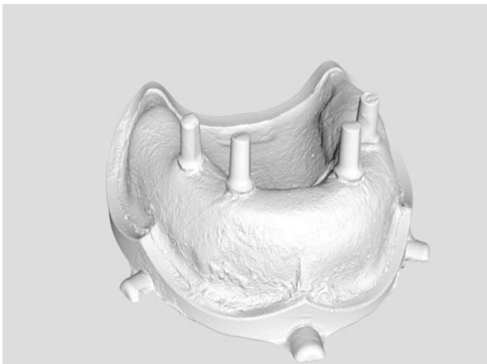

Figure 3. The physical casts and the reference

Result

1. Distance analysis: To find out which impression models from the two impression techniques are closer to the reference model, the data were analyzed using t-test. The results showed that the conventional impression technique models were closer to the reference model, which digital impression models showed significant dropping down, as shown in Table 1.

2. Angulation analysis:

To discover which impression technique, reproduce the exact angle of dental implant the angulation differences between the mean of each method with the control group was compared. Table 2 explores that in A position and AP angulation measurements, there was no statistically significant difference between Dig and control group, and we failed to reject the null hypothesis, which means that there is no difference between Dig and control group from the drawn data.

While, in LP angulation measurements, the result was relatively opposite, and based on p-values, there was a significant difference in mean value between Con and control group with p=0.012, as shown in Table 3. Unlike the conventional technique, the digital technique showed better angle registration.

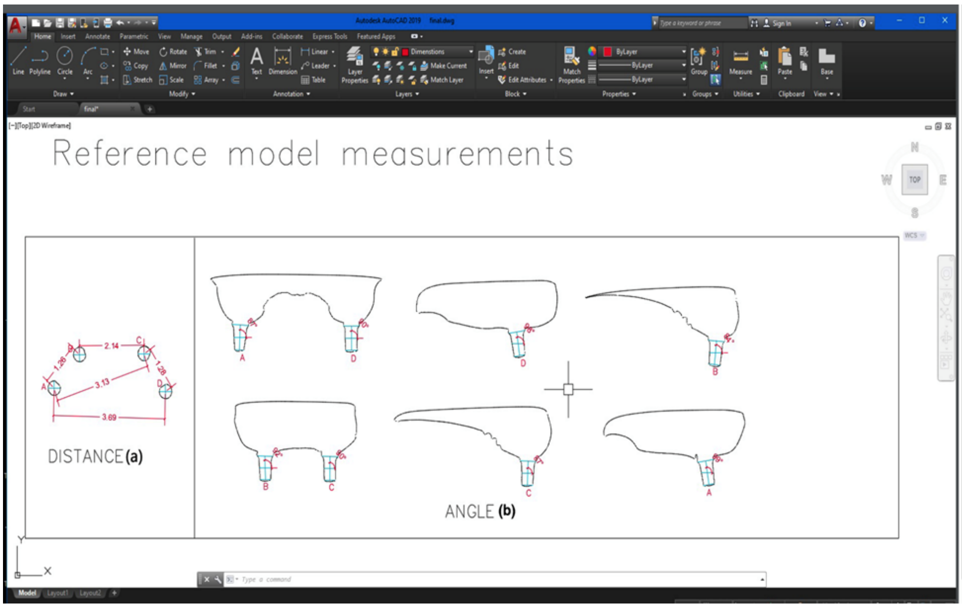

Figure 4. (a) The 2D horizontal section of the model exposed into the AutoCAD software for the measurements of the distances between the center of the implants. (b) The 2D longitudinal sections of the model for implant angulation measurements.

Table 1. One sample t-test comparison with a control group

Position	Methods	Mean Difference	t-value	*P*-value
AB	Con vs. Control group	-0.014	-1.681	0.127
	Dig vs. Control group	0.018	2.648	0.027
AC	Con vs. Control group	0.016	1.693	0.125
	Dig vs. Control group	-0.057	-6.459	0.000
AD	Con vs. Control group	0.017	1.596	0.145
	Dig vs. Control group	0.057	8.761	0.000

Table 2. One sample t-test comparison the AP angulations

Position	Methods	AP Measurements		
		Mean Difference	t-value	*P*-value
A	Con vs. Control group	3.900	3.393	0.008
	Dig vs. Control group	0.500	0.535	0.605
B	Con vs. Control group	4.700	5.045	0.001
	Dig vs. Control group	3.600	3.959	0.003
C	Con vs. Control group	4.900	6.391	0.000
	Dig vs. Control group	-0.800	-0.851	0.417
D	Con vs. Control group	1.900	2.055	0.070
	Dig vs. Control group	2.100	2.243	0.052

Table 3. One sample t-test comparison of LP angulations

Position	Methods	LP Measurements		
		Mean Difference	t-value	*P*-value
A	Con vs. Control group	-1.800	-3.139	0.012
	Dig vs. Control group	0.600	1.616	0.140
B	Con vs. Control group	-3.500	-10.247	0.000
	Dig vs. Control group	-0.700	-2.333	0.055
C	Con vs. Control group	-2.600	-2.860	0.019
	Dig vs. Control group	-0.200	-0.802	0.443
D	Con vs. Control group	-3.200	-4.496	0.001
	Dig vs. Control group	0.000	0.000	1.000

Discussion

This study aimed to compare the accuracy of gypsum models obtained from conventional open tray implant impression technique, with models obtained from the 3D impressions (TRIOS 3 pod 3shape). All data obtained were paired and imported into an inspection software (sketch up and auto - CAD). It was found that in (A) implant position (A) and (AP) angulation measurements, there was no statistically significant difference between Dig and control group, as shown in Table 2. However, in LP angulation measurements, the result is relatively opposite, and based on p-values, there was an only significant difference in mean value between Con and control group with p-value (0.012), as shown in Table 3. This means that the digital method is more accurate than the conventional open tray technique regarding the angulation of the implant. This agrees with Alikhasi et al. (2018) study, which demonstrated that digital impression has significantly less angular and linear distortion than conventional methods. That could be linked to influences like the impression material, impression technique, expansion of stone, pouring stone technique, and machine tolerance of the prosthetic parts. Additionally, different scan bodies of two studies could be an additional factor for contrary results.[10]

Clinically it is sometimes difficult to obtain an exact parallel placement of implant due to the limitations of the anatomical structures. The angulations of these implants can range from 5 degrees to 40 degrees; such a scenario faces difficulties in obtaining accurate impressions.[22] The tilted implant showed more accuracy than straight implants in the digital impression which can be explained by the fact that, in conventional impression, the operator may remove the tray unexpectedly in the direction of the tilted implant to prevent distortion.[11]

Regarding the distance measurement in this study, the difference of mean values of AB, AC, and AD distances showed that only the digital and control group was statistically significant with p=0.027 and >0.001, respectively. As a result, this study concludes that Conventional is more accurate than the digital technique that may be because even experienced dentists require training in the use of the IOS, and the accuracy improves with practice.[19]

In Gimenez et al. (2014) study, a statistically significant difference was found between experienced and inexperienced operators, one inexperienced operator accommodating significantly lesser impression accuracy compared to two experienced operators and one other inexperienced operator.[20] The experienced operator also can produce less accurate digital impressions if he or she rotates the scanner regularly to capture a larger area. Currently, researches marked that the longer the scan is, the less accurate the IOS. They are accurate for short distances, but inaccurate for full arch scans.[21] That disagrees with a study done by Aragon et al. (2016) that focused on the accuracy and reliability of images obtained from intraoral scanners compared to images obtained from conventional impressions.

The study concluded that inter- and intra-arch measurements from digital models produced from intraoral scans appeared to be reliable and accurate in comparison to those from conventional impressions.[22] While this finding is in disagreement with Calvarho et al. (2018) who carried out a literature review on the accuracy of the digital and conventional impression methods, they stated that the digital scanning systems were not superior to conventional moldings when comparing fidelity, accuracy and detail replica. but, they were better than the conventional impression when bearing in mind clinical chair time, patient and operator preference, and patient comfort.[23]

Conclusion:

Within the limitation of this in vitro study, it may be concluded that the digital implant impression is more accurate than the open tray conventional one in a single angled implant. In contrast, in a long span or full arch edentulous area, the conventional impression is preferable regarding the accuracy**.**

Conflicts of interest:

The authors report no conflicts of interest.

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