IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 22, Issue 3 Ser.4 (March. 2023), PP 34-39
www.iosrjournals.org

The Influence of Different Designs and Geometries of Scan Body on the Accuracy of Implant Position in Digital Impression: In-Vitro Study

Abdulrahman MohamadMonzer Azien Ani[1],Mohammed Farouk Abdullah[2],Mohammad M Rayyan[3],Amr Ahmed Naguib[4]
[1](B.D.S Faculty of Oral and Dental Medicine/ Cairo university, Egypt)
[2](Professor of prosthodontics Faculty of Dentistry/ Cairo university, Egypt)
[3](Professor and Chairperson of Fixed Prosthodontics Department/ Sinai university, Egypt)
[4](Lecturer of Prosthodontics, Faculty of Dentistry/ Cairo university, Egypt)

Abstract:
Background: *The aim of this in-vitro study was to compare the implant position accuracy when using different designs of scan bodies for the same implant system.*
Materials and Methods*:A 3 different designs of scan bodies was attached to a refence 3d printed model, the first is an original one from the implant's manufacture (control- group), the second one from accessories company (compatible group) and the third is custom made (custom made group). The scan bodies were scanned with the model and RMS values were recorded and a cuboid was designed and milled for each scan, then the cuboids were attached to the model and scanned to obtain RMS values. RMS Values Were used to analyze the deviation for each scan body.*
Results*: The collected values were tabulated and statistically analyzed. The results showed that the control group had the lowest RMS Values compared to the other two groups regarding the scan bodies scan and the cuboid scans.*
Conclusion:*Control group scan body was the most accurate regarding implant position registration. There was statistically significant difference regarding the implant position between the control group and the other two groups.*
Key Word*: Scan body; Implant; Digital Impression; Position Registration.*

Date of Submission: 26-02-2023 Date of Acceptance: 10-03-2023

I. Introduction

Loss of teeth affects the masticatory ability, compromises the esthetics, and may consequently interfere with social interactions, that will significantly have a huge impact on the individual's life quality. Day after day the treatment options are continuously evolving, starting with the removable prosthesis then moving on towards the fixed prosthesis. Furthermore, the evolution of titanium implants manufacturing and their high success rates, have marked the beginning of a new era in prosthetic treatment options. Today dental implants play a vital a role in the daily dental practice and became the preferable choice for the dentists and the patients also.

An accurate impression making and placement of a single crown with passive fit are the two main steps required for crown restoration. Passivity is the key word for a long-term success of a dental implant. In the traditional workflow, the implant positions are recorded using impression material and transferred to the gypsum model. However, digital impressions have been introduced in the dental implant prosthetic procedures. With an intraoral or extraoral scanning device, implant position can be located and transferred to a virtual implant position within the dental arch using a scan body.

Digital workflow reported higher patient acceptance, and any digital impression could be stored as a part of the patient records in an electronic database, which also facilitate the communication between the dental lab and the clinician.

Despite all these advantages the accuracy of digital impressions could be compromised by many factors such as implant depth, angulation, position in the arch, and even the scan body used for the scanning procedure. Digital impressions could not yet supplant the traditional impressions. One of the main concerns is that the digital impressions accuracy is still *scrutinizedand not well established.*

II. Material And Methods

In the existing in-vitro study, 3 Scan bodies were used on a reference model, 10 digital impressions were made for each scan body,accuracy of implant position registration was evaluated using RMS Values comparison Between control group and the other two groups.

Study Design: In-vitro study.

Study Location: Study Was done in Department of Implantology and the Digital Center , Cairo University, Egypt.

Study Duration: July 2021 to July 2022.

Sample size: 10 Digital Impression for each Scan body

Sample size calculation: A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that the effects of different tested variables and their interaction are not significant. By adopting an alpha level of (0.05) a beta of (0.8) i.e. power=80% and an effect size (f) of (0.77) calculated based on the results of a previous study, the predicted sample size (n) was found to be (10) samples. Sample size calculation was performed using G*Power1 version 3.1.9.7.

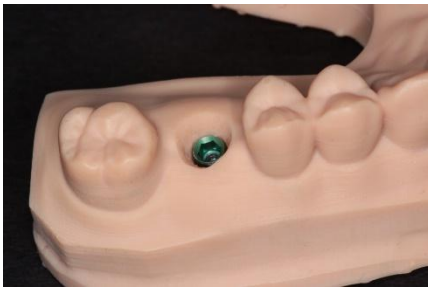
Procedure methodology

A:Scan body fabrication:

The scan body (referred to as the custom-made) was digitally designed and manufactured from a PEEK disc (Bredent, Bredent Bedical GmbH & Co.KG, Senden , Germany), and it was calibrated to be used with the original digital implant library (Implant direct). The SB was designed using SOLIDWORKS Desktop 3D CAD (Soildworks, **Dassault Systèmes SolidWorks,** Massachusetts, USA), characterized by cylindrical shape with 2 beveled flat surfaces in the scan flag area.

Then the scan body was milled using dental milling machine. (CORiTec 350i PRO+, imes-icore GmbH, Eiterfeld, Germany).

B: Reference Model Fabrication:



A generic digital maxillary model was designed and prepared with a CAD software (Exocad Polvdiv, Exocad GmbH, Darmstadt, Germany), in order to receive a digital analog (Implant Direct, Implant Direct Corporation, California, USA) in the site of missing left first molar.

The Model was printed with an SLA 3D-printer (Form3, Formlabs , Somerville, Massachusetts, USA) with 50 μm layer thickness, then the post-printing instructions from the manufacturer were done which includes cleaning, and curing of the object to finalize the polymerization process. The digital analog was screwed into its position in the 3D printed model.

C: Digital Impressions for the manufacture's scan body (Group 1):

For the control group, the Implant direct scan body was unscrewed and screwed before each scan to the analog with a tightening torque of 10 N and the model was scanned 11 times with a laboratory scanner (MEDIT T5oo, MEDIT corp., Seoul, Korea), and the first scan is considered the reference scan.

D: Digital impressions for DAS scan body (Group 2):

for this group, DAS scan body was unscrewed and screwed to the analog before each scan with a tightening torque of 10 N and the model was scanned eleven times with the same laboratory scanner, and the first scan is considered the reference scan.

E: Digital impressions for the custom-made scan body:

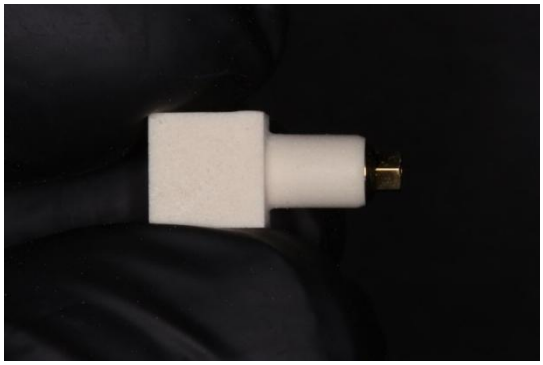
The same process was performed for the custom-made groups. A total of 33 STL files were obtained, 11 for each group. The first scan in each group was considered the reference scan.

For each group, the 10 STL files were digitally superimposed to the reference scan and saved for precision evaluation.

F: Designing and fabrication of test Cubes:

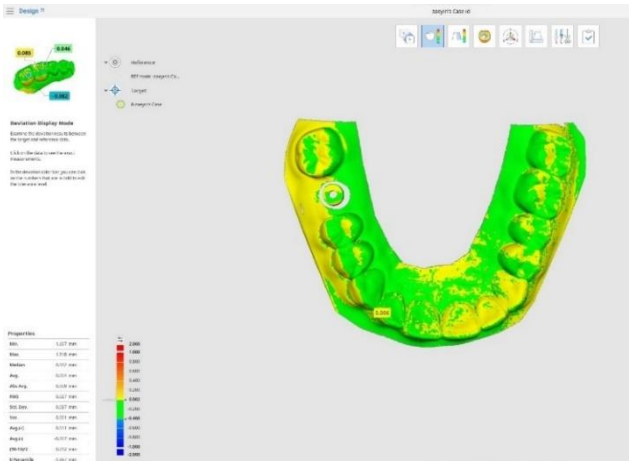
These cubes were designed to mimic the screw retained restorations in real practice.

The 10 STL files from each group and will be used to compare the three groups in terms of scan body trueness for detecting the implantposition.The ten STL files were accurately superimposed over each other with best fit algorithm utilizing the whole model surface regardless of the scan body position. A geometrical 3D object, measuring 7mm in height x 6mm in the mesio-distal dimension x 7mm in the bucco-lingual dimension, was then designed and virtually placed over the virtual implant site in the exact same position for the digital models. Using imes-icore 350i Pro Plus ((CORiTec 350i PRO+, imes-icore GmbH, Eiterfeld, Germany). utilizing the same milling strategy and the same milling tools.



For each group, the resulting object was detached from the disc and measured using a digital caliper. The cuboid was attached to its respective ti-base and the complex was repositioned to the 3D printed model on the implant analog. It was screwed to a tightening torque of 25 N. The model was rescanned using the extra-oral scanner and a total of 10 STL files were created for each group.
implant position was detected for each group using the digital library respective to each scan body and the resulting virtual ti-base was connected to the previously placed 3D Cuboid creating 10 STL files to be manufactured for each group. The 30 objects were manufactured from a wooden disc (VHF CalibrationDisc, vhf camfacture AG, The Ammerbuch, Germany),Each STL file was superimposed digitally over the reference file containing the reference model along with the cuboid design at the reference position. and saved for trueness evaluation.

G: Accuracy assessment for scan bodies.
Precision test:
The 10 STL files of the three groups were superimposed and compared to their reference STL file to evaluate the precision between the three different designs regarding the repeatability.
Trueness test:
The Ten cubes of each group were superimposed and compared to the reference design on the CAD software to evaluate the trueness of the implant position generated by scan body alignment on CAD software.
To calculate the 3D linear deviations of the scan body in each group, the digital volumes from the three groups was registered using best fit algorithm.
The Root Mean Square Deviation (RMS) were then calculated using (Medit Compare, MEDIT corp., Seoul, Korea) for data comparison.
The software calculated the deviation, and the results were being in form of color map.
The color represents the deviation between reference cast and the two groups. The result of the deviations was measured in micrometers.



Statistical analysis
The SPSS statistical analysis software (version 25, IBM, Armonk, NY, USA) was used to analyze the RMS values obtained from the 3D analysis. Bonferrroni method was performed to compare between groups. One-way ANOVA was performed to identify significant differences between groups and within groups in RMS values. Mean standard deviation values were calculated for each group, and then the obtained errors were compared and evaluated. Scheffe's posttest was performed, and the significance cutoff was = 0.05.

III. Result

This in-vitro study was conducted to evaluate the accuracy of the implant position registered using three different designs of scan body obtained for the same system using extra oral scanners.
The ten cuboids for each group were compared to the reference design of each group and the RMS values were compared for trueness and precision test.

Table no 1 Shows the RMS values for the ten cuboids of each group compared to the reference design of each group and the RMS values were compared for trueness and precision test.

Table no 1:RMS values for each group

Cuboid Scan No.	Control group cuboids RMS	Compatible group cuboids RMS	Custom made group cuboids RMS
1	0.068	0.108	0.111
2	0.069	0.095	0.105
3	0.055	0.111	0.113
4	0.070	0.085	0.118
5	0.063	0.107	0.120
6	0.052	0.099	0.113
7	0.060	0.104	0.099
8	0.063	0.108	0.108
9	0.059	0.115	0.123
10	0.068	0.088	0.107

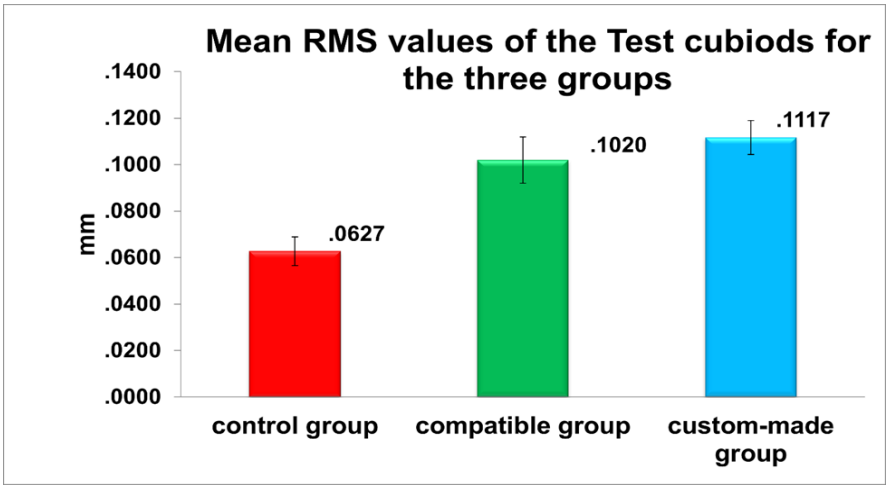


Figure (1): Bar chart showing the Mean of the RMS values for each group

The results in Table (1) and Figure (1) Showed that the Control group had the lowest standard deviation and mean values, which is an indication for precision and trueness.

By using One Way ANOVA test its found that the null hypothesis of equality of means is rejected, and there are highly statistically significant differences between the groups means.

So Bonferroni method was used again to compare between groups to find out statistically significant differences. and results showed that the control group has statistically significant lower RMS values than both compatible group ($P<0.001$) and custom-made group ($P<0.001$). And the compatible group also has statistically significant lower RMS values than custom-made group ($P < 0.05$).

IV. Discussion

This study was done in vitro rather than in vivo to facilitate controlling the results and eliminate several variations that might occur during an in vivo setup. However, it has low evidence compared to in vivo studies.

In this study a 3D printed Model was used in comparing the accuracy of 3 different designs of scan body rather than a stone model, following a study performed by (Revilla-León et al., 2018). This could be attributed to the recent advances in 3D printing technology that provides access to digitally fabricated model with sufficient accuracy to be used as reference models for several testing procedures

.Post processing of the 3D printed model was of great importance so as to control the dimensional stability of the model during the study period. A digital implant analog was attached to the 3D printed model and screwed into place to ensure its tight fixation throughout the whole testing process. Only one model was used for all the groups.

In the control group, the choice of the scan body was the original part fabricated by the implant system company to ensure maximum accuracy as these parts were tested by the same company that manufactured the implant and cleared for use. Despite some digital libraries for several implant systems are not yet verified or digitally signed, the digital library for the implant system included in this study. Implant Direct is verified and digitally signed by Cad software.

In the compatible group, the choice of the scan body was a compatible part manufactured by Dynamic Abutment Solutions. It is a well-known brand that provides compatible parts for several implant systems with a high degree of accuracy. It is not always recommended by several implant systems to use compatible prosthetic parts. However, these parts showed high accuracy and clinically acceptable results that are comparable to the original parts

In the custom-made group, the scan body was digitally designed using SOLIDWORKS to ensure dimensional accuracy and control and to generate a digital implant library for Exocad, (Exocad Polvdiv, Exocad GmbH, Darmstadt, Germany) to be used during implant position registration. It was manufactured from Polyether ether ketone (PEEK) as it is naturally scannable using optical extraoral scanners. This is due to the nature of the material as it decreases light reflection that can occur with metal scan bodies. Care was taken during the milling process to avoid attaching milling supports near the area that was used for digital scan body alignment on the software. The milling tools were new, and the milling machine was calibrated to avoid errors such as gauges or excesses. (1)

The aim of the study was comparing the accuracy of 3 different designs of scan bodies to be used either with intraoral or extraoral scanning techniques regarding implant position registration. An extra oral scanner was used in this study to ensure maximum accuracy of the scans and to reduce the variations that might be generated by intraoral scanning devices. Therefore, the results of this study would lack other inaccuracies that should be taken into consideration while using intraoral scanning devices. Moreover new technologies for digital impression taking are now available as intraoral digital scanners and extra oral digital scanners which will soon be able to achieve the long-awaited aim of saving patients from conventional impressions. (2,3)

Thus 3 different peek scan bodies were attached to implant analog for taking 11 digital impression using extra oral scanner. For each group, the scan body was unscrewed and screwed before each scan to the analog with a tightening torque of 10 N to decrease the incidence of scan body displacement while tightening the screw of scan bodies. Torque f 10 N was recommended in a study by (4)

Fabrication of a single screw retained prosthesis was used to compare between digital and conventional workflow (5)

In the present study, a cuboidal body was designed measuring 7mm in height x 6mm in the mesio-distal dimension x 7mm in the bucco-lingual dimension. The reason of these dimensions was to facilitate identification of the buccal and proximal surfaces of the cuboid to ensure its correct replacement on the implant analog. The choice of a cuboid rather than a tooth design was based on the need of accurate measurement of the cuboid after milling to eliminate variations or errors that could happen during fabrication. This allowed measuring the cuboid accurately using a digital caliper for all three dimensions. Thus, deviations that would arise during the alignment process would be attributable to errors from implant position registration only. The cuboid was fabricated from special wood disc that is used in milling machines calibration. The use of wooden disc provides the least resistance for the milling tools during milling and perfect dimensional replication and stability.

Rms values where calculated using medit Compare software, it is an open source dental software made the famous digital scanner manufacture (Medit Corp., korea) , the software calculate the RMS values with the same equation that is used in Engineering software.(6,7).

A study evaluated the influence of scan body geometry and shape on the accuracy and found significant differences in the 3D positioning and angular deviation between 2 commercially available scan bodies. (1).

Two studies compared the accuracy of various Intra oral scanner devices when using scan bodies and found significant differences among the systems; however, those studies used only 1 type of scan body.(8,9).

A new study shows that improved scanning accuracy was obtained when a newly designed scan bodies that have flag like extensions were used instead of the original scan body.(10)

More studies are necessary to investigate the relationship between scan body features and implant position accuracy

V. Conclusion

Within the limitations of this in vitro study, it could be concluded that:

- The scan body is a sophisticated apparatus with considerable varieties in designs and specifications.
- The Manufacture's scan body is superior to the other two designs.
- There was statistical significance difference in trueness between the three groups
- The control Group showed the best result regarding the implant position registration.

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Abdulrahman MohamadMonzer Azien Ani, et. al. "The Influence of Different Designs and Geometries of Scan Body on the Accuracy of Implant Position in Digital Impression: In-Vitro Study." *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)*, 22(3), 2023, pp. 34-39.