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Accuracy of digital versus conventional multiple implant impression procedures using 3-dimensional super imposition technique - An in-vitro study.

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ABSTRACT

PURPOSE: To compare the accuracy of digital and conventional impression techniques in completely edentulous model and to determine the effect of different variables on the accuracy outcomes.

MATERIALS AND METHODS: An edentulous maxillary model with six implants was prepared to serve as master cast (control) for both conventional and digital implant impression technique. Digital impressions (n = 5) were taken with an intraoral optical scanner (TRIOS, 3shape, Denmark) after connecting polymer scan bodies. For the conventional impressions of the master cast, window tray and chimney tray technique were used for implant-level impressions (n = 5 each). Master casts and conventional impression casts were digitized with an extraoral high-resolution scanner (IScan D103i, Imetric, Courgenay, Switzerland) to obtain digital volumes. Standard tessellation language (STL) datasets from the 3 groups of digital and conventional impressions were superimposed with the STL dataset from the master cast to assess the 3D (global) deviations. To compare the master cast with digital and conventional impressions at the implant level Geomagic Freeform; Geomagic Control X (superimposition software) were used to calculate the 3D deviation.

RESULTS: Results of this study revealed that the accuracy of digital impressions is the same as that of conventional impressions. About the implants, the digital impressions of six maxillary implants resulted in similar accuracy to the conventional techniques.

CONCLUSION: Digital implant impressions are as accurate as conventional implant impressions. Both, digital impressions and chimney tray techniques were superior to the window tray impression technique.

Key words: accuracy, dental implants, digital impressions, edentulous, implant impressions, impression techniques.

1. INTRODUCTION:

An implant impression is primarily a three-dimensional record of the implant and the surrounding tissues.[1].Impression accuracy is a significant factor for the prosthesis to be made which in turn necessary for implant long-term success. Inaccuracies or errors occurring at any stage of the impression making may lead to a lack of precision fit between various components at the implant restoration. The lack of potential compensatory readjustment, due to the absence of intervening periodontal ligament, may have the consequence of related complications or failure[2,3]. Misfit of implant prosthesis by inaccurate impression brings about mechanical and biological complications like e frequent retaining screw loosening and fracture, ceramic veneer chipping, accelerated wear of the implant components, and early prosthesis failure. Several factors affect the accuracy of the impression and hence the accuracy of the implant cast, including the type of impression, implant position and angulation, the number of implants, the impression technique: whether splinted or not, open or close tray impressions, and the use of stock tray or customized impression tray, and finally, the type of prostheses.

Every conventional step (impression material, impression procedure, fabrication of master cast, wax pattern, framework, and definitive prosthesis) generates a certain amount of error due to the nature of the materials used and the environment. [4,5.] This is due to the additional components used to facilitate the transfer of the three-dimensional implant position from the mouth to the cast. Moreover, if the implants are tilted at different angles, performing a highly accurate conventional impression may be challenging. The distortion of the impression material, i.e. the elastic recovering potentiality is exceeded within the highly applied forces during removal of the impression- reason (Mpikos et al., 2012).[6]

The accuracy of the conventional implant impression-making procedure is a critical factor that can significantly influence the quality and fit of the restoration onto the dental implants. The 20th century showed remarkable advances in technology, and digital impressions for use in dentistry came about in the early 1980s.

Digital impressions offer speed, efficiency, the ability to store captured information indefinitely, and transferring digital images between the dental office and the laboratory. The advantages of the digital impressions and scanning systems are improving patient acceptance, reducing the distortion of impression materials, 3D pre-visualization of tooth preparations, and potential cost and time-effectiveness.[7]

It is necessary to compare the effectiveness of digital impressions to substantiate and encourage clinicians to use them. There have not been many studies reported on the comparison of multiple implants.

The purpose of this study was to evaluate and compare the digital and conventional dental implant impression techniques for restorations involving multiple implants.

2. MATERIALS AND METHODS:

PREPARATION OF MASTER MODEL:

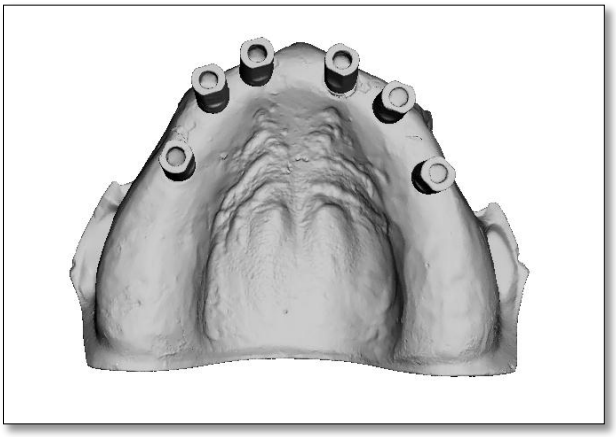
A polyurethane edentulous maxillary cast, which simulates the human maxilla bone according to the standards of ASTM F1839 (the standard specification for rigid polyurethane foam to simulate the consistency and the density of the bone) was used.

Six implants were placed in this cast at the bone level, following implant protocol and asepsis care, with conical-type and internal hexagonal-type connections, by a single operator.

The implants were inserted into the polyurethane cast using surgical drills at a velocity of 800 rpm. A physio dispenser and a 20:1 counter-angle reducer were used.

The implants were placed in the following areas:
(1) implant 15 (maxillary right second premolar)
(2) implant 13 (maxillary right canine)
(3) implant 12 (maxillary right lateral incisor)
(4) implant 22 (maxillary left lateral incisor)
(5) implant 23 (maxillary left canine)
(6) implant 25 (maxillary left second premolar).
All implants were placed using a manual torque wrench until a torque of 20 Ncm was reached, as recommended by the manufacturer.

MASTER CAST SCANNING FOR CONTROL FILE:
The prepared model was digitized with an extraoral high-resolution scanner (can D103i, Imetric, Courgenay, Switzerland) to obtain digital volumes.
The scanning was done after connecting polymer scan bodies to each implant.
A standard tessellation language (STL) file was created. This STL file of the master model was used as a control file for the superimposition procedure.



CHIMNEY TRAY FABRICATION:
For fabricating the chimney tray, initially, two sheets of baseplate wax were placed over the master model as a spacer, and a light-cured acrylic resin material (Vertex Dental, Soesterberg, Netherlands) was used for the tray fabrication.
The tray of the chimney technique was fabricated with six openings and vertical height to allow for coverage of the impression copings.
Approximately 2 mm space was allowed between the external surface of the coping and the internal surface of all the trays. This was followed by providing an opening for the impression pin.

CHIMNEY TRAY

WINDOW TRAY FABRICATION:

A custom tray was fabricated after four fiducial mark stops were made on the master cast to standardize custom tray positioning during open-tray impression taking. During custom tray fabrication, two layers of baseplate wax were applied to provide 3 mm of space relief for the impression material. , and a light-cured acrylic resin material (Vertex Dental, Soesterberg, Netherlands) was used for the tray fabrication.

WINDOW TRAY ADAPTATION

For the splinted impression technique, the tray had a wide opening that corresponded to accommodate the splint between the impression copings.

IMPRESSIONS MADE USING CONVENTIONAL METHOD: (WINDOW TRAY AND CHIMNEY TRAY):

Five implant level impressions were taken using each technique.

Addition silicone impression material (Enthus PVS Impression Material, Dharma Research, USA) with medium consistency was used for impression procedures.

After impression copings with positioning, pins were screwed into the reference model with a hand force wrench and finger tightened as per the manufacturer's recommendation.

For window tray: Dental floss was wounded in a crisscross manner around all the copings to firmly secure them. Pattern resin (GC ASIA Dental PTE. Ltd., Singapore) was mixed and adapted to surround the copings and dental floss with a paintbrush. This was allowed to set for 10 minutes before making the impression.

The impression materials were injected around the copings and the tray seated to expose the guide pins through the window opening in the tray. After the material undergoes an initial set, the guide pins were unscrewed, and the tray was removed from the cast.

For chimney tray: Without splinting, the impression materials were injected around the copings and the tray seated to expose the guide pins through the small chimney-like opening in the tray of each implant.
After the material set, the guide pins were unscrewed, and the tray was removed from the cast.

IMPRESSION MADE USING CHIMNEY TRAY

FABRICATION OF CASTS FROM CONVENTIONAL IMPRESSIONS:
Standardized pouring techniques were used for the fabrication of all casts.
After connecting the implant analogs to the impression copings, low expansion (0.09%) type IV die stone (Silky Rock; Whipmix Corp, Louisville, KY, USA) was mixed. First, the stone was mixed manually with distilled water for 15 s to aid the incorporation of the water and then under vacuum (Vacuum spatulator; Whipmix Corp, Louisville, KY, USA), and an initial pour of stone up to the middle of the analogs was carried out.
All of the stone mixes were vibrated before and during the pouring. After 30 min, the second pour of vacuum-mixed die stone was carried out. This double pouring technique minimizes the volumetric expansion of the stone and has been shown to lead to more accurate die casts (Del'Acqua et al. 2008; Papaspyridakos et al. 2012).
The stone casts were allowed to set for 1 h, as per the manufacturer's recommendation, before separation from the impressions.
Subsequently, they were trimmed and finished. All casts were stored at room temperature for 1 week before the measurements.
The same double pouring technique was used for the fabrication of casts from all the conventional impressions. All impression and pouring procedures were carried out by the same clinician.

STONE CAST FABRICATED FROM THE CONVENTIONAL METHOD

DIGITIZATION OF THE STONE CASTS:

The two test groups of stone casts were digitized for comparison with a high-resolution extraoral scanner at 6- μm precision scanner (can D103i; Imetric) as described in Bergin et al. 2013; Ender & Mehl 2013.

At first, titanium scan bodies (Scan markers; Dentwise, Leuven, Belgium) were placed on the first test cast and digital scanning was performed. The same scanning procedures were carried out for all 5 casts of two test groups.

For all digital scans, the same scan bodies were moved from their corresponding position in cast 1 to cast 5 of each group to eliminate the effect of scan bodies. An operator blinded to the type of casts performed all scanning procedures. The STL digital files were saved.

DIGITAL IMPLANT IMPRESSION PROCEDURES:

Following the manufacturer's protocol, 5 repeated digital impressions were taken with a digital intraoral scanner (TRIOS; 3shape, Denmark) at the implant level. This digital intraoral scanner uses confocal optical imaging technology to generate digital point cloud surfaces that can be exported as STL datasets and are used for both partial and complete arch intraoral scans.

Polymer implant impression scan bodies were connected to the implants on the master cast (control) by hand tightening.

The digital implant impression was gradually captured by scanning the master cast and implant scan bodies with the scanner’s handheld wand without spraying powder. The digitally acquired volumes could be viewed on the touch screen during scanning, allowing direct visual feedback to make sure no parts were missing.

After the acquisition of five repeated digital impressions, the digital volumes were exported as STL files for comparison.

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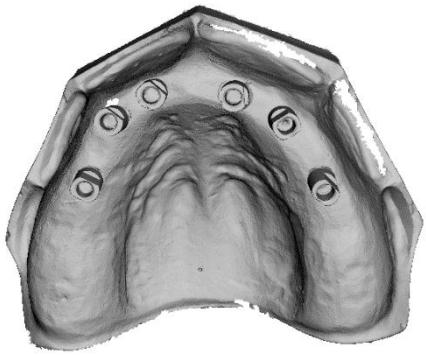
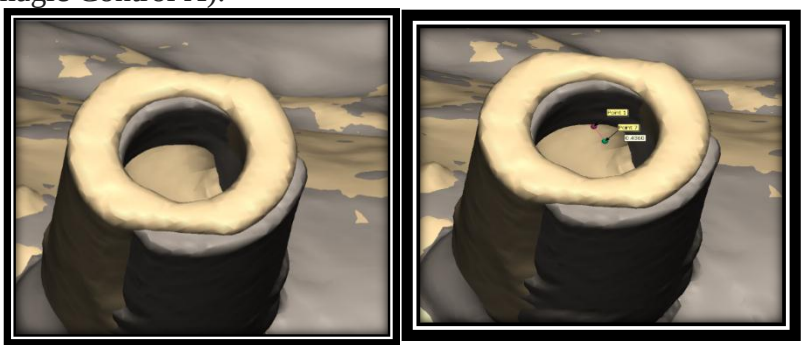


STL FILE OF DIGITAL IMPRESSION DONE USING INTRAORAL SCANNER

Test groups – implant impression techniques:
Three test groups of casts were formed, and each group was compared with the control cast as follows:
• **GROUP I** (n = 5): Stone casts generated from the conventional impression technique (window tray) at the implant level (internal connection)
• **GROUP II** (n = 5): Stone casts generated from the conventional impression technique (chimney tray) at the implant level (internal connection)
• **GROUP III** (n = 5): Digital casts generated from the digital impression technique at the implant level (internal connection).

ACCURACY ASSESSMENT WITH SUPERIMPOSITION PROCEDURE OF DIGITAL (STL FILE) AND CONVENTIONAL (STL FILE) METHODS:
Digital scan of the master cast at the implant level with the same high-resolution extra-oral scanner at 6- μm precision (IScan D103i; Imetric), were used as control (golden reference) and compared with the scans of the casts of the two test groups produced by digital and conventional impression techniques.
To capture the 3D orientation of the implants in each cast and their 3D discrepancies, the digital volumes from the 2 test groups were registered using a surface-based registration algorithm. The 3D deviations were then calculated with superimposition software (Geomagic Freeform; Geomagic Control X).



SUPERIMPOSITION OF TWO SCAN BODIES

CENTRE POINT IS PLOTTED IN THE 2ND SCAN BODY AND THE DEVIATION MEASURED

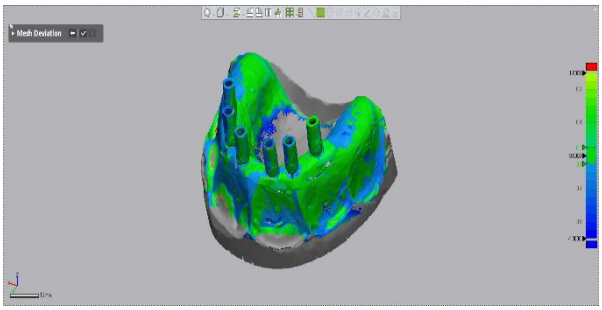
3. RESULTS:

The results were discussed with the help of qualitative analysis of trueness and precision of the 3 impression techniques.

QUALITATIVE ANALYSIS

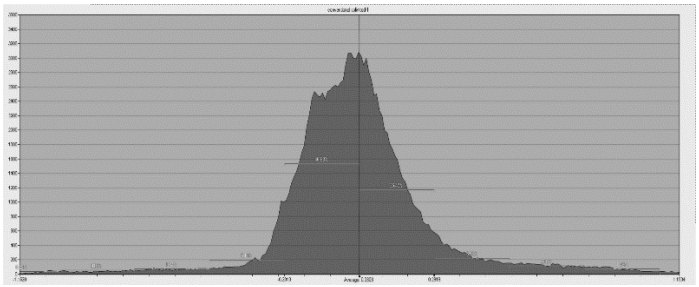
As a qualitative analysis, the 3D deviations between the test casts and the control cast were illustrated in a color-coded gradient. When the color-difference maps of the superimposed scans were predominantly green this indicated an exact fit between scans and the reference model; however, red or blue color indicated positive or negative discrepancies of the fit.

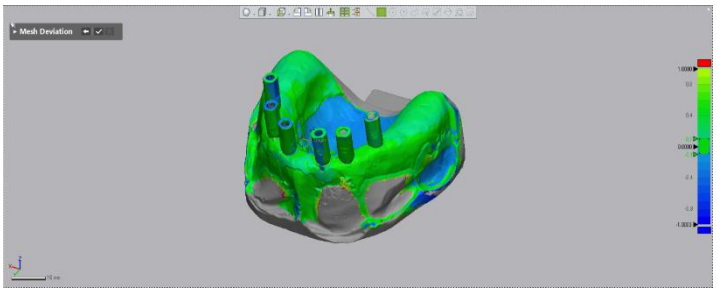
TRUENESS



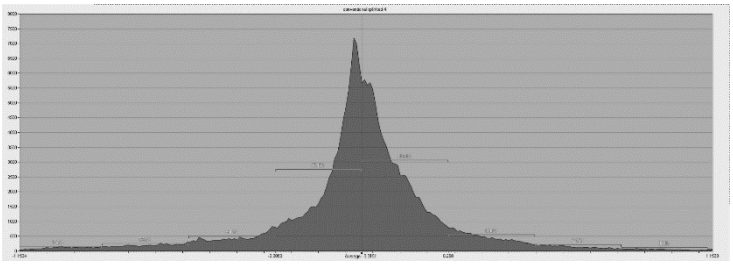
QUALITATIVE ANALYSIS BY THE SUPERIMPOSITION OF CONTROL AND WINDOW TRAY TECHNIQUE.

GRAPHICAL REPRESENTATION OF WINDOW TRAY OVER CONTROL FILE

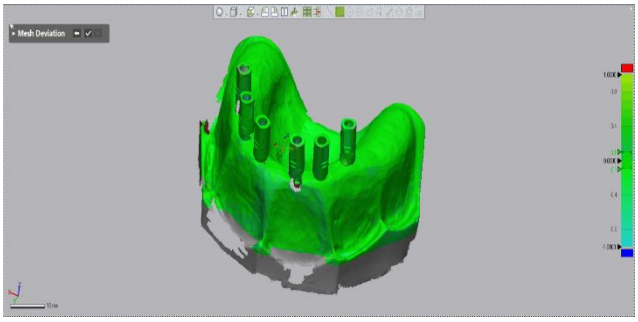




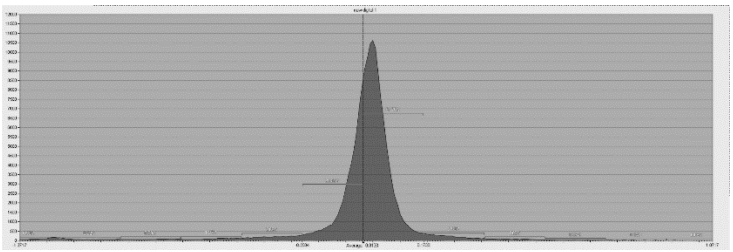
QUALITATIVE ANALYSIS BY THE SUPERIMPOSITION OF CONTROL AND CHIMNEY TRAY TECHNIQUE.



GRAPHICAL REPRESENTATION OF CHIMNEY TRAY OVER CONTROL FILE

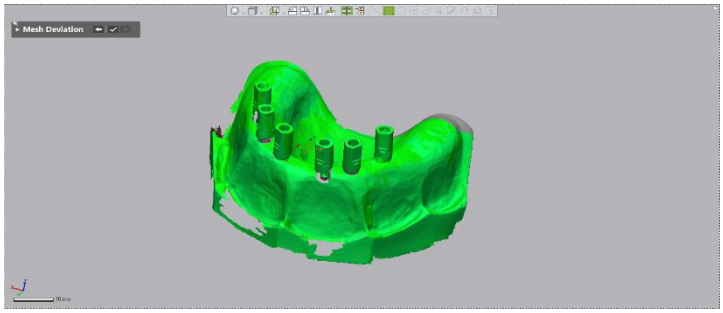


QUALITATIVE ANALYSIS BY THE SUPERIMPOSITION OF CONTROL AND DIGITAL IMPRESSION TECHNIQUE.

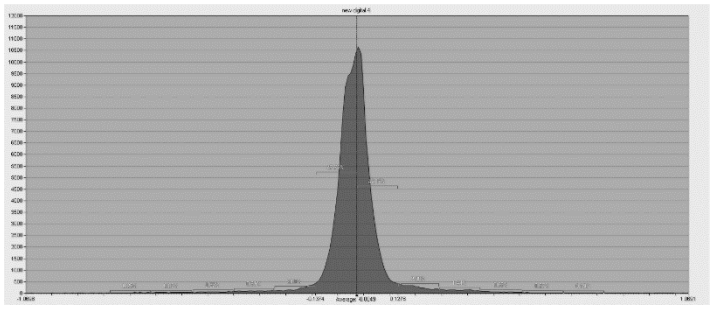


GRAPHICAL REPRESENTATION OF DIGITAL IMPRESSION OVER CONTROL FILE

PRECISION



A QUALITATIVE ANALYSIS OF DIGITAL IMPRESSION TECHNIQUE IN PRECISION



GRAPHICAL REPRESENTATION OF DIGITAL IMPRESSION STL FILE OVER ANOTHER DIGITAL STL FILE (PRECISION)

4. DISCUSSION:

Results of this study revealed that the accuracy of digital impressions is the same as that of conventional impressions. About the implants, the digital impressions of six maxillary implants resulted in similar accuracy to the conventional techniques. Both digital impressions and chimney tray techniques were superior to the window tray impression technique.
Digital impressions were proposed as a possible alternative to the conventional workflow a few decades ago.
It was observed that digital impression making took a shorter time compared to the conventional method.
Digital scanning has brought innovative dental treatments, such as computer-guided implantation in combination with a computed tomography (CT) scan or digital impression system, which allows for CAD-CAM-based restorations. IOS impressions help in decreasing the chairside time, enhance patient comfort, and allow for immediately visualizing the adequacy of the impression. Only a few scientific data are available about the accuracy of the

digital impression system in the literature. Direct digitalization showed higher accuracy compared to conventional impression taking and indirect digitalization (Guth et al.,2013a).[8,9]Angulated implants and the deeply placed implants did not seem to decrease the accuracy of the digital impression.[10,11,12]

A recent study has reported the superior accuracy of a modified tray design where the custom tray is altered to increase the support of the impression material around copings. This modification involves the addition of a "chimney" around each impression coping to ensure that the rigid tray material surrounds the external surfaces of the coping. This design also ensures that a uniform amount of impression material surrounds the copings.Clinically, the new tray design has multiple potential advantages such as ease of use, simplicity, time efficiency, convenience, and less material usage in comparison to the splinting technique. Clinically, however, it is frequently observed that the implants are not parallel and have an angle between them that imposes an extra challenge on the impression, as illustrated in multiple studies. Thus, before a modified tray design can be recommended as a replacement for splinting, it is important to evaluate its accuracy in scenarios that are clinically more relevant, such as the presence of a moderate angle between the implants.[13,14]

The modified tray design is advantageous in reducing the bulk of the impression material surrounding the impression copings. This may reduce the magnitude of the total distortion of the impression material. Several laboratory studies have shown that most of the elastomeric impression material bulk is associated with greater shrinkage and subsequent inaccuracies in the impressions.[15],[16],[17]Eventually, as the modified tray design reduces the bulk of the impression material around the coping, the likelihood of errors in coping orientation is reduced to a similar level to that of the splinting technique. This may have clinical relevance as the modified tray technique is simpler, less time consuming, and more convenient for both the clinician and patient than the splinting technique.[13]

5. CONCLUSION:

1. Different impression techniques and implant systems had variations in the accuracy of the generated definitive cast; however, the accuracy with all 3 techniques was within a clinically acceptable range.
2. The new tray design concept investigated in this study appeared to be advantageous and produced more accurate implant impressions than window tray techniques.
3. The accuracy of digital impressions was not different than the implant-level, chimney tray impression technique for completely edentulous patients and both were more accurate than the implant-level, window tray impression technique.

Conflict of Interest – Nil
Source of Funding– Nil
Ethical Clearance– SBDCH/IEC/12/2019/23

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