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Accuracy of digital and conventional implant impression techniques - A comparative clinical study

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Abstract:

Because an incorrect transfer of 3D implant sites might result in an ill-fitting prosthetic replacement with problems including peri-implantitis, screw loosening, screw fracture, prosthesis or implant fracture, precise implant impressions are crucial. Therefore, it is of interest to evaluate and compare the accuracy of digital and conventional implant impression techniques in partially edentulous cases with two posterior implants. Fifteen patients underwent both conventional polyvinyl siloxane impressions and digital intraoral scanning and the resulting master models were analyzed using laboratory scanning and three-dimensional reverse engineering software to assess inter-implant distance, angulation, rotation and surface mismatch. There was statistically insignificant differences were noted between the two impression techniques for inter-implant distance, angulation, rotation, or distal implant surface mismatch, whereas a significantly greater mesial implant surface mismatch was found with the digital impression technique ($p = 0.02484$). Strong positive correlations were observed between the two techniques for distance, angulation and rotation, while a moderate positive correlation was noted for mesial and distal implant surface mismatch. Thus, digital impressions showed accuracy comparable to conventional impressions for short-span posterior implant restorations and can be considered a reliable alternative for routine clinical application.

Keywords: Conventional impression, dental implant impression, digital impression, implant accuracy, intraoral scanner

Background:

A diverse array of impression techniques has been employed to produce precise implant-supported prostheses. The conventional implant impression (CII) technique has been employed for an extended period to document the implant's precise location from the oral cavity to the master cast. Nevertheless, various factors exhibit an impact on the impression accuracy, including the type of impression material and technique, the tray selected, an impression coping's shape, the number of implants, the form of implant connection and angulation, cast pouring and dental stone expansion [1]. The CII technique involves a series of sequential steps that increase the probability of error at any given stage of the process. Additionally, these errors are inevitable and undermine the precision of the final prosthetic replacement that is supported by a dental implant [2]. CIIs, which are produced with alginate or elastomers such as vinyl poly-siloxane and polyether, are commonly employed in general dentistry due to their adequate stability and precision. Although these materials are capable of producing high-quality impressions, numerous laboratories maintain that CIIs are not sufficiently satisfactory. Stone dies frequently exhibit impregnated debris, indistinct margins, gaps in critical locations and poor reproduction of preparation borders [3]. In response to the aforementioned factors, an appropriate alternative to the CII procedure is deemed necessary. The techniques of computer-aided design (CAD) and computer-aided manufacturing (CAM) have been popularised by advancements in digital technology, which have also facilitated more efficient and predictable therapeutic results. The accuracy of CII prosthetic selections has been demonstrated through the collection of three-dimensional images, which also enables the virtual definition of a range of treatment procedures and the digital design and development of

a variety of restorations [4]. Several CAD/CAM systems have showed efficacy in both aesthetics and functionality when designing and manufacturing prostheses from stone castings of CIIs. Nevertheless, the prosthetic fit may be compromised by factors that impact the precision of the stone cast, such as deformation in the impression material and air bubbles. Intraoral scanners (IOS) have been designed to streamline the process and enhance accuracy [5]. Impressions must be precise as a prerequisite for restoration to be successful and the process of obtaining impressions is indispensable. CIIs have drawbacks, including poor patient tolerance and material-related issues, despite their efficacy. Over the past few years, IOSs that utilise structured light or lasers have emerged as a viable alternative, offering advantages such as reduced distortion risk, faster procedures, increased patient comfort and improved patient-reported results. IOSs are an emerging technology that is constantly evolving and digital implant impressions (DIIs) are a form of it. Their acceptance by patients is fairly high, which is the reason their usage is increasing, as a result of their numerous advantages, such as the enhanced comfort that results from the absence of impression trays and materials [6]. Dentists also favour digital IOSs for real-time visualisation, convenient repeatability, selective capture of pertinent regions and no requirement to disinfect impressions and impression trays, cast pouring, no model wear, prompt communication and ease of use [7]. Consequently, in recent years, DIIs have been suggested as a potential alternative to the CIIs workflow. Although there have been numerous randomised clinical studies that have investigated the accuracy of DIIs on intact teeth, there is a scarcity of information in the scholarly literature pertaining to the accuracy of DIIs for implant-supported prosthetic replacement [8]. Precise implant impressions are essential due to

the fact that the inaccurate transfer of 3D implant locations can lead to an ill-fitting prosthetic replacement with complications, such as peri-implantitis, screw loosening, screw fracture, prosthesis or implant fracture [9]. Therefore, it is of interest to report the objective of the investigation, which was to assess and compare the precision of DIIs and CII in a clinical setting.

Materials and Methods:

The investigation was carried out at the Mahe Institute of Dental Sciences and Hospital's Department of Prosthodontics, Crown & Bridge and Implantology. The Institutional Ethical Committee granted ethical approval for the study before it started (Ref. No: MINDS/MEC-IX/15042024/PG-10). Every patient who consented to take part in the trial provided written informed consent. The inclusion criteria were: patients of both genders aged 18 years, partially edentulous maxillary and mandibular posterior region, patients who had undergone surgical placement of 2 dental implants in the same edentulous span and scheduled for prosthetic rehabilitation and healthy implant and periodontal status with good oral hygiene. The exclusion criteria were: any pathology associated with placed implants, severely tilted implants and inaccessible areas with reduced inter-arch space for placement of open tray coping. The sample size was estimated by applying the formula: $N = (Z\alpha + Z_{1-\beta})^2 \times SD^2 / d^2$; where $Z\alpha = 0.05$, $Z_{(1-\beta)} = 90\%$, Standard Deviation (SD) = $(S1+S2)/2 = (3.22+36.69)/2 = SD$ calculated from prior study, $d =$ clinically significant difference. A sample size of 15 at a 95% confidence level and 90% power, considering a 1:1 allocation ratio, was estimated for a two-sided test for the two impression methods. Fifteen individuals who have had dental implants surgically placed were chosen. Two distinct impression techniques were used to record the implant site in each patient: i) the CII technique and ii) the DII using a fine IOS (NES MEDICORP Pvt. Ltd). Both impressions were used to create master models. Jig trials were used to verify master models. Following verification, the laboratory scanner D2000 (3Shape) were used to scan the master models (CII group). Reverse engineering software was used to import 3D models from CII and DII workflows and overlay them with high-resolution 3D CAD models of scan bodies. CII and DII impressions were compared in terms of the distance between center points, angulation, rotation, vertical shift and surface mismatch of the scan bodies. Thirty impression samples were made and divided into 2 groups based on the method of making the impression, CII and DII (n=15/group).

Making of conventional implant impression:

The Healing Cap was unscrewed. The internal connection of the implant was cleaned with saline. The impression coping was attached to the implant site without impinging the soft tissue collar around the implant. The accurate positioning of the impression coping was checked (confirmed with RVG) before tightening (20Ncm). A window was cut 1.5 cm x 1.5 cm in the metal tray and try-in of the tray was done in the mouth before making the impression. Light-bodied polyvinyl siloxane impression material was applied around the open tray

impression coping in the mouth. The impression tray was loaded with extra heavy-bodied polyvinyl siloxane impression material (Putty consistency) and was seated in the mouth. The head of the screw was wiped off of any impression material for easy accessibility of the open tray coping. When the impression had set, the integral guide screw was unscrewed to remove the impression and checked for good adaptation of the impression material around the MIS implant open tray coping. Rinsing of the internal connection of the implant was done with saline. The healing caps were replaced. The implant analogue was now attached to the open tray impression coping in the impression.

Making of digital implant impression:

Seating of the scan bodies (MIS SCAN BODIES) was done and torqued to the implants at 20 Ncm. The scanning was done using a D-fine IOS. The scanning was started from the occlusal surface in the maxillary and mandibular arches. Later, buccal and palatal/lingual surfaces were captured. The scanned Standard Tessellation Language (STL) files were exported to the respective dental lab for the fabrication of the working model (master cast).

Fabrication of master cast for the open tray impression:

The impression was disinfected with a suitable disinfectant. A suitable separator was applied onto the impression surface near the implant site. The gingival moulage was fabricated around the implant site using GINGIFAST- ZHERMACK to simulate the soft tissue collar around the implant. After the setting of the moulage, the casts were made using Type 4 die stone (KALABHAI - kalrock) and set for 24 hours. The master cast was retrieved and trimmed.

Fabrication of verification jig:

After retrieving the model (master cast) from the impression, verification jigs were fabricated using pattern resin with the open tray coping for the model made through conventional impression technique and also for the digital impressions. This jig was employed to assess the accuracy of the position of the implant analogues in the master model by performing a jig trial on the implant site in the patient's mouth. (CII and DII groups). Passive fit evaluation techniques, such as finger pressure and Sheffield screw-resistance tests, were utilized for the validation process. The radiographic confirmation regarding the fit of the jig over the implant was also evaluated.

Conversion of master cast (CII) into a digital model:

The same scan bodies at the same implant locations and rotational positions were attached to the implant analogues utilizing 15 Ncm torque in the master model. Scanning of master models was executed utilising a D2000 (3Shape, Copenhagen, Denmark) laboratory scanner and Dental system software. The scanned STL files were saved.

Digitalization of the scan body:

The high-resolution and high-accuracy 3D CAD models were imported into Geomagic Design X (Geomagic Inc., Morrisville,

North Carolina) reverse engineering software. A digital model of the original scan bodies was made.

Alignment of the 3D models:

3D models produced from data captured by the IOS and laboratory scanner were contrasted with 3D CAD models of scan bodies using Geomagic Control X (Geomagic Inc., Morrisville, North Carolina) software. Each imported 3D model was appraised for any non-manifold, redundant, crossing and unstable faces in the imported shell. The 3D model has its own rotation and position and therefore, coarse alignment and fine alignment were applied.

Comparison of models:

A high-precision 3D CAD model of the scan body was employed at every stage of the procedure. To determine the scan body axis, the section plane was designed on the scan body shell. The distance between centre points, the angulation and the rotation of the scan bodies were determined. The mismatch between the original and the 3D models of the scan body was also measured. Five repeated measurements per case for each parameter were conducted.

Comparison of the distance of the implant and the adjacent marked landmarks on both models:

The centre point of the scan body was at the intersection between the axis and the top plane, determined by selecting three reference points on the top surface of the scan body. The centre point of the adjacent structure was also marked using the same means. The Euclidean distance between centre points P1 (x1, y1, z1) and P2 (x2, y2, z2) of two scan bodies was determined as the length of the straight line connecting the two points.

Comparison of the angulation of the scan body on both models:

The angulation of scan bodies was determined as the angle between two vectors (u and v). These vectors (u and v) were derived from the scan body axis. The angle between the two lines u and v was then estimated.

Comparison of the rotation of the scan body on both models:

The vertical edges of the scan body were employed to measure the rotation. The side front plane and top plane of a flat surface of the scan body were determined by identifying three points on

each wall. The intersection of two selected front and top planes was the edge vector. The angle between the top edges of two scan body models was determined, which was the rotation of one scan body in relation to the other.

Comparison of the mismatch of the scan body and the impression:

The mismatch between the original and the 3D models of the scan body was evaluated and the average distances between the surfaces were determined. The Euclidean distances were then calculated for each pair.

Statistical analysis:

The values were obtained in millimetres, micrometres and degrees. Data were evaluated using IBM SPSS (Statistical Package for Social Sciences, IBM Co., Armonk, NY, USA) version 26.0 statistical software at a 5% significance level. The mean values were contrasted between the groups using a paired samples t-test or Wilcoxon signed rank test, appropriately. Assessment of correlation between various parameters of the study was done using Pearson's and Spearman's correlation tests.

Results:

The results obtained show that there is a statistically insignificant difference observed between the two impression techniques (**Table 1**). The findings reveal that there is statistically insignificant difference between the two impression techniques in relation to angulation and rotation (**Table 2**). The findings obtained show that there was a statistically significant difference ($p=0.02484$) observed between the two groups concerning mismatch mesial implant, with the mean and median value being significantly higher in digital impression than in the conventional impression. However, there is no statistically significant difference regarding the mismatch distal implant between the two groups (**Table 3**). Concerning the parameters of distance between scan body, angulation and rotations, it was revealed that there was a very strong positive correlation observed between the two impression techniques, indicating them to be very similar in terms of the result. Similarly, concerning mismatch mesial and mismatch distal implant, it was observed that there was a moderately positive correlation between the two impression techniques (**Table 4**).

Table 1: Comparison of distance between the scan bodies

Groups	Mean and SD (μm)	Minimum and maximum (μm)	95% CI	t-value	p-value
Conventional implant impression	5.874 $\pm$ 0.312	5.248, 6.324	5.702100, 6.047633	0.293	0.3608
Digital implant impression	5.841 $\pm$ 0.304	5.357, 6.302	5.672183, 6.009817		

$p < 0.05$ - statistically significant

Table 2: Comparison of angulation and rotation between the two impression techniques

Angulation between the two impression techniques					
Groups	Mean and SD ($^{\circ}$)	Minimum and maximum ($^{\circ}$)	95% CI	t-value	p-value
Conventional implant impression	9.10 $\pm$ 0.56	8.2570, 10.268	8.796360, 9.420986	-0.14	0.4889
Digital implant impression	9.13 $\pm$ 0.584	8.2862, 10.356	8.814769, 9.462191		
Rotation between the two impression techniques					
Conventional implant impression	18.16 $\pm$ 0.38	17.3780, 18.98	17.95318, 18.37654	0.32	0.4474

Digital implant impression	18.11±0.46	17.1617, 18.75	17.85388, 18.37408
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p<0.05 - statistically significant

Table 3: Comparison of Mismatch mesial implant and Mismatch distal implant between the two impression techniques

Comparison of Mismatch mesial implant between the two impression techniques											
Groups		Mean and SD (µm)	Median and Inter quartile range	Minimum maximum	and 95% CI					v-value	p-value
Conventional implant impression		10.27± 0.25	10.234 (0.206)	9.998, 11.021	10.12914, 10.41513					20	0.02484
Digital implant impression		11.35± 2.24	10.324 (0.218)	9.898, 16.320	10.11626, 12.59921						
Comparison of Mismatch distal implant between the two impression techniques											
Conventional implant impression		10.35±0.29	10.35(0.277)	9.890, 11.020	10.19556, 10.52178					38	0.2219
Digital implant impression		11.24±1.83	10.53(0.411)	9.879, 15.135	10.22672, 12.25368						

p<0.05 - statistically significant

Table 4: Describes the correlation between the two impression techniques in relation to its various parameters

Correlation assessed between		Variables	Correlation coefficient	p-value	Interpretation	Correlation using	assessed
Conventional impression - Digital impression		Distance between Scan body	0.8989	0.0000	Very strong positive	Pearson's test	correlation
		Angulation	0.9606	0.0000	Very strong positive	Pearson's test	correlation
		Rotation	0.8448	0.0001	Very strong positive	Pearson's test	correlation
		Mismatch Mesial implant	0.4450	0.0965	Moderately positive	Spearman's test	correlation
		Mismatch Distal implant	0.3821	0.1598	Weak to moderately positive	Spearman's test	correlation

Discussion:

The current clinical study showed that digital implant impressions provided accuracy comparable to that of conventional open-tray implant impressions for short-span posterior implant restorations. There were no substantial differences detected between the two techniques with respect to inter-implant distance, angulation and rotational measurements. These results confirm an increasing body of literature showing that present intraoral scanners are able to accurately replicate implant positions in partially edentulous patients [10-12]. Accurate three-dimensional transfer of implant position is critical for achieving a passively fitting implant-supported prosthesis. Because osseointegrated implants do not possess the compensatory mobility of natural teeth, even minor imprecision in impression making could result in adverse effects [10, 12]. Therefore, impression accuracy is still one of the most important determinants of long-term success of the implant. The conventional open-tray impression technique has long been regarded as the clinical reference standard because of its predictable transfer accuracy. However, the procedure is susceptible to dimensional changes resulting from impression material polymerization, cast expansion, analogue positioning and laboratory procedures. Digital impressions eliminate several of these intermediate steps and therefore reduce cumulative procedural errors while improving communication with the laboratory and patient comfort [13, 14]. The present investigation demonstrated an insignificant difference in the distance between scan bodies. Preservation of inter-implant distance is fundamental for achieving passive fit of implant-supported prostheses. Similar findings were reported by Papaspyridakos *et*

al. [10], who concluded that DIIs exhibit comparable three-dimensional accuracy to CIIs in partially edentulous situations, although CIIs showed a slight numerical advantage in some studies. More recently, Ma *et al.* [12] reported that intraoral scanners provide clinically acceptable accuracy for implant impressions *in vivo*, particularly in short-span restorations, while emphasizing that scanning strategy influences the outcome. Similarly, insignificant differences were observed in implant angulation and rotational measurements between the two impression techniques. Accurate reproduction of implant orientation is particularly important for restorations with internal implant connections because rotational discrepancies may compromise prosthesis seating and induce stress at the implant-abutment interface. Albánchez-González *et al.* [11] concluded that advances in intraoral scanner technology and scan body design have significantly improved the precision of digital implant impressions, making them comparable to conventional techniques for short-span implant restorations. A crucial finding of the present investigation was the considerably greater surface mismatch observed at the mesial implant in the digital impression group, whereas the distal implant demonstrated no statistically significant difference. Although statistically significant, the clinical relevance of this localized mismatch should be interpreted cautiously because three-dimensional superimposition software can detect minute deviations that may not influence the passive fit of the definitive prosthesis. Furthermore, the absence of differences in the primary positional parameters suggests that the overall implant position was accurately transferred despite localized surface discrepancies [12]. The greater mismatch observed at the mesial

implant may be attributed to factors inherent to the digital workflow, including image stitching errors, scanning strategy, scanner calibration, scan body geometry, saliva contamination and limited accessibility in posterior regions. Conversely, conventional impressions are also subject to inaccuracies related to impression material distortion and cast fabrication. Therefore, the localized difference observed in the present study probably reflects procedural variation rather than a systematic limitation of digital impressions [11, 12]. The strong positive correlation observed between digital and conventional impressions for distance, angulation and rotation further confirms the consistency of both techniques in reproducing implant positions. Although only a moderate positive correlation was observed for surface mismatch, this parameter represents localized surface deviation rather than overall implant position. Similar conclusions have been reported in recent systematic reviews, which indicate that digital implant impressions provide reliable and clinically acceptable accuracy for partially edentulous implant restorations [10-12]. From a clinical perspective, digital implant impressions offer several additional advantages, including improved patient comfort, elimination of impression materials, immediate verification of scan completeness, simplified communication with dental laboratories and integration with CAD/CAM workflows. Recent systematic reviews have also showed comparable clinical outcomes between prostheses fabricated using digital and conventional impressions, supporting the increasing adoption of digital workflows in implant dentistry [15-18].

Conclusion:

We show that both measures accord for parameters including scan body distance, angulation and rotation without a statistically significant difference. When it comes to mismatch, mesial implants are very different from distal implants. Results showed a substantial positive association between the two imprint approaches for scan bodies, angulation and rotation.

Advancement to knowledge:

Caveat Emptor is applicable among the literate community where required and possible. The publisher, its journal, editors and the internal/external reviewers take adequate steps to check, evaluate, correct, edit, revise and improve content where possible and required.

Digital implant impressions showed accuracy similar to conventional open-tray impressions for short-span posterior restorations, with no major differences in inter-implant distance, angulation, or rotation.

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