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EVALUATION OF THE EFFECT OF IMPLANT SCAN BODY ALIGNMENT, EXPOSED HEIGHTS, AND INTER-SCAN BODY DISTANCES ON THE ACCURACY OF DIGITAL IMPLANT IMPRESSIONS.

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ABSTRACT

INTRODUCTION. Accurate digital impression of the scan body is important to record the actual implant position in the software program. However, studies that have analysed the scanning accuracy using different scan body angulations, exposures, and inter-scan body distances are scarce.

AIM OF THE STUDY. The aim of this in vitro study was to evaluate the effect of scan body alignment, exposed heights, and inter-scan body distances on the digital impressions accuracy.

MATERIALS AND METHODS. Two edentulous maxillary epoxy models were used in this study. The first model had 4 dummy implants. Two PEEK scan body, were tested together with the variable inter-scan body distances. The second model had 6 dummy implants; 3 with different angulations and 3 placed at different levels from the gingival margin. A laboratory scanner was used to scan PEEK scan bodies. All standard tessellation language (STL) files were imported into a surface matching software program (GOM Inspect; GOM).

RESULTS. Both linear and angular deviation values(µm) were significantly higher in the long inter-scan body distance group than the short one. Regarding the effect of the angulation, the highest deviation values (µm) were recorded at the 30-degree angulation. Regarding scan body exposed heights, the linear and angular deviation values (µm) were significantly increased as the supragingival exposed height of the scan body was decreased.

CONCLUSIONS. Short inter-scan body distance and more exposed part of the scan body can enhance the accuracy of the digital impression. Scan body angulation did not significantly affect the accuracy of the digital impression.

KEYWORDS: Digital impression, Scan body, Implant angulation, scan body, Implant alignment, Inter-scan body distance.

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INTRODUCTION

Accurate reproduction of the dental implant 3-dimensional (3D) position in relation to the surrounding structures is a crucial step in the construction of the implant prosthesis.[1-3]Digital impression accuracy is improved by the material of the scan body. PEEK showed the best results, after that titanium, then PEEK-titanium showed the least accuracy.[4-6]

Scan bodies that were only partially visible exhibited notably greater deviations compared to those that were fully visible, leading to the suggestion of using longer scan bodies for deep implant scans.[7,8] However, other research found no significant deviations related to the depth of subgingival implants.[9,10] In contrast, another study observed that the greatest deviations occurred when the scan body was completely exposed.[11]

The intraoral scanning accuracy might be affected by the inter-scan body distances.[12,13] It has been proposed that trueness decreases with the increase of the distance between the implants. However, too short inter scan body distance may complicate intraoral scanning, therefore the position of the implants may be inaccurately transferred.[14]

Numerous studies have investigated the effect of implant angulation on scanning accuracy, yielding mixed results. Some research indicated that angled implants produced more accurate scan data compared to parallel implants,[15,16] while others reported decreased accuracy with angled implants.[17,18]

This study aimed to assess whether factors such as scan body material, distance between scan bodies, the height of exposed scan bodies, and implant angulation influence the accuracy of scan body image alignment. The null hypothesis proposed no significant differences among the groups studied

MATERIALS & METHODS

Two edentulous maxillary epoxy resin models were used in the present study. To simulate the alveolar mucosa, the models were covered by a removable polyurethane layer (Epoxy maxillary model; Ramses Medical Products Factory) 2-mm in thickness.

In the first model: 4 internal connection dummy implants (Dentium Superline; Dentium Co, Ltd) Ø4.5×10-mm length were inserted at the right canine, right first premolar, left canine, and left first molar positions (Fig. 1). A dental surveyor (Ney surveyor; Dentsply Sirona) was used to ensure the parallel alignment of the implants placed.[21]

Sample size was estimated based on 95% confidence level to detect differences in linear absolute error (ΔASS) between titanium and peek scan bodies. Arcuri et al.[6] reported mean ΔASS of titanium= 99.3 and 95% confidence interval (CI)= 0.08, 0.12, while mean ΔASS of PEEK= 54.7 and 95% CI= 0.03, 0.07. The calculated mean ±SD ΔASS difference= 44.6 ±0.04 and 95% CI= 44.57, 44.63. The minimum sample size was calculated to be 17 per group, increased to 19 to make up for laboratory processing errors. The total sample size required=number of groups×number per group=4×19=76.

To evaluate the effect of different inter-scan body distances on the accuracy of the digital impression, 2 PEEK scan bodies were tightened at 15 Ncm to the dummy implants placed at the right canine and first premolar positions. The distance between the 2 scan bodies was considered as the short inter-scan body distance (SID). Scanning was done first without the gingival layer and the STL file obtained was saved as a reference file for comparison. The gingival layer was then adapted, and a total of 19 model scans were made, and STL files obtained were exported. The scan bodies were then removed and tightened to implants placed at the left canine and first molar positions. The same procedure was then repeated considering the distance between the 2 scan bodies as the long inter-scan body distance (LID) (Fig. 2).

In the second model, 6 internal connection dummy implants (Dentium Superline; Dentium Co, Ltd) Ø4.5×10-mm length were used (Fig. 3). Three were inserted at the right side with different angulations by using the abutment angle determining device.[19] A straight implant was inserted at the canine position, 15-degree distally tilted implant at the first premolar, and 30-degree distally tilted implant at the first molar position (Fig. 4). Three PEEK scan bodies were tightened to the dummy implants at 15 Ncm (Fig. 5). Scanning was done first without the gingival layer and the STL file obtained was saved as a reference file then the gingival layer was adapted, 19 model scans were done, and STL files were exported.

On the left side of the cast, 3 dummy implants were inserted at different depths as follows: 2-mm subgingival at the left canine position; 4-mm subgingival at the left first premolar and 6-mm subgingival at the left first molar position. The supragingival exposed height of the scan bodies were 10-mm, 8-mm, and 6-mm respectively. Scanning was done as mentioned before (Fig. 6). All scans in the present study were done by using the same laboratory scanner (inEos X5; Dentsply Sirona).

STL files were imported into a surface alignment software (GOM Inspect; GOM) for analysis. The designated areas of the test and reference scans were aligned using best-fit image matching. A consistent coordinate system was established and applied throughout the inspection process to measure 3D linear and angular deviations (μm) across all scans. To determine distance and angular deviations, the software fitted cylinders to each scan body in the test and reference models, generating a central axis for each. For distance deviation, a specific point along the axis was identified by the software in both models, and the resulting 3D distance between these points was measured to calculate the 3D distance deviation (Fig. 7). For the angular deviation, the original axis from the reference model was considered to be at an angle of zero, and the resultant angle between the 2 axes was recorded to generate the angular deviation (Fig.7).

Collected data were tabulated and analysed by using statistical software (IBM SPSS Statistics for Windows, v23.0; IBM Corp). The Shapiro-Wilk test was applied to assess data normality. The scan body material and inter-scan body distance variables followed a normal distribution, allowing for the calculation of means and standard deviations (SD). Independent samples t-tests were performed to compare study groups, with mean differences and 95% confidence intervals (CI) calculated. Variables related to scan body angulation and exposure showed a non-normal distribution, so non-parametric methods were used. Means, SDs, medians, and interquartile ranges (IQR) were calculated for all variables, and group comparisons were conducted using the Kruskal-Wallis test. Statistical significance was defined as $P < .05$.

RESULTS

The Mean values and standard deviations of linear and angular deviation values (μm) measured in the 2 study groups were presented in Table 1. The linear and angular deviation values (µm) were significantly higher in the (LID) group (0.31 ±0.04 and 1.00 ±0.27, respectively) than the (SID) group (0.08 ±0.06 and 0.49 ±0.37, respectively) (*P*<.001 and *P*=.002, respectively) as presented in Table 1.

Regarding the evaluation of the effect of the implant angulation and the scan body exposure variables on the accuracy of the digital scanning, comparison between the study groups in each variable were done using Kruskal Wallis. Significance was inferred at *P*<.05. The highest linear and angular deviation values (µm) were recorded at the 30-degree angulation group (1.24 ±2.95 and 2.19 ±1.44, respectively), followed by the 15-degree angulation group (1.52 ±3.08 and 1.43 ±0.59, respectively), and the least deviation values were reported in the 0-degree group (0.31 ±0.04 and 1.00 ±0.27, respectively) with no statistically significant difference between the 3 groups (*P*=.44 and *P*=.41, respectively) as presented in Table 2.

When different scan body exposure groups were compared, linear and angular deviation values (µm) were significant. The 6-mm exposed group showed the highest linear and angular deviation values (0.41 ±0.13 and 7.55 ± 1.65, respectively), followed by 8-mm exposed group (0.11 ± 0.06 and 2.55 ± 1.03, respectively), while the 10-mm exposed group showed the lowest variation values (0.08 ± 0.06 and 0.49 ± 0.37, respectively) as presented in Table 3.

Table 1. Mean and standard deviations of linear and angular deviation values obtained from 2 inter-scan body distance groups.

	Short Inter-scan body distance (SID) group	Long Inter-scan body distance (LID) group	*P*
Linear deviation (µm) Mean ±standard deviation	0.08 ±0.06	0.31 ±0.04	*P*<.001*
Angular deviation (µm) Mean ±standard deviation	0.49 ±0.37	1.00 ±0.27	*P*=.002*

*Statistically significant at *P*<.05

Table 2. Mean values and standard deviations of linear and angular deviation values obtained from 3 different implant angulation groups.

	30-degree group	15-degree group	0-degree group	*P*
Linear deviation (µm) Mean ±standard deviation	1.24 ±2.95	1.52 ±3.08	0.308 ±0.04	*P*=.44
Angular deviation (µm) Mean ±standard deviation	2.19 ±1.44	1.43 ±0.59	1.00 ±0.27	*P*=.41

Kruskal Wallis test

Table 3. Mean values and standard deviations of linear and angular deviation values obtained from 3 different scan body exposure height groups.

	6-mm exposed height group	8-mm exposed height group	10-mm exposed height group	*P*
Linear deviation (µm) Mean ±standard deviation	0.41 ±0.13	0.11 ±0.06	0.08 ±0.06	*P*<.001*
Angular deviation (µm) Mean ±standard deviation	7.55 ±1.65	2.55 ±1.03	0.49 ±0.37	*P*<.001*

*Statistically significant at *P*<.05

Figure 1. Four dummy implants inserted into epoxy resin maxillary model.

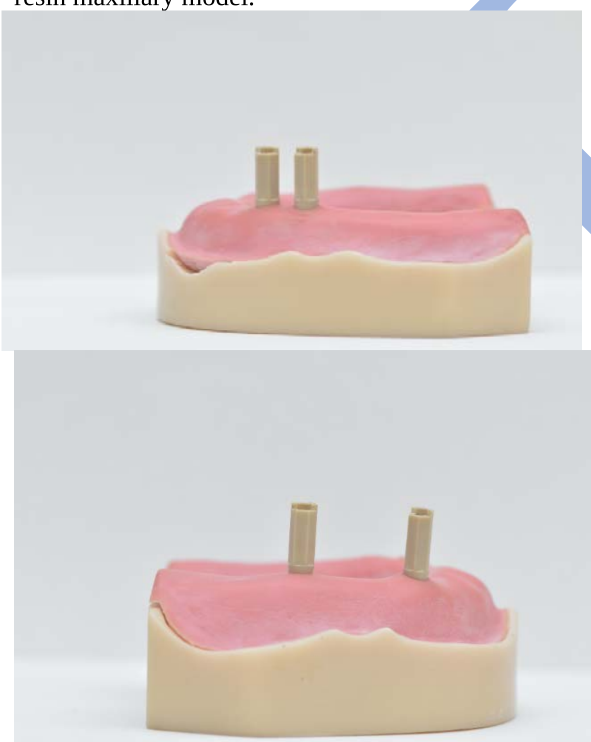


Figure 2. PEEK scan bodies tightened to dummy implants at different distances. a, short inter-scan body distance. b, long inter-scan body distance.

Figure 3. Six dummy implants inserted into epoxy resin maxillary model.

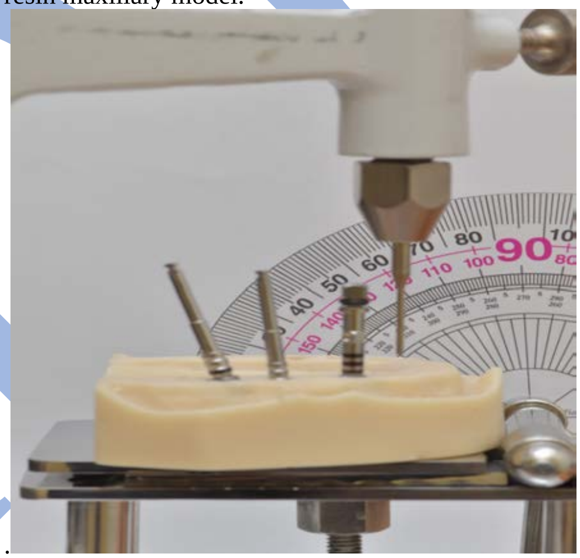


Figure 4. Implants placed at different angulations by using abutment angle determining device

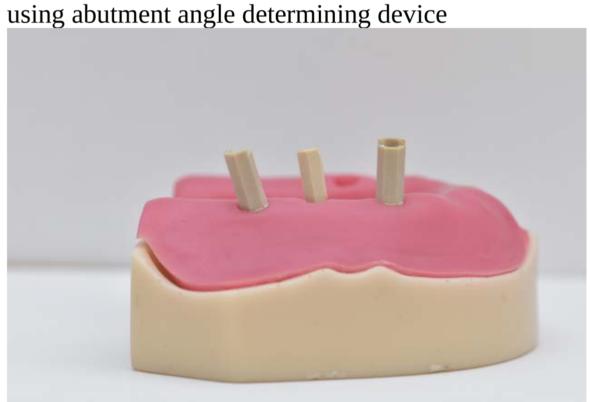


Figure 5. PEEK scan bodies tightened to dummy implants placed at different angulations

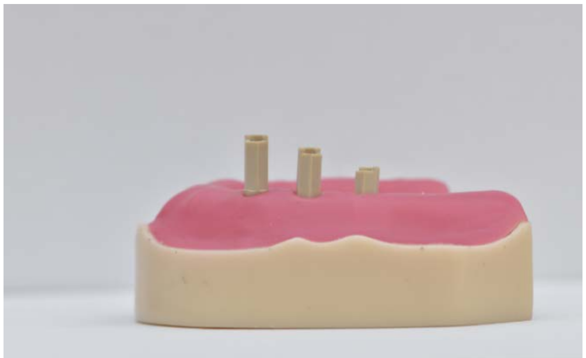
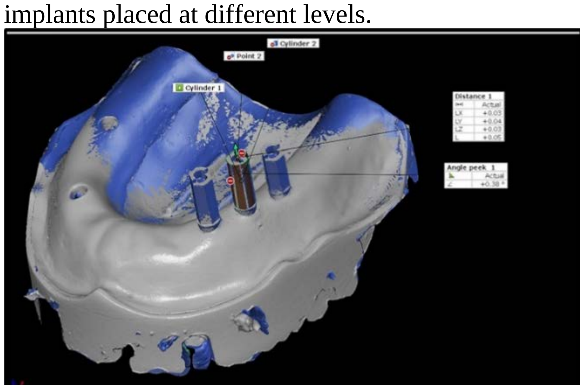
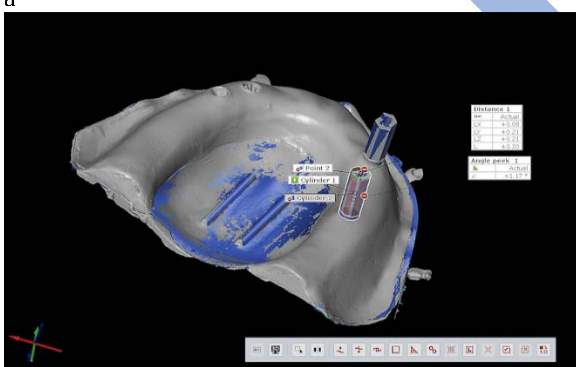


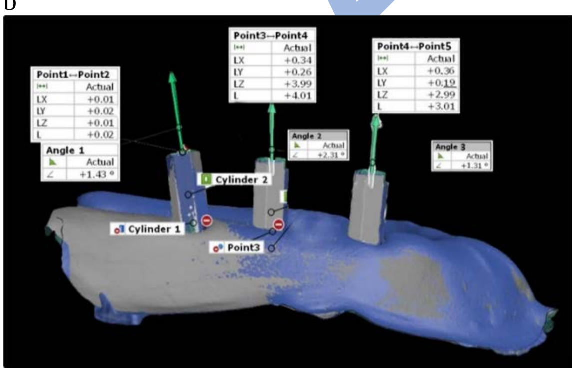
Figure 6. PEEK scan bodies tightened to dummy implants placed at different levels.



a



b



c

Figure 7. Positioning of cylinders in inspection software program and representative linear and angular deviation measurements in a, Inter- scan body distance. b, alignment. c, exposure height variables.

DISCUSSION

Accurate digital impression can guarantee accurate implant position reproduction and consequently a passively fitted implant prosthesis.[1,2] This study was designed to investigate different variables that may affect the accuracy of scan body image matching. The null hypothesis was partially rejected as the linear and angular deviation values showed no statistically significant difference between the study groups when the angulation variable was evaluated.

An extraoral laboratory optical scanner (inEos X5; Dentsply Sirona) was used in the present study to ensure standardization and precision of the scans produced.3 The test scans were superimposed onto the reference scans using the best-fit method through surface alignment software (GOM Inspect; GOM), enabling precise analysis of deviations in both linear and angular dimensions.[6]

The results of the present study showed significantly higher deviation values when the LID was compared to the SID. A possible explanation is that during the stitching process of the 3D images obtained during scanning, errors may accumulate resulting in collective deviation in long-span scanning.[13,14]

The effect of the supragingival height of the scan body exposed on the accuracy of the image matching in the software was evaluated in the present study. The results showed that the less the exposed height of the scan body, the more linear and angular deviation values have been reported. Those results are in accordance with 2 studies concluding that the more the amount of the scan body submerged in the gingiva, the less accurate was image superimposition of the scan body image in the software program.[7,8]

The results of the present study showed that the implant angulation has no significant effect on the accuracy of the digital impression. However, 30-degree implant angulation showed the highest deviation results. Those results are consistent with some studies[17,18] and in contrary to a previous study concluding that more accurate definitive casts were produced when the implant divergence was great.[15]

The limitations of this study include its in vitro design, which standardizes all variables, a condition that cannot be replicated in clinical practice. Further in vivo studies are recommended to validate the findings. Further research is needed to assess whether the linear and angular deviation findings of the present study might cause a clinical misfit of the implant prosthesis.

CONCLUSIONS

Based on the results of this in vitro study, the following conclusions were made:

Increasing the inter-scan body distance significantly raises both linear and angular deviation values.

1. Implant angulation does not significantly influence the accuracy of digital impressions, although a 30-degree angulation produced the highest linear and angular deviation values.
2. A lower supragingival exposed height of the scan body is associated with reduced accuracy in digital implant impressions.

LIST OF ABBREVIATIONS

PEEK: Polyetheretherketone
STL: Standard Tessellation Language
3-D: 3-Dimensional
SID: Short Inter-Scan Body Distance
LID: Long Inter-Scan Body Distance

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