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The effect of height of scan body on the accuracy and duration of digital scanning

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Aim: The purpose of this study was to investigate the effect of the height of scan body on the accuracy and scan time of making a digital implant impression in three implant positions. **Methods:** Three maxillary reference models with partial dentition (missing teeth#1,2,3,4, and 14) were prepared for placing implants. Implants were placed in position of tooth#2 (named distant implant [Dis]), tooth#4 (named adjacent implant [Adj]), and #14 (named single implant [Sin]). Depth of insertion of implants and height of scan bodies were selected in a way that scan part of scan body stayed on heights of higher (Hi), lower (Lo), and equal (Eq) relative to the occlusal plane. The models were scanned with intraoral scanner (Omnicam) (22 scans for each model), and with desktop scanner (inEos X5) (one scan as reference scan). The scans were superimposed on the reference scan and deviations of each implant (single, adjacent to edentulous area, and distant in edentulous area) and scanning time of each group were measured (α=.05). **Results:** In contrast to adjacent implant position, deviations in Equal (p< 0.03) and Lower (p<0.001) groups were significantly more than Higher in mean distance deviation in single implant position. Findings were similar in terms of different heights in the distant implant position. The three dimensional angular deviation comparison demonstrated that Sin-Eq group had greater deviation (p<0.0001). Kruskal Wallis test showed that there was a significant difference among the groups (p= 0.001) and the least scanning time was in the Lower height group. **Conclusion:** The scan body higher than the occlusal plane is a safer option when there is an adjacent tooth. When there is space around the scan body there would be less rotational deviations.

Keywords: Digital implants. Dental impression technique. Dimensional measurement accuracy. Imaging, three-dimensional.

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Introduction

Accurate impression making is an important step that guarantees the survival and continuing clinical services of implant restorations[1,2]. The introduction of computer-aided design/computer-aided manufacturing (CAD/CAM) technology has minimized the human and technical errors of conventional impressions. This technology has made it possible to digitally fabricate implant-supported restorations both directly or indirectly[1,3,4]. In the indirect workflow, a conventional implant impression is first made and then is digitized in the laboratory using a benchtop scanner and laboratory implant scan bodies (ISBs). The whole process is digitized in the direct workflow. Intraoral scan bodies are used, and a digital scan is directly generated from the patient's mouth with an intraoral scanner[2,5-7]. Factors affecting the digital scan accuracy include implant angulation, the distance between the implants, ISB design, scanning protocol, calibration of the intraoral digitizer device, handling and learning, and ambient scanning light conditions. Depending on the scanning technique, the clinician should presume some scanning accuracy differences[2,8-12].

Intraoral scan bodies are basically used to transfer the direction and position of implants, similar to what impression copings do in conventional implant impressions[2,13]. Other than implant companies, there are various suppliers of digital components that produce ISBs matching different implants. Commercial ISBs vary greatly in material, size, shape, surface, reusability, software/ scanner compatibility, and price. Despite being greatly variable, the ISB normally has three diverse components: scan region (the upper portion), body (the middle portion), and base (the most apical portion). The accuracy of digital scans depends on the scan region that may have one or multiple scan areas. The second part, the body, which can be made of different materials such as polyetheretherketone (PEEK), titanium alloy, aluminum alloy, and various resins, connects the scan region to the base. Finally, the base, made of the same or a different material from the body, creates the matching surface between the ISB and the implant[2]. Intraoral scan bodies might have different designs and heights (3 to 17 mm), and their dimensions vary depending on the implant size. Similar to conventional impression making, these features may influence the accuracy of the digital impression. Also, the scanning time changes depending on the ISB's surface details, materials, and size[1,2].

An increase in the height of ISB is equivalent to an increase in its surface. When the scanned surface is greater, we have denser point clouds that result in more accuracy in the image reconstruction[2]. There is not a single meticulous figure for the height of ISB. However, exposing the scan region out of the gingiva or at the level of the adjacent tooth to prevent this shadow is debatable.[14] Scant research has worked on the effects of factors associated with ISB on the accuracy of the impression[11,15]. This study was designed to investigate the effect of the height of ISB relative to the occlusal plane on the accuracy and scan time of digital dental impressions, when implants were in diffident situation (between two teeth, adjacent to one tooth, and in an edentulous area).

Materials and Methods

Three maxillary reference models with partial dentition (missing teeth#1,2,3,4, and 14) were used in the present study. Three implants with regular diameter (4mm), 11mm height, and internal hexagonal connection (Implantium, Dentium, South Korea) were inserted in the left first molar (group "Sin"), right second premolar (group "Adj") and second molar (group "Dis") sites (Figure 1). Implants were placed in the center of each tooth position based on trial set up. Implants were inserted perpendicular to the occlusal plane and parallel to each other, and fixed with acrylic resin (GC Reline Hard, GC, Japan). Implants angulations and locations were exactly the same in the three models. Using two heights (6 and 8mm) of scan bodies (Implantium, Dentium, South Korea) and changing depth of implant insertion, the scan part was set higher, equal, or lower than the occlusal plane in each model. Intraoral scan bodies were hand tightened until they got stable on each implant replica, as recommended by the manufacturer. Table 1 and figure 2 illustrate the study groups. First, reference scans were provided by scanning each model with a desktop scanner (inEos X5, Sirona, Germany) with an accuracy of 1.2µm. Without removing or changing the scan body position, 63 digital scans (21 scans for each group) were obtained by using an IOS (Omnicam, Sirona, Germany) in the same environmental conditions (light and temperature) following the scanning protocol recommended by the manufacturer. Standard tessellation language (STL) file of each scan was created. A trained operator did all the scans with one scan strategy. Scanning of each group was done in a day to avoid operator fatigue. To compare the differences between the scans produced by the IOS with the reference models, the operator superimposed each scan on its reference model.

Figure 1. Implant sites in the three models, single implant in position of tooth#14, adjacent implant in second right premolar, and distant implant replaced second right molar.

Table 1. Abbreviations for group definition.

Abbreviation	Implant position in the model
Sin	Single: left first molar
Adj	Adjacent: right second premolar
Dis	Distant: right second molar

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Abbreviation	Scan area position related to occlusal plane
Lo	Lower: 2mm lower than the occlusal plane (Figure 2A)
Eq	Equal: At the occlusal plane (Figure 2B)
Hi	Higher: 2mm higher than the occlusal plane (Figure 2C)

Figure 2. Scan part of scan body position in each group. A, Lower than occlusal plane. B, Equal to the occlusal plane. C, Higher than occlusal plane.

The best-fit algorithm in GOM Inspect software (GOM Inspect 2019, GOM GmbH, Braunschweig, Germany) was used to assess accuracy. The extent each model's scan superimposed the reference model indicated trueness, and the extent the data obtained from the repeated scans were homogenous showed the precision. The central point of ISB was considered as the scan reference point. A coordinate system was generated and used to measure the accuracy of scans (distance and angular deviations). The scanning time was measured from the initiation until the end of scanning. Two examiners used a chronometer to measure the time to reduce bias and variability. The average value of the measured time was reported as the scanning time.

The normality assumption of the continuous variables was assessed using the Shapiro-Wilk W-test. Two-factor ANOVA was conducted to assess the effect of implant status (single, adjacent and distant) and height of scan body relative to the occlusal plane (lower, equal and upper) on distance deviation and angular deviation. A Tukey test was applied for pairwise comparison effects. Kruskal-Wallis test was applied to determine if there are statistically significant differences among various heights of scan body relative to the occlusal plane on scan time. Then, Mann-Whitney U-test was used for pairwise comparisons.

Results

The distance and angular deviations from the reference scan and the 63 test scans were calculated for each ISB over the angulation and X, Y, Z-axes. Regarding two-factor ANOVA, distance and angular deviations had been significantly affected by implant position (Dis, Sin, Adj) ($p < .001$, $p < .0001$, respectively), ISB height ($p < .0001$, for angular deviation) and their interaction ($p = 0.049$, $p < .0001$, respectively), whereas the effect of ISB height on distance deviation was not significant (p=0.126). According to the post hoc Tukey test, the only significant difference was found in Sin-Hi/Sin-Eq (p= 0.03), Sin-Hi/Sin-Lo (p<.001), Adj-Hi/Adj-Eq (p<.0001), and Adj-Hi/Adj-Lo (p<.0001) comparisons regarding 3D distance deviation. Concerning 3D angular deviation, all differences were significant, except difference observed in Dis-Lo vs. Dis-Hi (p = 0.17) and Dis-Lo vs. Dis-Eq (p= 0.16) comparisons.

Table 2 tabulates that the highest ΔX, ΔZ, and ΔR were in Dis-Hi (0.13±0.1, 0.09±0.07, 0.19±0.9, respectively), while the highest ΔY was in the Dis-Lo (0.06±0.04). The lowest ΔX (.04±.03) was in Adj-Lo, whereas the lowest ΔY (.01±.00) was in Sin-Lo. The lowest ΔZ and ΔR were in Adj-Eq (.02±.01 and .07±.02, respectively). Regarding ΔA, the highest value was in Sin-Eq (3.51±0.36), and the lowest was in Sin-Hi (0.54±0.59). Kruskal Wallis test demonstrated a significant difference among various heights of scan body relative to the occlusal plane concerning scan time (p=0.001).

Regarding scanning time, the least scanning time was in the Lower height group (figure 3). Kruskal Wallis test showed that there was a significant difference among the groups (p= 0.001). Pairwise comparisons using Mann-Whitney U-test demonstrated a significant difference between Lower height with other groups (Lo/Eq [p<.001], Lo/Hi [p=0.01].

Table 2. Mean and Standard deviation (SD) of distance (μm) and angular deviation (degree).

Implant Position	ISB height	Group	ΔX	ΔY	ΔZ	ΔR	ΔA
Single	Lower	Sin-Lo	.07 (.05)	.01(.00)	.11(.03)	.14(.03)	1.46(.89)
	Equal	Sin-Eq	.14 (.04)	.06 (.03)	.02 (.04)	.15 (.04)	3.51 (.36)
	Higher	Sin-Hi	.07 (.04)	.05 (.02)	.04 (.04)	.11 (.03)	.54 (.59)
Adjacent	Lower	Adj-Lo	.04 (.03)	.02 (.01)	.05 (.03)	.08 (.04)	3.12 (.24)
	Equal	Adj-Eq	.05 (.02)	.04 (.01)	.02 (.01)	.07 (.02)	.85 (.37)
	Higher	Adj-Hi	.1 (.06)	.04 (.03)	.04 (.03)	.13 (.05)	1.60 (.69)
Distant	Lower	Dis-Lo	.05 (.04)	.06 (.04)	.05 (.02)	.11 (.04)	1.19 (.44)
	Equal	Dis-Eq	.1 (.09)	.05 (.03)	.05 (.05)	.13 (.08)	.75 (.88)
	Higher	Dis-Hi	.13 (.1)	.05 (.03)	.09 (.07)	.19 (.09)	1.59 (.86)

ISB: Implant scan body; ΔX: deviations in X axis; ΔY: deviations in Y axis; ΔZ: deviations in Z axis; ΔR: rotational (angular) deviations; ΔA: distance deviations

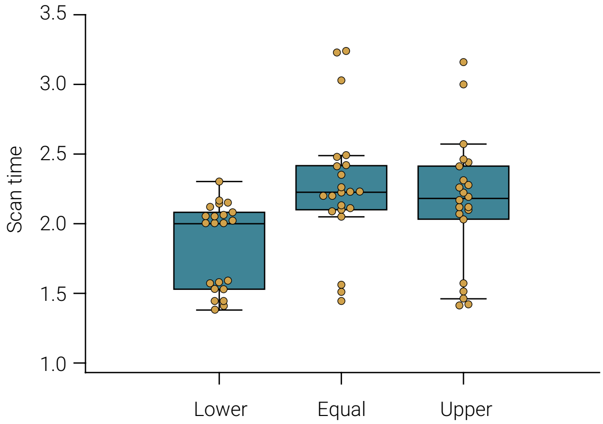

Figure 3. Scanning time (in minute) of the three groups.

Discussion

This in vitro study evaluated the effects of changes in the height of the ISB relative to occlusal plane on the accuracy and scan time of making a digital implant impression using an intraoral scanner. The null hypothesis was that different heights of scan body relative to the occlusal plane would lead to similar results, though the findings rejected the null hypothesis.

Differences between Sin-Lo and Sin-Eq groups were not significant and Sin-Hi group performed more accurately. Nam et al. used ISBs in different exposed height to evaluate reproducibility of digital implant impression (normal, 1.5mm, 3mm, 4.5mm and 6mm submerged)[16]. Normal group and 1.5mm submerged group are respectively equivalent to Equal and Lower height groups in the present study. Findings revealed both trueness and precision decreased by decreasing ISB's exposed height ($p< 0.05$). Except precision in normal and 1.5mm submerged group that were similar. Whenever the exposed length of the ISB was sufficient, a small change in that length did not significantly affect the accuracy[16]. Yilmaz et al. compared healing abutment-scanpeg system with a conventional scanbody on a single implant. The mean distance in the healing abutment-scanpeg (longer scan body) was close to 0.2 μ, while it was close to 0.3 μ in the conventional scanbody. Another study, that evaluated similar subject in single status, reported that as the exposure of the scan body was reduced, the deviations in implant positioning were significantly increased ($P<.001$) and the fit of restorartion will not be ideal[17]. The results of previous studies are consistent with our findings[18]. In contrast to Sin-Lo and Sin-Eq scan bodies, Sin-Hi group yield better results. It may be because of the presence of adjacent teeth and ease of scannable area detection for IOS and the greater surface of the scan body preventing shadow effect on scan area[14]. Cakmak et al. assessed the accuracy of different intraoral scanners in making impression from combined healing abutment-scan body. They inserted a single implant in the first molar position in which the combined healing abutment-scan body was higher than the occlusal plane. Regardless of the intraoral scanners' type, the angular deviations (0.14μm to 0.47μm) were similar to the findings of this study (0.30 to 0.55μm), whereas the distant deviation (14.1 to 47.5μm) was greater compared to the upper scan body in the single position in the present study (0.08 to 0.12μm)[19]. By contrast, Laohverapanich reported scan body located at the level of the occlusal plan in single implant position showed the least linear and angular deviation, following by lower and higher than the occlusal plan scan bodies. May be errors in image stitching process cause deviations in higher scan body[20].

When evaluating ΔR, in single implant position, higher scan body was significantly more accurate compared to Equal (p value <.001) and Lower (p value = 0.03) scan body groups. In Adjacent implant position, higher scan body had significantly most distant deviation compared to Equal (p value <.0001) and Lower (p value <.0001) scan body groups.

Evaluating ΔA revealed that there was significant difference (p value <.0001) among various heights in all positions (except Dis-Lo with Dis-Hi and Dis-Eq). Sin-Hi, Adj-Eq, and Dis-Eq had the least angular deviation in their own groups.

Comparing the different heights of the scan bodies to the occlusal showed that the scan body higher than the occlusal plane, particularly when there were teeth on both sides, was a safer alternative. Nevertheless, scan bodies at the level or lower than occlusal plane recorded their optimal results in adjacent and distant implant positions. Regarding time, we can point out the effect of the required area for the scan on scanning time because the intraoral scanner records the lower scan body surface in a shorter period.

The present in vitro study was performed under standardized conditions; however, the accuracy of digital impressions obtained in the real oral cavity may differ from the results obtained in in vitro studies, since factors such as, the environment the scans were performed, and the presence of saliva or blood, shiny metal restorations, and tongue movement can interfere with the scanning process so as to make data acquisition more difficult. Deeper insights can be gained by conducting additional clinical studies[16,18].

In conclusion, within the limitations of this study, the results showed that scan body height could affect the accuracy of digital implant impression. The scan body higher than the occlusal plane is a safer option when there is an adjacent tooth and has the least scan time.

Conflict of interest

There is no conflict of interest.

Data availability

Datasets related to this article will be available to the corresponding author upon request.

Author Contribution

Pooya Jannati: Concept/design, elaboration of the project, data collection, critical revision of the manuscript and approval of article. **Shima Younespour:** Concept/design, data collection, statistics, critical revision of the manuscript and approval of article. **Marzieh Alikhasi:** Guided all stages of the work and participated in the elaboration of the project and manuscript and funding. We declare that all actively participated in the manuscript's findings, revised and approved the final version of the manuscript.

Abbreviations

Dis: Distant

Adj: Adjacent

Sin: Single

Hi: higher

Lo: lower

Eq: Equal

CAD/CAM: computer-aided design/computer-aided manufacturing

ISB: implant scan bodies

PEEK: polyetheretherketone

STL: standard tessellation language

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