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Does Scan Aid Use Improve the 3D Trueness of Digital Implant Impressions with Different Inter-Implant Distances?

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Abstract

BACKGROUND/AIMS: The aim was to compare the trueness of digital scans with and without the use of scan aids in the case of different inter-implant distances.

MATERIALS AND METHODS: Three mandibular edentulous models with 4 implants were prepared by altering the inter-implant distance between the implants (12, 15, and 18 mm) on the left side. The models were lab-scanned and reference data were acquired. An intraoral scanner (iTero Element 5D Plus) was used to obtain experimental scan data of the models. Twenty digital scans were recorded from each model with or without using scan aids (n=10). The best-fitting alignment strategy (Geomagic Control 3D Systems) was used for the superimposition of the reference scan data onto the experimental scan data. Angular deviation (AD) and linear deviation (LD) were determined, and the data were statistically analyzed.

RESULTS: The inter-implant distance significantly affected both the AD and LD values only in the left posterior implants ($p<0.001$). The use of scan aid significantly improved ADs and LDs in the left anterior, left posterior, and right anterior implants ($p<0.001$). However, no significant effect was noted in the deviation values of right posterior implants ($p=0.26$ and $p=0.18$, respectively). The interaction between scan-aid use and inter-implant distance, was significant for both ADs and LDs, concerning the left posterior implant ($p<0.001$).

CONCLUSION: The use of scan aids significantly enhances the trueness of digital implant impressions, particularly in cases with varying inter-implant distances.

Keywords: All-on-4, auxillary-device, implant-impression, scan-aid, trueness

INTRODUCTION

The advancements in digital dentistry provide a fully digital workflow in implantology (Albanchez-González, 2022). Digital implant impressions have the advantages of shorter chairside time, higher patient comfort, elimination of impression and cast materials, thereby reducing the distortion risk associated with these materials, and enhanced communication with both dental technicians and patients through the use of virtual visualization.[1,2] The accuracy of the intraoral scanners (IOSs) is crucial to obtaining a passive fit between the prosthetic framework and implant components. A lack of passive fit results in manifold biological and mechanical complications, which jeopardize the clinical success of implant-supported restorations.[3] The span length is one of the parameters that influence the accuracy of IOSs.[4] In short-span restorations, the accuracy of intraoral scans was comparable with conventional impressions.[5] However, in the case of a larger span or complete edentulism, a significant decrease in the accuracy

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of digital scans has been reported.[6-9] The absence of stable anatomic reference points on the mucosa between the implants makes the image stitching process of IOS challenging. Therefore, a larger scanning area and longer inter-implant distance lead to accumulated errors during stitching, which culminates in higher inaccuracies in impression.[10,11] Several methods have been proposed to overcome this drawback and provide a continuous scanning path for IOSs, including creating artificial landmarks on the mucosa[12], splinting the scan bodies[13], using scan bodies with extensions[14], and employing prefabricated auxiliary geometric devices (scan aids).[15-17] Although the employment of scan aids has been shown to improve the trueness of IOSs[13,15,17,18], to the best of the authors' knowledge, no consensus exists on a device that does not require complex or additional procedures for fabrication and clinical application, and that offers flexible use regardless of implant position or angulation. The available literature provides limited data on both the relationship between the inter-implant distance and intraoral scan accuracy and the threshold inter-implant distance at which a scan aid becomes necessary. This study aimed to compare the trueness of digital scans with and without the use of scan aids in the case of different inter-implant distances in all-on-4 configuration. The null hypothesis was that neither the inter-implant distance nor the scan aid use would affect the trueness of scans.

MATERIALS AND METHODS

Three mandibular edentulous models were created by pouring a self-polymerizing acrylic resin (Meliodent Rapid Repair; Kulzer GmbH, Hanau, Germany) into a mould (AG-3 Edentulous Rubber Mould; Frasaco GmbH). Four sockets were prepared on the models by a rotary instrument to place multi-unit implant analogues (Nobel Active Multiunit Analog, Ø4.8 mm, Nobel Biocare) according to the all-on-4 configuration. In all models, anterior implants were inserted in the canine region and the right posterior implant was inserted in the second premolar region. The position of the left posterior implant was altered, and distances of 12 mm, 15 mm, and 18 mm were set between the anterior and posterior implants on the left side of the arch in models 1 to 3, respectively (Figure 1). Four PEEK scan bodies (Elos Accurate Scan Body IO 2C-A; Elos Medtech) were attached to the multi-unit implant analogues to facilitate scanning. The models were first lab-scanned (inEOS X5; Dentsply Sirona) to obtain reference scan data. An IOS (iTero Element 5D Plus; Align Technology) was then utilized to capture experimental scan data of the models. A single experienced operator (T.M), conducted the digital scanning procedure of models following the manufacturer's instructions. Scan aids were fabricated by using a fused deposition modelling device (Prusa i3 MK3S, Prusa Research AS) with a filament type of. Scan aids were mechanically attached to the scan bodies. Twenty digital scans were recorded for each model with or without using scan aids (n=10) (Figure 2). A metrology software program (Geomagic Control X, 3D Systems) was used for the 3D analysis of data. The reference and experimental data were superimposed by a single operator to calculate the deviation values. Identical virtual cylinders were created from scan bodies on both reference, and experimental data. The centre lines of these virtual cylinders were measured by recording their x, y, and z coordinates. The angular deviation (AD) and linear deviation (LD) between the centre lines of the reference and experimental cylinders were calculated according to the method outlined in a previous study.[17]

Statistical Analysis

All statistical computations were performed using specialized analytical software (IBM SPSS Statistics, version 23, IBM Corp). The Shapiro-Wilk test was employed to evaluate data normality, confirming a normal distribution ($p>0.05$). Subsequently, a parametric two-way analysis of variance (ANOVA) was performed, complemented by Tukey's honest significant difference test for examining the effects of two variables-inter-implant distance and scan aid usage-on AD and LD values.

RESULTS

Table 1 presents the mean AD and LD values ± standard deviations with pairwise comparisons. According to the 2-way ANOVA results, the inter-implant distance (factor 1) significantly influenced both the AD and LD values in the left posterior site ($p<0.001$); however, no significant differences were detected in other sites ($p>0.05$). The use of a scan aid (factor 2) significantly affected both the AD and LD values in all sites ($p<0.001$), except for the right posterior site ($p=0.26$ for AD and $p=0.18$ for LD). The interaction term between the tested factors was significant for AD and LD values in all sites ($p<0.001$), except for AD values in the right posterior site ($p>0.05$). Not only AD, but also LD values increased progressively from the right posterior site to the left posterior site. The LD values of all groups in all sites were below the acceptability threshold (<100 µm). The AD values of scans with SA were lower than the acceptability threshold (<0.5 degrees). For the scans without SA, only the AD values of the right posterior site were clinically acceptable.

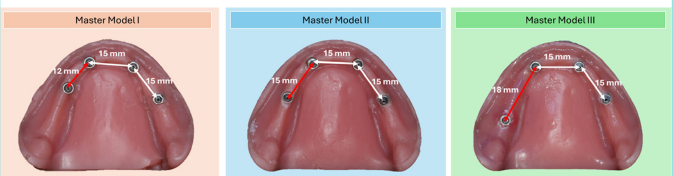

Figure 1. Master models.

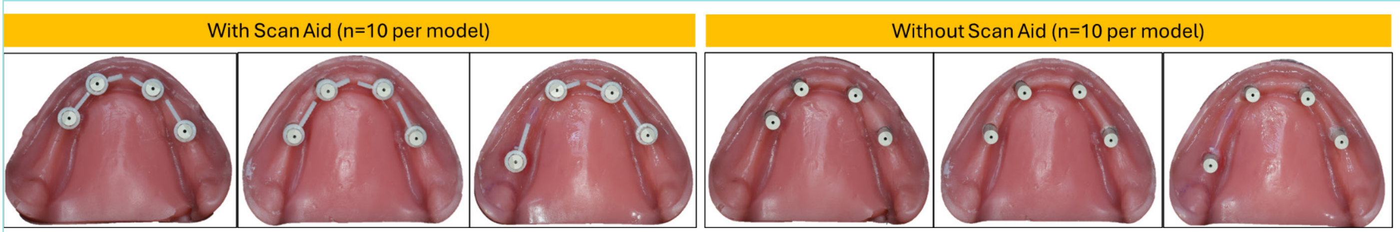

Figure 2. Experimental groups.

Table 1. Mean AD (degrees) and LD (μm) values ± standard deviations with Tukey Post Hoc comparison

Site	Model	Angular deviations			Linear deviations		
		Without SA	With SA	Total	Without SA	With SA	Total
Left posterior	Model 1	0.83±0.07^{A,a}	0.31±0.04^{B,a}	0.57±0.29^{a}	15.33±2.31^{A,a}	5.67±0.58^{B,a}	10.50±5.50^{a}
	Model 2	1.14±0.11^{A,b}	0.37±0.04^{B,ab}	0.76±0.42^{b}	20.00±1.73^{A,b}	6.67±0.58^{B,ab}	13.33±7.39^{b}
	Model 3	1.42±0.07^{A,c}	0.44±0.09^{B,b}	0.85±0.52^{c}	25.67±1.15^{A,c}	8.67±0.58^{B,b}	17.17±9.35^{c}
	Total	1.13±0.27^{A}	0.39±0.77^{B}	0.76±0.42	20.33±4.74^{A}	7.00±1.41^{B}	13.67±7.65
Left anterior	Model 1	0.72±0.06^{A,a}	0.24±0.03^{B,a}	0.48±0.27^{a}	13.67±1.15^{A,a}	4.67±0.58^{B,a}	9.17±5.00^{a}
	Model 2	0.75±0.01^{A,a}	0.28±0.07^{B,a}	0.52±0.24^{a}	13.00±0.00^{A,a}	6.00±1.00^{B,a}	9.50±3.89^{a}
	Model 3	0.76±0.03^{A,a}	0.31±0.03^{B,a}	0.53±0.26^{a}	14.67±1.53^{A,a}	6.33±1.53^{B,a}	10.50±4.76^{a}
	Total	0.74±0.04^{A}	0.28±0.05^{B}	0.51±0.24	13.78±1.20^{A}	5.67±1.22^{B}	9.72±4.34
Right anterior	Model 1	0.61±0.05^{A,a}	0.18±0.03^{B,a}	0.39±0.24^{a}	11.67±1.15^{A,a}	3.33±0.58^{B,a}	7.50±4.64^{a}
	Model 2	0.63±0.02^{A,a}	0.19±0.03^{B,a}	0.41±0.24^{a}	11.00±0.02^{A,a}	4.33±1.15^{B,a}	7.67±3.72^{a}
	Model 3	0.62±0.03^{A,a}	0.21±0.02^{B,a}	0.42±0.23^{a}	10.67±0.58^{A,a}	4.67±1.53^{B,a}	7.67±3.44^{a}
	Total	0.62±0.03^{A}	0.19±0.03^{B}	0.41±0.22	11.11±0.78^{A}	4.11±1.17^{B}	7.61±3.73
Right posterior	Model 1	0.15±0.01^{A,a}	0.13±0.05^{A,a}	0.14±0.03^{a}	4.00±1.00^{A,a}	2.67±0.58^{B,a}	3.33±1.03^{a}
	Model 2	0.17±0.06^{A,a}	0.14±0.04^{A,a}	0.15±0.05^{a}	4.07±0.58^{A,a}	3.33±0.58^{B,a}	4.00±0.89^{a}
	Model 3	0.16±0.01^{A,a}	0.15±0.20^{A,a}	0.16±0.02^{a}	4.60±0.02^{A,a}	4.00±1.00^{B,a}	3.50±0.84^{a}
	Total	0.16±0.03^{A}	0.14±0.03^{A}	0.15±0.03	3.89±0.93^{A}	3.33±0.87^{B}	3.61±0.92

Distinct superscript uppercase letters denote statistically significant differences within the same row, while distinct superscript lowercase letters indicate significant differences within the same column. SA: Scan aid, AD: Angular deviation, LD: Linear deviation.

DISCUSSION

This study aimed to investigate the effect of inter-implant distance and scan-aid use on the 3D trueness of digital implant impressions. The null hypothesis of the study was rejected, since both the scan-aid use and inter-implant distances significantly affected the AD and LD values. The use of IOSs for complete-arch implant impressions is still considered controversial[19] due to limited reference points between scan bodies, which may lead to the misinterpretation of data during the stitching process.[10] In the present study, 3 inter-implant distances were simulated in the left posterior arch, and the scanning process using IOS was initiated from the right posterior implant site. The deviation values increased from the right posterior arch to the left posterior arch; this increase can be attributed to the accumulation of stitching errors, increasing in parallel with the amount of scanned area.[20] A limited number of studies[11,21,22] have evaluated the effect of inter-implant distance on the trueness of digital scans. The findings of the current study were consistent with previous studies, as higher deviation values were observed with the longer inter-implant distances.[11,21,22] Scan aids act as artificial landmarks providing a continuous scan between the implants, and thereby enhancing the trueness of the stitching process.[18] The scan aid used in this study was designed to be practically attached to the scan body and adjustable in length according to varying inter-implant distances. The scan aid had a lateral extension, which was directed towards the edentulous region to increase the reference points between implants. Statistical analysis revealed that when a scan aid was used, significantly lower LD and AD values were found in all models and all implant sites, except for right posterior implants. The starting points of the intraoral scanning have been shown to exhibit lower deviation values in comparison to the most distal implants of the scanned arch.[23] The lower deviation values in the right posterior implant may be attributed to the scan path followed in this study. Although the LD values were below the clinical acceptability threshold (<100 μm), the AD values were detected in the right anterior, left anterior, and left posterior implants of all models were above this threshold (<0.5 degrees)[24] when scan-aids were not used. AD has been reported to impose more stress on implant components than LD.[25] Therefore, the use of scan aids is an effective method to reduce AD in complete arch implant impressions. In addition to being an in vitro study, this research has several other limitations, including the utilization of a single IOS, the use of only one scan aid design, and the evaluation of only the trueness. The findings of the current study suggest that incorporating scan aids into the digital workflow for implant impressions can significantly enhance accuracy, especially in cases with extended inter-implant distances. This improvement may lead to better prosthetic fit, reduced risk of complications, and increased efficiency in clinical practice, making scan aids a valuable addition to digital implantology. Further studies investigating both trueness and precision, comparing different IOSs and scan aid designs in cases of varying inter-implant distances are needed.

CONCLUSION

Within the limitations of this *in vitro* investigation, it can be inferred that incorporating a scan aid may serve as an efficacious approach to enhancing the three-dimensional accuracy of digital implant impressions in fully edentulous arches, particularly when addressing extended inter-implant distances.

Within the limitations of this in vitro study, it can be concluded that the use of a scan aid may be an effective method for improving the 3D trueness of digital implant impressions in complete edentulous arches, especially in longer inter-implant distances.

MAIN POINTS

- Intraoral scanners (IOSs) have significantly improved dental workflows by eliminating traditional impression methods, offering increased patient comfort, and fostering better communication between dental teams and patients.
- The study emphasizes the critical role of artificial landmarks, specifically prefabricated auxiliary devices, in enhancing the precision of digital impressions, especially when natural anatomical landmarks are not available.
- The study seeks to overcome challenges associated with image stitching in extended edentulous areas, aiming to enhance the overall performance and reliability of IOS technology in clinical dental practice.

ETHICS

Ethics Committee Approval: Not available.

Informed Consent: Not available.

Footnotes

Authorship Contributions

Concept: S.K.Y., Design: S.K.Y., Data Collection and/or Processing: T.M., Analysis and/or Interpretation: Ö.Ö., Literature Search: T.M., Writing: T.M., Ö.Ö.

DISCLOSURES

Conflict of Interest: No conflict of interest was declared by the authors.

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