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Auxiliary Scanning Devices Influence On Scanning Bodies' Reliability And Implant Positioned Accuracy For Prosthetic Design

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Dental Implants, Digital Impression, Intraoral Scanner, Full-arch implant

Abstract:

Objectives-The aim of the present *in vitro* study was to evaluate the effect of a novel auxiliary geometric device (AGD) on the accuracy of full-arch scans captured with 3 different intraoral scanners (IOS). **Methods**- Three separate IOS were used to scan an edentulous maxillary model with four interior connecting implantation replicas: iTero Element, Trios 4 (TRIOS), and Carestream 3700. Each IOS was used in 36 scans, 18 of which had the AGD installed and 18 of which did not. An industrial optical scanner was used to build a digital master model. The scanning regions were used as a benchmark area to align the master and IOS models. To assess the linear and angular deviation, an area comparisons was carried out and deviation labels were exported for every scan body. Angular deviations, the platform, and the entire body were recorded. **Results**- The angular deviation increased statistically significantly when AGD was used: 0.87° (SD=0.21) in the AGD group compared to 0.64° (SD=0.46) in the no AGD group (p-value=0.005). Total body and platform deviation values did not differ statistically significantly among AGD and no AGD groups (p-value=0.051 and 0.302, respectively). For another IOS, no statistically significant variations were discovered. **Conclusions**-TRIOS and CS was not helped from the usage of AGD.

Introduction

Restoring lost teeth can be accomplished using full-arch implant-anchored restorations. Nevertheless, minor bone loss and more technical problems may result from a misfit at the implant-prosthesis connection brought on by subpar impressions or other mistakes in the clinician or mechanical workflow.[1] Improved comfort for patients and precise implant location registration employing scan bodies while intraoral scanning are two benefits of digital imaging.[3] Intraoral scans have demonstrated similar accuracy to traditional imprints whether it comes to single-unit restoration or three-unit fixed dental prostheses.[2]Nevertheless, a decline in accuracy has been noted in implant full-arch rehabilitations, which could have an impact on the restoration's passive fit.[4] It's crucial to remember that, as Revell et al.[5] have shown, the accuracy evaluation approach can have a big influence on the outcomes. When total surface orientation was utilised on the implant structure rather than scan body alignment, their investigation revealed noticeably larger deviation values. The last degree of precision might be influenced by a number of factors.[5]

The current in vitro research's objective was to assess IOS accuracy both with and without AGD. Comparing the impact of AGD on trueness across various iOS was the secondary goal. Thus, the primary the null hypothesis that was investigated

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was that accuracy would remain the same regardless of whether AGD was used or not. There would be no variations in accuracy amongst various IOS with or without AGD, according to the alternative null hypothesis.

Methodology

According to earlier research, gypsum was used to create an edentulous maxillary prototype. The scan bodies were fitted into the implant head of the four internal link implants that were replicated in the model at the lateral incisor and first molar locations. The angulation of the implants in sites 1.2 and 2.2 was 15° towards the buccal aspect. The implant head was at the gypsum level, and the implant depth was fixed at 0 mm (Fig. 1). The distances between implants at sites 1.6 and 1.2 were 18.61 mm, those between sites 1.2 and 2.2 were 19.95 mm, and those between sites 2.2 and 2.6 were 22.22 mm.

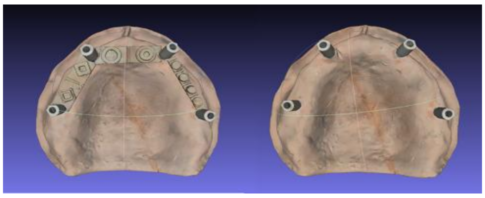

Figure 1- Scan of the master model with and without the AGD.

Digital representations were created using 36 scans of each IOS (TRIOS, CS, ITERO), 18 scans with an AGD and a dedicated design, and 18 scans without the AGD (Fig. 1). Polymethylmethacrylate discs were used to grind the AGD, which was manufactured by Sweden & Martina. For the purpose to improve stitching procedures and lower algorithm errors, a geometrical texture was created on top of the AGD utilising square and circle shapes of varying widths (6 and 3 mm). A smooth AGD was trimmed away from the mucosa in accordance with the inter-implant spacing, and the AGD was fixed to the base of the scan bodies using cyanoacrylate adhesive. These shapes were made to be as straightforward to scan as feasible, with simple shapes and substantially distinct from one another when needed to enhance the combining procedure shortly after a standard intraoral images acquisition.

An commercial optical structured light scanner with precision of 1.7 µm and a level of accuracy of 3 µm was used to build a digital master image.

To match the scan bodies libraries with the mesh dataset employing a best fit algorithm, each trial scan was loaded as standard tessellation languages files (.stl) into specialised software. For the final surface assessment, the aligned scan bodies from the library were exported as.stl files to inspection software (GOM Inspect Professional, GOM GmbH, Braunschweig, Germany). Employing the pre-alignment tool, each experimental scan was carefully aligned with the master scan, which was chosen as the CAD geometry. A "surface comparison on actual elements" was carried out using the "CAD comparison" tool. The 3D deviation between the aligned scan bodies was calculated by using the RMS error for trueness evaluation (total body RMS). In addition, a fitting cylinder was aligned on the cylindrical lower part of each scan body and the centre of the base (centroid) and the axis were determined. Angular deviation was calculated as the angle between the axes of the two cylinders. Platform deviation (PD) was calculated as the Euclidean distance from the corresponding centroid

A priori sample size calculation was performed using SPSS Software. A priori sample size was calculated taking into account the root mean square (RMS) trueness difference based on the use of AGD vs no AGD on the whole scan body. Power analysis revealed that 16 scans in each group would have provided a power of 80% to detect a significant difference, with an alpha error set at 0.05, based on results coming from a previously published study. The normality test was used to investigate the normal distribution of the platform deviation and the total body RMS values as well as of the angular deviation (Shapiro-Wilk p-value<0.001). ANOVA was used despite of the non-normal distribution as it has been shown to be quite robust to violations of normality and to provide reliable results.

Results

When comparing the use of AGD with the no AGD group (Table 1), a statistically significant difference was found in the mean total angular deviation, regardless of IOS type (Mann-Whitney p-value=0.005). In general, the addition of AGD led to an increase in this outcome, resulting in 0.87° (SD=0.21) versus 0.64° (SD=0.46). This comparison was not statistically significant when considering both mean total body RMS and platform deviation values (p-value=0.051 and 0.302 respectively).

Table 1. Mean deviations for each scan body and total mean values. * statistically significant.

Empty Cell		Sample size	Mean	Standard deviation	Standard error of the mean	p-value
A dev2.6 (°)	NO	54	0.61	0.27	0.04	0.097
	YES	54	0.99	0.79	0.11	
A dev2.2 (°)	NO	54	0.80	0.57	0.08	0.135
	YES	54	1.15	1.06	0.14	
A dev1.2 (°)	NO	54	0.65	0.41	0.06	0.116
	YES	54	0.84	0.67	0.09	
A dev1.6 (°)	NO	54	0.52	0.31	0.04	0.623
	YES	54	0.52	0.22	0.03	
Platform dev 2.6 (µm)	NO	54	86.85	42.24	5.75	0.081
	YES	54	105.93	53.47	7.28	
Platform dev 2.2 (µm)	NO	54	105.19	82.57	11.24	0.948
	YES	54	95.93	48.55	6.61	
Platform dev 1.2 (µm)	NO	54	177.41	103.29	14.06	0.051
	YES	54	134.44	72.49	9.87	
Platform dev 1.6 (µm)	NO	54	123.70	76.39	10.40	0.046*
	YES	54	90.00	52.16	7.10	
Body RMS 2.6 (µm)	NO	54	45.91	40.87	5.56	<0.001*
	YES	54	59.00	23.68	3.22	
Body RMS 2.2 (µm)	NO	54	48.39	27.44	3.73	0.433
	YES	54	53.15	30.54	4.16	
Body RMS 1.2 (µm)	NO	54	48.52	31.06	4.23	0.499
	YES	54	52.11	33.63	4.58	
Body RMS 1.6 (µm)	NO	54	60.30	51.25	6.97	0.319
	YES	54	45.93	24.18	3.29	

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Total Body RMS (µm)	NO	54	50.78	26.95	3.67	0.051
	YES	54	52.55	15.00	2.04	
Total Platform dev (µm)	NO	54	123.29	56.29	7.66	0.302
	YES	54	106.57	38.33	5.22	
Total Angular dev (°)	NO	54	0.64	0.21	0.03	0.005*
	YES	54	0.87	0.46	0.06	

Table 2- Table 2. Mean deviations for each scan body and total mean values. * Statistically significant

Empty Cell	**ITERO**			**TRIOS**			**CS**			**Empty Cell**	
Empty Cell	**Sample size**	**Mean**	**Standard deviation**	**Standard error of the mean**	**Mean**	**Standard deviation**	**Standard error of the mean**	**Mean**	**Standard deviation**	**Standard error of the mean**	p-value
A dev2.6 (°)	36	1.016	0.852	0.142	0.81	0.537	0.089	0.567	0.241	0.040	0.051
A dev2.2 (°)	36	0.962	1.175	0.196	0.80	0.737	0.123	1.16	0.538	0.090	0.001
A dev1.2 (°)	36	0.814	0.689	0.115	0.85	0.477	0.079	0.566	0.454	0.076	0.006
A dev1.6 (°)	36	0.400	0.257	0.043	0.49	0.250	0.043	0.667	0.235	0.039	<0.001
Platform dev 2.6 (µm)	36	83.6	19.4	3.24	96.4	41.7	7	109	69.5	11.6	0.243
Platform dev 2.2 (µm)	36	95	98.8	16.5	91.7	36.9	6.15	115	49.9	8.31	<0.001
Platform dev 1.2 (µm)	36	160	134	22.3	120	51.7	8.62	188	50.4	8.40	<0.001
Platform dev 1.6 (µm)	36	124	83	13.8	103	60	10.0	93.0	53.2	8.86	0.399

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Body RMS 2.6 (µm)	36	48.1	26.2	4.36	45.9	22.9	3.82	63.3	46	7.66	0.288
Body RMS 2.2 (µm)	36	43.1	33.4	5.56	40.5	16.7	2.78	68.7	26.0	4.33	<0.001
Body RMS 1.2 (µm)	36	47.5	38.3	6.38	44.8	28.2	4.70	58.6	28.5	4.75	0.047
Body RMS 1.6 (µm)	36	57.2	50.2	8.37	42.7	25.1	4.18	59.4	41.3	6.88	0.133
Total Body RMS (µm)	36	49	23.7	3.95	43.5	13.6	2.25	62.5	22.4	3.73	<0.001
Total Platform dev (µm)	36	116	70.1	11.7	103	27.9	4.66	126	35.4	5.90	0.011
Total Angular Dev (°)	36	0.798	0.538	0.090	0.740	0.33	0.056	0.740	0.146	0.024	0,321

A two-way ANOVA was performed to examine the effect of the presence of AGD for each scanner on the mean values of both total body RMS and platform deviation and total angular deviation. There was a statistically significant interaction between the presence of AGD and scanner typology on the mean total body RMS value, two-way ANOVA p-value=0.026.

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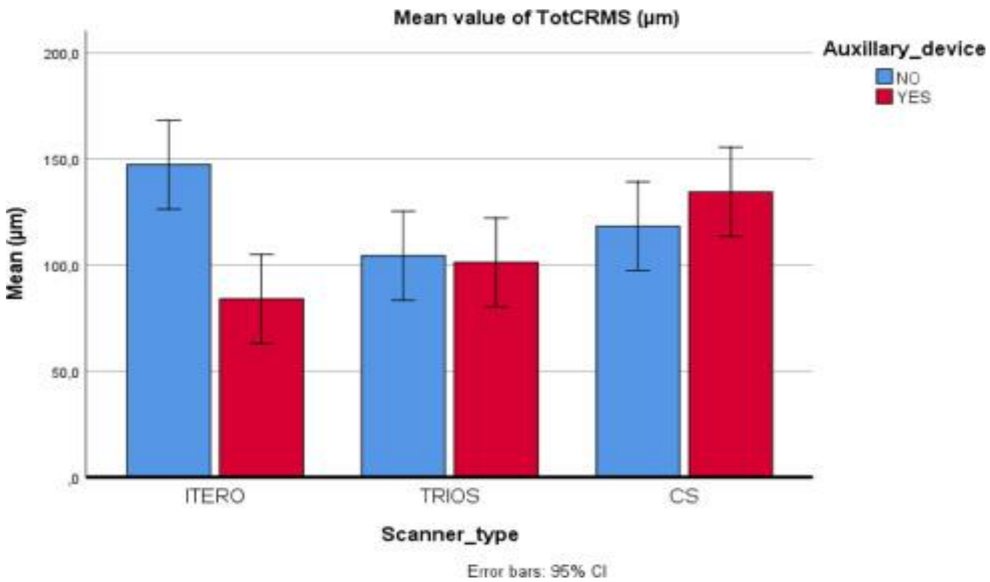

Figure 2- Graphical representation of differences among IOS with or without AGD – platform deviation (µm).

Discussion

The aim of this study was to evaluate the accuracy of full-arch intraoral scans using different IOS with and without an auxiliary geometric device (AGD). Angular deviation is a critical variable, since angular misalignment can exert more stress on implant devices than linear misalignment.[6] New algorithms and hardware for intraoral scanning procedures have shown that it is possible to obtain full-arch digital impressions of edentulous jaws *in vitro* with acceptable clinical accuracy. However, the passive fit of a prosthodontic framework still needs to be evaluated to assess implant tolerance. In the present study, AGDs were found to influence scanner performance with a worsening of the angular deviation. These findings should be confirmed by *in vivo* studies, considering the various factors that can affect accuracy during clinical procedures[6], such as light reflection of the mucosa, the presence of saliva, steam, the number and tridimensional position of the scan bodies, a discrepancy between the fit of scan body with implant replica and the implant fixture.[7] The results of the present investigation are in contrast with previously published research. Kim et al. scanned with three different IOS a mandibular model with 4 prepared teeth and an edentulous space of 26 mm where an artificial alumina landmark was created.[8] Their results showed an improvement in both accuracy and precision when the landmark was used. Similar results were obtained by Iturrate et al. who used three IOS to scan an edentulous model with four scan bodies screwed on.[9] They used an AGD simulating a denture prototyped on a 3D printing machine and found a statistically significant improvement in both trueness and precision when the AGD was used. Rutkunas et al. analyzed the effect of artificial landmarks in an edentulous model rehabilitated with four implants and reported that artificial landmarks had no statistically significant effect on trueness and precision, although there was an improvement in accuracy.[10]

Conclusions

The use of AGD did not add benefit on CS and TRIOS. On ITERO, there was an improvement in platform deviation, that was outweighed by the worsening of the angular deviation.

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