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Comparative Evaluation of TRIOS 5, Primescan, and Medit i900 Intraoral Scanners for Full-Arch Implant-Supported Prostheses: An in Vitro Study

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Abstract **Background:** Accurate digital recording of implant positions is essential for the fabrication of full-arch implant-supported prostheses. The accuracy of intraoral scanners may vary because of differences in image acquisition and data-processing technologies. **Objective:** To compare the trueness and precision of three intraoral scanners for full-arch implant-supported prostheses and evaluate their linear and angular deviations. **Methods:** A completely edentulous maxillary model containing six implant analogs was scanned using three intraoral scanners: TRIOS 5 (3Shape, Denmark), Primescan (Dentsply Sirona, Germany), and Medit i900 (Medit, Republic of Korea). Ten repeated full-arch scans were obtained with each scanner, resulting in 30 experimental datasets. A laboratory reference scan was used for three-dimensional comparison. Trueness and precision were evaluated using root mean square (RMS) deviations, while implant positional accuracy was assessed through linear and angular deviations. Statistical comparisons were performed using one-way analysis of variance or the Kruskal–Wallis test, as appropriate, with post-hoc pairwise comparisons adjusted for multiple testing. Statistical significance was set at $P<0.05$. Linear and angular deviations were measured at the six implant positions, and the mean deviation across the six positions was calculated for each scan. These scan-level values were used for comparisons among scanner systems. **Results:** Mean trueness deviations were 42.6±7.8 µm for TRIOS 5, 58.4±10.1 µm for Primescan, and 76.9±13.5 µm for Medit i900. Corresponding precision deviations were 31.8±6.4 µm, 44.7±8.6 µm, and 61.2±11.3 µm, respectively. Mean linear deviations were 54.3±11.2 µm, 72.8±14.6 µm, and 96.5±18.7 µm, while angular deviations were 0.31±0.10°, 0.48±0.16°, and 0.71±0.22°, respectively. The manuscript reports overall differences among the scanner groups for all four outcomes ($p< 0.001$). **Conclusion:** Under the standardized laboratory conditions of this in vitro study, TRIOS 5 demonstrated the lowest mean trueness, precision, linear, and angular deviations, followed by Primescan and Medit i900. These findings indicate differences in the measured accuracy of the three scanner systems within the experimental model. Further clinical investigations are required to determine whether these differences influence prosthesis fit and clinical outcomes.

Key Words Digital Impression, Dental Implants, Full-Arch Prosthesis, Intraoral Scanner, Precision, Trueness

INTRODUCTION

Digital technologies have substantially changed contemporary implant prosthodontics. Computer-aided design and computer-aided manufacturing, three-dimensional imaging, intraoral scanning, and digital laboratory workflows have progressively replaced several conventional clinical and laboratory procedures. Among these developments, intraoral scanners (IOSs) have become an important method for acquiring digital impressions. They allow direct recording of the oral structures and implant positions without the need for conventional impression materials and trays. The resulting digital datasets can be incorporated directly into computer-aided prosthetic workflows, potentially reducing the number of intermediate procedures and improving communication between the clinician and dental laboratory [1,2].

The accuracy of an implant impression is particularly important because the definitive prosthesis must reproduce the three-dimensional positions and orientations of multiple implants with sufficient accuracy. The accuracy of an implant

impression is an important consideration in implant prosthodontics because the definitive prosthesis must reproduce the three-dimensional positions and orientations of multiple implants. Inaccuracies introduced during impression acquisition may contribute to discrepancies in the digital representation of implant positions and could potentially affect subsequent prosthetic fabrication. This consideration is particularly relevant for screw-retained, full-arch implant-supported prostheses, where accurate transfer of multiple implant positions is desirable for achieving appropriate framework adaptation [2,3]. However, the relationship between digital impression accuracy and definitive prosthesis fit depends on several additional clinical and laboratory factors. The present investigation focused exclusively on the dimensional accuracy of digital impressions and did not evaluate framework fit or patient-related outcomes. [2,3]. Although conventional implant impression techniques have been used successfully for many years, digital implant impressions have attracted increasing interest because of their simplified workflow and ability to transfer implant positions directly to a virtual environment [3,4].

The accuracy of a digital impression is generally described in terms of trueness and precision. Trueness indicates the closeness of a measurement to the accepted reference value, whereas precision represents the degree of agreement among repeated measurements obtained under specified conditions. Consequently, a scanner may demonstrate high repeatability while still showing a systematic deviation from the reference geometry. Both components should therefore be evaluated when comparing intraoral scanning systems for implant applications [5].

Digital implant impressions are obtained by attaching scan bodies to the implants or implant abutments and recording their surfaces using an IOS. The corresponding scan-body geometries are subsequently recognized or aligned with their library files within the digital workflow. The accuracy of the final virtual implant position therefore depends not only on the scanner but also on several interconnected factors. These include the scanning technology, acquisition strategy, scan-body geometry and material, implant depth and angulation, interimplant distance, operator experience, scanning environment, and the algorithms used for image acquisition and dataset reconstruction [2,4,6].

Full-arch implant scanning presents a greater technical challenge than short-span scanning. Intraoral scanners generally acquire multiple sequential images or three-dimensional frames rather than capturing the complete dental arch in a single acquisition. These individual acquisitions must be progressively aligned or “stitched” by the scanner software to generate a complete three-dimensional model. Small registration discrepancies arising during this process can accumulate as scanning progresses across the arch. Consequently, distortion may become more pronounced as the scanned distance increases, particularly in completely edentulous arches where the mucosal surface provides fewer distinct anatomical landmarks for image registration [4,5].

The presence of multiple implant scan bodies introduces additional difficulties. Implant scan bodies often contain relatively uniform geometric surfaces and are separated by areas of edentulous ridge with limited identifiable morphology. Increasing distances between scan bodies may reduce the amount of common geometric information available for sequential image matching. Implant angulation, scan-body visibility, surface characteristics, and the distribution of scan bodies throughout the arch may further affect the accuracy of the reconstructed digital impression [3,6].

Considerable technological development has occurred among commercially available intraoral scanners. Contemporary devices differ in their optical acquisition principles, hardware configuration, scanning speed, field of view, software architecture, and reconstruction algorithms. These differences can influence their performance when recording large or complex anatomical areas. Mangano *et al.* compared 12 IOS systems for full-arch implant impressions and demonstrated significant differences in trueness among the scanners evaluated, indicating that the accuracy of one scanner system should not necessarily be generalized to all IOS technologies [5]. Their findings also demonstrated the importance of assessing individual scanner systems under standardized experimental conditions.

Evidence from broader analyses supports this scanner-dependent variability. Vitai *et al.* conducted a systematic review and network meta-analysis evaluating complete-arch scanning accuracy across different clinical configurations. Fifty-three studies were included, and 26 intraoral scanners were represented in the network analyses. Significant differences in accuracy were identified among IOS systems, while scanner performance also varied according to the clinical configuration of the arch [7]. These findings suggest that complete-arch accuracy depends on an interaction between scanner technology and the anatomical or prosthetic situation being recorded.

The comparison between digital and conventional full-arch implant impressions has also produced heterogeneous findings. Revilla-León *et al.* compared conventional, photogrammetric, and intraoral scanning techniques for complete-arch implant impressions using coordinate-measuring-machine analysis. Differences were identified among the impression methods, emphasizing the influence of the acquisition technique on the three-dimensional reproduction of implant positions [3]. Similarly, systematic evaluations of the available literature have demonstrated substantial methodological heterogeneity among studies, including differences in reference scanners, implant numbers and distributions, scan bodies, scanning protocols, superimposition procedures, and accuracy metrics [8].

A recent systematic review and meta-analysis by Cai *et al.* evaluated intraoral scanning and conventional implant impressions for completely edentulous patients. Forty-nine studies, including eight clinical and 41 in vitro investigations, were included. The analysis demonstrated that the relative performance of digital and conventional

impressions was influenced by factors such as implant configuration and the measurement methodology used. The authors also reported variation in accuracy among different IOS brands and emphasized the need for further clinical evidence [9].

These findings are clinically relevant because the successful application of a digital full-arch implant workflow depends on the reliability of the initial digital impression. Improvements in IOS hardware and software have been rapid, and conclusions derived from earlier generations of scanners may not accurately represent the performance of newer systems. Moreover, evidence obtained for single crowns, short-span prostheses, or dentate complete-arch scanning cannot be directly extrapolated to completely edentulous full-arch implant situations because the scanning conditions and sources of error differ considerably.

Recent investigations have therefore focused increasingly on methods for improving complete-arch implant scanning. Modifications in scan-body design, orientation, scanning strategy, and splinting procedures have been investigated to reduce cumulative registration errors. Studies evaluating different scanning approaches have shown that the technique used to capture implant positions can interact with the IOS system and influence complete-arch accuracy [10]. This reinforces the need to evaluate scanners under a standardized protocol when their relative performance is being compared.

Although several investigations have evaluated the accuracy of intraoral scanners for complete-arch implant impressions, considerable methodological variation remains among published studies. Differences in implant distribution, scan-body configuration, scanning strategies, reference measurement systems, and accuracy assessment methods limit direct comparisons between scanner systems. Furthermore, findings obtained using earlier scanner generations may not adequately represent the performance of recently introduced devices. A controlled comparison of contemporary intraoral scanners using an identical full-arch implant model and standardized acquisition protocol may therefore provide additional evidence regarding scanner-dependent differences in accuracy.

TRIOS 5 (3Shape), Primescan (Dentsply Sirona), and Medit i900 (Medit) were selected for comparison as contemporary intraoral scanning systems used in digital prosthodontic workflows. These systems incorporate manufacturer-specific hardware, optical acquisition technologies, and software-based reconstruction processes that may influence complete-arch scanning accuracy. Evaluating these scanners under standardized experimental conditions permits comparison of their relative performance while reducing variation associated with the implant model, scan-body configuration, and scanning protocol.

The present in vitro study aimed to compare the accuracy of TRIOS 5, Primescan, and Medit i900 for recording implant positions in a completely edentulous maxillary model containing six implant analogs. The primary outcomes were trueness and precision, assessed using root mean square deviations. Secondary outcomes included three-dimensional linear and angular deviations. The null hypothesis was that no statistically significant differences would exist among the three intraoral scanners for the evaluated accuracy parameters. Differences in acquisition technology and data-processing algorithms may produce measurable variations in trueness and precision, particularly when scanning multiple implants distributed across a complete arch. Direct comparative evaluation under controlled conditions is therefore necessary to determine the magnitude and pattern of these differences.

Although several investigations have evaluated the accuracy of intraoral scanners for complete-arch implant impressions, considerable methodological variation remains among published studies. Differences in implant distribution, scan-body configuration, scanning strategies, reference measurement systems, and accuracy assessment methods limit direct comparisons between scanner systems. Furthermore, findings obtained using earlier scanner generations may not adequately represent the performance of recently introduced devices. A controlled comparison of TRIOS 5, Primescan, and Medit i900 using an identical full-arch implant model and standardized acquisition protocol may therefore provide additional evidence regarding scanner-dependent differences in trueness, precision, and implant positional accuracy.

TRIOS 5 (3Shape), Primescan (Dentsply Sirona), and Medit i900 (Medit) were selected for comparison as contemporary intraoral scanning systems used in digital prosthodontic workflows. These systems incorporate manufacturer-specific hardware, optical acquisition technologies, and software-based reconstruction processes that may influence the accuracy of complete-arch digital impressions. Evaluating the three scanners under the same experimental conditions permits assessment of their relative performance while minimizing variation associated with implant distribution, scan-body configuration, and scanning pathway. The comparison was intended to characterize the accuracy of the tested scanner configurations rather than establish the overall superiority of any commercial system.

The present in vitro study aimed to compare the accuracy of three intraoral scanners, TRIOS 5, Primescan, and Medit i900, for recording implant positions in a completely edentulous maxillary model containing six implant analogs. The primary objectives were to evaluate and compare the trueness and precision of the digital impressions using root mean square (RMS) deviations. The secondary objectives were to assess and compare three-dimensional linear and angular deviations of the implant positions among the three scanner systems.

The null hypothesis was that no statistically significant differences would exist among TRIOS 5, Primescan, and Medit i900 in each of the four evaluated outcomes: trueness, precision, linear deviation, and angular deviation. Each outcome was considered separately when testing the null hypothesis.

METHODS

Study Design

An in vitro comparative study was conducted to evaluate the accuracy of three intraoral scanners for recording the three-dimensional positions of implants in a completely edentulous full-arch model. The primary outcomes were trueness and precision of the digital datasets generated by each scanner. All experimental procedures were performed under standardized laboratory conditions to minimize variations related to environmental factors, operator technique, and specimen positioning.

The methodology was designed according to established approaches used for evaluating the accuracy of digital implant impressions. Accuracy was considered in terms of trueness and precision. Trueness represented the closeness of each experimental scan to the reference dataset, whereas precision represented the reproducibility among repeated scans obtained using the same intraoral scanner.

Reference Full-Arch Implant Model

A completely edentulous maxillary reference model fabricated from (specify material) (manufacturer: (name), country: (country)) was used for the experimental evaluation. The model contained six implant analogs ((manufacturer), (implant system), (model/reference number)) with a diameter of (value) mm and a length of (value) mm. The implant analogs were distributed bilaterally across the maxillary arch at (specify six anatomical positions) to simulate a full-arch implant-supported prosthetic configuration.

The angulation of each implant analog relative to the predefined reference axis was (specify values) degrees. The interimplant distances were (specify measurements) mm, measured between the corresponding implant reference points. All implant analogs were rigidly embedded in the model to maintain positional stability throughout the experimental procedures. The same reference model and implant configuration were used for all three intraoral scanner groups.

Six implant scan bodies ((manufacturer), (model/reference number), (country)) were attached to the corresponding implant analogs according to the manufacturer's recommended protocol. The scan bodies were fabricated from (material) and had a (specify geometry) configuration, with a height of (value) mm and diameter of (value) mm. The corresponding digital scan-body library ((software/library name and version)) was used for implant-position identification during three-dimensional analysis, where applicable. Each scan body was inspected before scanning to verify complete seating and the absence of visible surface damage. The same scan-body configuration was maintained throughout the experimental procedures.

The model was secured on a stable platform during scanning. Its position was standardized to minimize differences in orientation between repeated scans. No modification of implant positions or scan-body orientation was performed after acquisition of the reference dataset.

Reference Dataset Acquisition

The reference dataset was acquired using a laboratory scanner ((manufacturer), (model), (country)) with a manufacturer-reported accuracy of (value) μm under (specify measurement conditions). The scanner was operated using (software name and version). Before reference data acquisition, calibration was performed according to the manufacturer's recommended procedure using (specify calibration method or equipment). A total of (number) reference acquisitions were obtained from the edentulous maxillary model with all six implant scan bodies attached. The acquired datasets were inspected for incomplete surface capture, scanning artifacts, and irregularities before selection of the final reference dataset.

Following acquisition, the reference datasets were evaluated for completeness of the model surface, visibility of all six scan bodies, and the presence of surface artifacts or reconstruction irregularities. The final reference dataset was selected using [specify actual selection procedure and acceptance criteria]. The selected dataset was exported in Standard Tessellation Language (STL) format and used as the reference for subsequent three-dimensional comparisons. Peripheral regions not required for the analysis were excluded according to the predefined processing protocol. The reference dataset was not modified after its acquisition, except for removal of irrelevant peripheral areas that were not required for three-dimensional comparison.

Intraoral Scanning

Three commercially available intraoral scanners were evaluated: TRIOS 5 (3Shape A/S, Copenhagen, Denmark), Primescan (Dentsply Sirona, Bensheim, Germany), and Medit i900 (Medit Corp., Seoul, Republic of Korea). These systems were designated as Scanners A, B, and C, respectively. The software versions used were (version) for TRIOS 5, (version) for Primescan, and (version) for Medit i900. Scanning was performed using (specify acquisition mode and relevant settings for each system). Scanner tips were prepared according to the respective manufacturer's instructions, and calibration or system-readiness checks were performed as applicable to each device.

Ten full-arch scans were obtained with each scanner, resulting in 30 experimental datasets. The same trained operator performed all scanning procedures. A standardized scanning pathway was followed, beginning in the posterior region of one side of the arch, progressing toward the anterior region, and continuing to the contralateral posterior region. The completed datasets were exported in STL format for three-dimensional analysis.

All scanning procedures were performed by a single operator with (specify professional qualification and experience) and prior experience of (specify duration or number of procedures) with the evaluated intraoral scanning systems. The use of a single operator was intended to minimize interoperator variability during data acquisition.

Standardization of Scanning Conditions

To minimize operator fatigue and systematic variation in scanning technique, data acquisition was performed in separate scanning sessions. The sequence of scanner use was

(specify actual scanner order or randomization procedure). Repeated acquisitions were performed according to (specify repetition sequence). Environmental conditions, model positioning, and scanning pathways were standardized across the three scanner groups. The potential influence of scanner order and operator familiarity was considered when interpreting the results.

Each repeated scan was obtained as a separate acquisition using the corresponding intraoral scanner. Between successive acquisitions, (specify whether the scanning session was restarted, the model was repositioned, and the scan bodies were removed and reseated). The scan bodies remained attached to the implant analogs between acquisitions unless inspection was required. The reference model and scanning environment were maintained under standardized conditions throughout the experiment. Accordingly, the repeated acquisitions represented measurements obtained under controlled repeatability conditions rather than independently prepared implant-model configurations.

Three-Dimensional Data Processing

The STL datasets obtained from the three intraoral scanners were imported into Geomagic Control X three-dimensional inspection software (3D Systems, Rock Hill, SC, USA; version (specify version)). Each experimental dataset was compared with the reference dataset using a standardized three-dimensional alignment procedure.

Initial alignment was performed using (specify anatomical or scan-body reference regions). This was followed by best-fit alignment using (specify the exact regions included in the final alignment). The implant scan-body surfaces were (included/excluded) during final best-fit alignment. Regions excluded from the analysis comprised (specify excluded surfaces). The alignment algorithm, iteration settings, convergence criteria, and deviation calculation parameters were maintained consistently across all datasets.

Following alignment, root mean square (RMS) surface deviations were calculated using the predefined region of interest. Three-dimensional color-coded deviation maps were generated using (specify scale and tolerance limits) to evaluate the spatial distribution of discrepancies. Identical analysis parameters were applied to all three scanner groups.

Assessment of Trueness

Trueness was evaluated by comparing each experimental intraoral scan with the laboratory reference dataset following three-dimensional superimposition. Root mean square (RMS) deviation was calculated over (specify the exact surface or region of interest used for measurement). The same region of interest and analysis parameters were applied to all experimental datasets to maintain consistency between scanner groups.

The RMS deviation was calculated from the differences between corresponding surface points in the experimental and reference datasets. Lower RMS values indicated smaller deviations from the reference geometry and therefore greater trueness. For each scanner, the mean RMS deviation and standard deviation were calculated from the 10 repeated acquisitions.

Assessment of Precision

Precision was evaluated by assessing the agreement among repeated digital impressions obtained using the same intraoral scanner. The 10 scans acquired with each scanner were compared pairwise using the standardized three-dimensional alignment procedure. This generated 45 unique pairwise comparisons per scanner group.

For each comparison, RMS surface deviation was calculated using the predefined region of interest. Lower RMS deviations represented greater agreement between repeated acquisitions and therefore higher scanning precision. The pairwise RMS measurements were summarized descriptively for each scanner system.

Because individual scans contributed to multiple pairwise comparisons, the resulting 45 measurements were not considered statistically independent.

Linear and Angular Deviation

Three-dimensional implant positional accuracy was evaluated by measuring linear and angular deviations between the experimental intraoral scans and the reference dataset. The measurements were performed using the six implant scan bodies positioned across the edentulous maxillary arch.

For each implant position, a corresponding reference point was identified in the reference and experimental datasets using (specify anatomical or geometric landmark). The three-dimensional coordinate system was defined using (specify coordinate-system origin and orientation). The x-, y-, and z-axis coordinates of the corresponding reference points were recorded to determine positional discrepancies.

Angular deviation was assessed by comparing the longitudinal axis of each scan body in the experimental dataset with its corresponding axis in the reference dataset. The scan-body axes were established using (specify axis-identification method). Measurements were obtained at (confirm number) implant positions per scan, and the resulting values were aggregated using (specify actual aggregation method) for subsequent statistical analysis.

Three-dimensional linear deviation was calculated as the Euclidean distance between corresponding reference and experimental implant positions. The differences along the x-, y-, and z-axes were combined to obtain the resultant spatial displacement for each implant position. Linear deviations were expressed in micrometres (μm), with lower values indicating greater positional agreement with the reference dataset.

Outcome Measures

The primary outcome measures were:

- Three-dimensional trueness expressed as RMS deviation from the reference dataset

- Precision expressed as RMS deviation among repeated scans obtained with the same scanner
- Secondary outcomes included three-dimensional linear deviation, angular deviation, and the spatial distribution of scanning discrepancies across the complete arch

For all accuracy parameters, smaller deviation values represented better scanning accuracy.

Sample Size

The number of repeated scans was determined pragmatically with reference to the experimental designs of previous in vitro investigations evaluating complete-arch digital implant impression accuracy. Ten full-arch scans were obtained using each of the three intraoral scanners, resulting in 30 experimental datasets. No formal a priori power calculation was documented for the present investigation. Therefore, the sample size was considered exploratory, and the findings were interpreted with consideration of the limited number of repeated measurements per scanner.

Statistical Analysis

Statistical analysis was performed using a standard statistical software package, spss ver 21.0. Continuous variables were summarized as mean, standard deviation, median, interquartile range, minimum, and maximum, as appropriate.

The individual full-arch scan was considered the unit of analysis for trueness and the scan-level linear and angular outcomes. Trueness was represented by one RMS deviation value for each experimental scan. Linear and angular deviations were measured at the six implant positions, and the arithmetic mean of the six measurements was calculated to obtain one summary value per scan. Accordingly, 10 scan-level observations were available for each scanner group for these outcomes. The precision analysis was conducted separately because the pairwise comparisons between repeated scans were statistically dependent.

The distribution of quantitative variables was assessed using the Shapiro–Wilk test and visual inspection of the data. Homogeneity of variances among scanner groups was evaluated using (specify whether Levene's test or another method was performed). For outcomes satisfying the relevant assumptions, differences among the three scanner groups were evaluated using one-way analysis of variance (ANOVA), followed by (specify actual post-hoc procedure). When the assumptions for conventional ANOVA were not satisfied, (specify the alternative statistical test used) was applied. All statistical procedures were selected according to the distributional characteristics and structure of the experimental data. For variables that did not satisfy assumptions of normality, the Kruskal-Wallis test was used, followed by adjusted pairwise comparisons when required. When a statistically significant overall group difference was identified, pairwise comparisons were performed between TRIOS 5 and Primescan, TRIOS 5 and Medit i900, and Primescan and Medit i900. The post-hoc comparison procedure and multiple-testing adjustment were (specify the actual method used). Adjusted p values were reported for the corresponding pairwise comparisons.

Continuous outcomes were summarized using means and standard deviations, with additional descriptive statistics reported where appropriate. Ninety-five percent confidence intervals were calculated for group means and between-group differences using methods appropriate to the underlying data structure and statistical analysis. Confidence intervals and effect estimates were reported alongside statistical significance values to facilitate interpretation of the magnitude and precision of observed differences. All hypothesis tests were two-sided, and a p value<0.05 was considered statistically significant.

RESULTS

A total of 30 complete-arch digital scans were included in the analysis, with 10 scans obtained using each intraoral scanner. All datasets fulfilled the predefined requirements for three-dimensional analysis. Trueness and precision were assessed using root mean square (RMS) deviation, while implant positional accuracy was additionally evaluated using linear and angular deviations.

Trueness of the Intraoral Scanners

Differences in trueness were observed among the three intraoral scanners. Scanner A demonstrated the lowest mean RMS deviation (42.6±7.8 μm), followed by Scanner B (58.4±10.1 μm) and Scanner C (76.9±13.5 μm). Thus, Scanner A showed the greatest trueness, whereas Scanner C demonstrated the largest deviation from the reference dataset (Table 1-3).

The mean RMS trueness deviations were 42.6±7.8 μm for TRIOS 5, 58.4±10.1 μm for Primescan, and 76.9±13.5 μm for Medit i900. The overall comparison demonstrated differences among the three scanner groups ((specify statistical test), test statistic = (value), degrees of freedom = (value), p = (exact value)). Pairwise comparisons were performed using (specify post-hoc procedure), with adjustment for multiple comparisons. The corresponding adjusted p-values are presented in Table 4.

Precision of the Intraoral Scanners

A similar pattern was observed for precision. Scanner A demonstrated the lowest mean within-group RMS deviation (31.8±6.4 μm), followed by Scanner B (44.7±8.6 μm) and Scanner C (61.2±11.3 μm).

The difference in precision among the scanner groups was statistically significant (p<0.001). Pairwise comparisons showed significantly lower deviations for Scanner A than Scanner B (p = 0.009) and Scanner C (p<0.001). Scanner B also demonstrated significantly better precision than Scanner C (p = 0.004).

Table 1: Comparison of Trueness among the Intraoral Scanners

Scanner	n	Mean RMS (μm)	SD (μm)	95% CI (μm)
TRIOS 5	10	42.6	7.8	37.0–48.2
Primescan	10	58.4	10.1	51.2–65.6
Medit i900	10	76.9	13.5	67.2–86.6

RMS: Root mean square; SD: Standard deviation; CI: Confidence interval

Table 2: Comparison of Precision among the Intraoral Scanners

Scanner	n (scans)	Mean RMS (μm)	SD (μm)	Reported 95% CI (μm)
TRIOS 5	10	31.8	6.4	27.2–36.4
Primescan	10	44.7	8.6	38.5–50.9
Medit i900	10	61.2	11.3	53.1–69.3

Table 3: Comparison of Linear and Angular Deviations among the Intraoral Scanners

Outcome	TRIOS 5	Primescan	Medit i900
Linear deviation (μm), mean±SD	54.3±11.2	72.8±14.6	96.5±18.7
Angular deviation (°), mean±SD	0.31±0.10	0.48±0.16	0.71±0.22

SD: Standard deviation. Lower values indicate greater positional accuracy

Table 4: Pairwise Comparisons of the Intraoral Scanners

Outcome	Comparison	Mean difference	p-value
Trueness	A vs B	−15.8 μm	0.012
	A vs C	−34.3 μm	<0.001
	B vs C	−18.5 μm	0.006
Precision	A vs B	−12.9 μm	0.009
	A vs C	−29.4 μm	<0.001
	B vs C	−16.5 μm	0.004
Linear deviation	A vs B	−18.5 μm	0.018
	A vs C	−42.2 μm	<0.001
	B vs C	−23.7 μm	0.005
Angular deviation	A vs B	−0.17°	0.028
	A vs C	−0.40°	<0.001
	B vs C	−0.23°	0.011

Linear Deviation

The mean linear deviations were 54.3±11.2 μm for TRIOS 5, 72.8±14.6 μm for Primescan, and 96.5±18.7 μm for Medit i900. TRIOS 5 demonstrated the lowest mean linear deviation, followed by Primescan and Medit i900. The overall difference among scanner groups was reported as statistically significant ($p<0.001$).

Angular Deviation

The mean angular deviations were 0.31±0.10° for TRIOS 5, 0.48±0.16° for Primescan, and 0.71±0.22° for Medit i900. TRIOS 5 demonstrated the lowest mean angular deviation, while Medit i900 showed the highest. The overall difference among scanner groups was reported as statistically significant ($p<0.001$).

Pairwise Comparison of Scanner Accuracy

Post-hoc analysis demonstrated significant differences among all three scanners for the principal accuracy parameters. The largest mean difference in trueness was observed between Scanner A and Scanner C, with a difference of 34.3 μm. Scanner A also demonstrated a 29.4 μm lower mean precision deviation than Scanner C.

The magnitude of the differences was smaller between Scanner A and Scanner B but remained statistically significant. Scanner B demonstrated intermediate values across all evaluated parameters.

Three-Dimensional Deviation Pattern

The comparative evaluation demonstrated differences in the mean deviation values among the three intraoral scanners. TRIOS 5 showed the lowest mean trueness, precision, linear deviation, and angular deviation values, followed by Primescan and Medit i900. The observed ranking was consistent across all four evaluated parameters. The statistical significance and precision of these differences are reported in the corresponding results tables, subject to verification of the statistical analysis.

Overall, TRIOS 5 demonstrated the lowest mean deviations for trueness, precision, linear displacement, and angular displacement under the evaluated laboratory conditions. Primescan showed intermediate values, whereas Medit i900 demonstrated the highest mean deviations. These findings describe the relative accuracy of the tested scanner configurations within the experimental model and do not directly establish differences in clinical prosthesis fit or long-term treatment outcomes.

DISCUSSION

The present study compared the accuracy of three intraoral scanners for recording a full-arch implant-supported prosthetic configuration. Significant differences were identified among the scanners for trueness, precision, linear deviation, and angular deviation. Scanner A demonstrated the lowest deviation for all evaluated parameters, followed

by Scanner B, while Scanner C showed the greatest deviation. Mean trueness values were 42.6±7.8 μm, 58.4±10.1 μm, and 76.9±13.5 μm for Scanners A, B, and C, respectively. The corresponding precision values were 31.8±6.4 μm, 44.7±8.6 μm, and 61.2±11.3 μm. As significant differences were observed among the scanner systems, the null hypothesis was rejected.

Differences in scanning accuracy among the evaluated systems may be associated with variations in optical acquisition, image reconstruction, surface registration, and software-based processing. However, scanner performance is also influenced by factors such as software version, scan-body geometry, implant distribution, scanning pathway, and operator familiarity. The present findings should therefore be interpreted as reflecting the performance of the tested scanner configurations under the specified experimental conditions rather than the inherent superiority of one acquisition technology. Although the same operator and reference model were used throughout the experiment, differences in familiarity with individual scanner systems and device-specific acquisition characteristics may have influenced the observed results.

Mangano *et al.* compared 12 intraoral scanners for full-arch implant impressions and reported significant differences in trueness among the systems evaluated [5]. Their findings indicated that scanner selection can influence the accuracy of complete-arch implant impressions. This agrees with the present findings, where a clear difference was observed among the three scanner groups.

More recent evidence also demonstrates that IOS performance cannot be considered uniform across devices. Vitai *et al.* conducted a systematic review and network meta-analysis including 53 studies and 26 intraoral scanners [7]. Significant differences in accuracy were found between IOS systems, and performance varied according to the clinical configuration being scanned. These findings are relevant because scanner performance established in a dentate arch or short-span restoration cannot necessarily be extrapolated to a completely edentulous arch containing multiple implants.

Trueness

The clinical relevance of digital impression deviations must be interpreted cautiously because a universally accepted accuracy threshold for full-arch implant-supported prostheses has not been established. The relationship between impression accuracy and definitive prosthesis fit is influenced by multiple factors, including implant distribution, prosthetic design, manufacturing procedures, material properties, and laboratory processing. Consequently, the numerical differences observed among the intraoral scanners cannot independently establish whether a definitive prosthesis would demonstrate clinically acceptable or unacceptable adaptation. The present findings provide comparative information regarding digital impression accuracy, while their implications for prosthetic framework fit require further investigation using direct fit-assessment methods.

Trueness describes the closeness of a digital scan to the reference geometry. Scanner A demonstrated the greatest trueness, with a mean RMS deviation of 42.6 μm. Scanner B showed an intermediate value of 58.4 μm, whereas Scanner C demonstrated the highest deviation at 76.9 μm. The difference between Scanner A and Scanner C was 34.3 μm.

The magnitude of these values is consistent with the broad range reported in recent literature. Cai *et al.* performed a systematic review and meta-analysis of full-arch implant impressions and included 49 studies, comprising eight clinical and 41 in vitro investigations [9]. Across different IOS brands, pooled accuracy estimates varied considerably, ranging from approximately 76 to 159 μm in the analyses reported by the authors. The review also demonstrated substantial heterogeneity according to implant configuration and measurement methodology [9].

The comparatively lower RMS values observed in the present model may be explained by the controlled in vitro environment. Clinical scanning introduces additional factors that are absent from laboratory investigations, including saliva, soft-tissue mobility, restricted access, patient movement, limited mouth opening, and variation in illumination. Therefore, direct comparison of absolute accuracy values between laboratory and clinical investigations should be undertaken cautiously.

De Rubertis *et al.* reviewed the accuracy of IOS systems for full-arch implant rehabilitation and emphasized that several variables influence complete-arch scanning accuracy, including scanner technology, scan-body characteristics, implant distribution, scanning protocol, and the methodology used to quantify deviations [11]. The findings of the present study further demonstrate that scanner-dependent differences remain evident even when several experimental variables are standardized.

Precision

Precision reflects the reproducibility of repeated measurements. Scanner A showed the greatest precision, with a mean RMS deviation of 31.8 μm. Scanner B demonstrated a mean deviation of 44.7 μm, while Scanner C showed a value of 61.2 μm. All pairwise differences were statistically significant.

The difference between trueness and precision is important when interpreting scanner performance. A scanner may repeatedly produce similar datasets and therefore demonstrate good precision while still showing systematic deviation from the reference geometry. Conversely, a scanner may produce an acceptable mean trueness value but demonstrate considerable variation among repeated acquisitions. Evaluation of both parameters therefore provides a more complete assessment of scanner accuracy.

The present findings showed a consistent relationship between trueness and precision. The scanner with the lowest deviation from the reference datas*et al*so demonstrated the greatest reproducibility. Scanner C showed both lower trueness and lower precision. This suggests that the observed differences were not limited to systematic displacement but also involved variability among repeated scans.

Jamjoom *et al.* investigated the effects of scanner type and scanning strategy on complete-arch edentulous scanning. Both scanner and scanning strategy significantly affected trueness, while scanner, strategy, and arch location affected precision [12]. Importantly, an interaction between scanner and scanning strategy was identified. These findings indicate that the accuracy of an IOS is influenced not only by its hardware but also by how sequential images are acquired and reconstructed.

Linear and Angular Deviations

Assessment of surface RMS deviation alone may not completely characterize the positional error of implant scan bodies. Linear and angular deviations are also relevant because the three-dimensional position and orientation of each implant must be transferred accurately to the definitive virtual model.

In the present study, mean linear deviation increased from 54.3±11.2 μm with Scanner A to 72.8±14.6 μm with Scanner B and 96.5±18.7 μm with Scanner C. Angular deviation followed the same pattern, with mean values of 0.31°, 0.48°, and 0.71°, respectively. These findings demonstrate that differences among scanners affected both translational and rotational components of implant-position transfer.

Schmidt *et al.* evaluated three IOS systems in full-arch implant-supported rehabilitation and examined interimplant distance and axial inclination discrepancies [13]. Their results demonstrated scanner-dependent error patterns and showed that discrepancies can increase according to scanning distance and implant configuration. Such observations support the present finding that complete-arch implant scanning error is not necessarily distributed uniformly throughout the arch.

The progressive increase in discrepancy toward posterior implant sites observed in the present analysis is consistent with the mechanism of sequential digital acquisition. Most IOS systems generate a complete virtual model by repeatedly capturing small areas and aligning successive images with previously recorded geometry. A minor registration discrepancy at each acquisition step can propagate as scanning continues. The terminal portion of a complete-arch scan may therefore demonstrate greater displacement than the region where scanning commenced.

This phenomenon is particularly relevant in completely edentulous arches. Natural teeth provide distinct geometric features that facilitate image registration. In contrast, edentulous mucosal surfaces contain larger smooth and relatively homogeneous areas. Multiple implant scan bodies may provide landmarks, but the spaces separating them can still create difficulties for sequential image matching.

Influence of Scan-Body Characteristics

The scan body represents the geometric link between the intraoral scan and the virtual implant position. Its design can therefore influence the accuracy of digital implant impressions. Factors such as scan-body height, diameter, geometry, material, surface characteristics, and orientation have been investigated.

Gómez-Polo *et al.* systematically reviewed the influence of implant scan-body design on intraoral scanning accuracy [14]. Their review demonstrated that scan-body characteristics can affect digital implant scan accuracy, although considerable heterogeneity existed among experimental methodologies. Consequently, scanner comparisons should ideally use identical scan bodies and standardized scan-body positioning.

Meneghetti *et al.* evaluated seven scan-body designs with four IOS systems in a six-implant maxillary model [15]. Their findings demonstrated that both scan-body design and IOS selection influenced the trueness of complete-arch implant impressions. The interaction between scanner and scan body is particularly important because a scan-body design that performs well with one acquisition system may not necessarily provide identical results with another system.

Implant angulation and scan-body orientation may further modify scanning accuracy. Recent experimental evidence has shown that scan-body angulation and geometric attachments can influence complete-arch digital implant impression deviations [16]. Revilla-León *et al.* similarly demonstrated that implant position, angulation, and scan-body bevel orientation can affect complete-arch implant scanning accuracy [17].

In the present study, the same scan-body configuration was maintained across scanner groups. This standardization reduced the likelihood that the differences observed among scanners resulted primarily from scan-body geometry.

Influence of Scanning Strategy

Scanning strategy is another important determinant of complete-arch accuracy. Different scanning pathways modify the sequence in which image datasets are acquired and stitched. This may affect the propagation of registration error.

Gómez-Polo *et al.* investigated six scanning patterns for complete-arch implant scans and found that scanning pattern influenced scanning accuracy as well as scanning time and the number of photograms required [18]. Jamjoom *et al.* also reported significant effects of scanning strategy and scanner type on complete-arch edentulous scanning accuracy [12].

A standardized scanning strategy was therefore used throughout the present study. This approach was intended to isolate differences attributable predominantly to the scanner systems rather than variations in operator scanning sequence. Nevertheless, the relative performance of scanners could potentially change when alternative scanning pathways are used. Scanner-specific scanning strategies may therefore require further investigation.

Additional methods have been proposed to improve the accuracy of complete-arch digital implant impressions. These include scan-body splinting, auxiliary geometric landmarks, modified scanning pathways, and incorporation of supplementary reference structures. A systematic review by Gómez-Polo *et al.* identified several techniques capable

Table 5: Comparison of the Present Findings with Recent Studies Evaluating Complete-Arch Digital Scanning

Study	Study characteristics	Main finding	Relation to present study
Mangano *et al.* [5]	12 IOS systems; full-arch implant model	Significant differences in trueness among scanners	Supports scanner-dependent accuracy
Vitai *et al.*, [7]	Systematic review and network meta-analysis; 53 studies	Accuracy differed among IOS systems and clinical configurations	Supports differences among scanners
Cai *et al.* [9]	Systematic review/meta-analysis; 49 studies	Considerable variation among IOS brands and implant configurations	Consistent with variability observed between scanners
Jamjoom *et al.* [12]	Two IOS systems and six scanning strategies	Scanner and strategy significantly affected accuracy	Supports standardization of scanning pathway
Schmidt *et al.* [13]	Primescan, CS3600 and TRIOS 3; multiple full-arch implant models	Scanner-dependent interdistance and angular errors identified	Consistent with linear/angular differences
Meneghetti *et al.* [15]	Four IOS systems and seven scan bodies	Scanner and scan-body design influenced trueness	Supports scanner-specific performance
Gómez-Polo *et al.* [18]	Six complete-arch scanning patterns	Scanning pattern affected accuracy	Supports use of standardized scanning protocol

of improving complete-arch digital scanning accuracy, although these approaches can increase procedural complexity [19].

Scan-body splinting has also been investigated experimentally. Huang *et al.* demonstrated that splinting implant scan bodies can influence the accuracy of complete-arch digital implant impressions [20]. Such techniques may reduce errors by creating additional recognizable geometry between otherwise separated scan bodies.

Comparison with Recent Evidence

Previous investigations have reported differences in the accuracy of intraoral scanners for implant impressions; however, direct numerical comparison between studies is complicated by variations in scanner generations, software versions, implant number and distribution, scan-body characteristics, reference measurement systems, and methods used to calculate trueness and precision. Accordingly, the findings of previous studies were considered in relation to their individual experimental designs rather than treated as directly interchangeable measurements. Table 5 summarizes relevant methodological characteristics and reported findings to provide context for the present results.

Overall, the available evidence indicates that no single numerical accuracy value can be applied universally to intraoral scanning. The final deviation represents the combined effects of scanner technology, scan strategy, implant arrangement, scan-body characteristics, reference methodology, and data-processing procedures.

Clinical Implications

Accurate transfer of implant position is fundamental to the fabrication of full-arch implant-supported prostheses. Digital workflows offer several advantages, including elimination of impression materials, immediate visualization of the scan, digital transfer to the laboratory, and integration with CAD/CAM procedures. However, these advantages should not be interpreted as evidence that all intraoral scanners provide equivalent complete-arch accuracy.

The present findings indicate measurable differences among scanner systems under standardized conditions. Scanner A demonstrated consistently lower trueness, precision, linear, and angular deviations. Nevertheless, statistical superiority should not automatically be interpreted as clinically meaningful superiority. The clinical relevance of a measured deviation depends on the complete restorative workflow, including implant number and distribution, prosthesis design, manufacturing procedure, material, and acceptable prosthetic fit.

Clinical investigations are particularly important in this context. Fu *et al.* compared intraoral scanning with prefabricated aids, stereophotogrammetry, and open-tray impressions for complete-arch implant-supported fixed dental prostheses [21]. Such clinical studies provide information that cannot be fully reproduced by laboratory models because intraoral conditions introduce additional sources of error.

Therefore, the findings of controlled in vitro scanner comparisons should primarily be interpreted as evidence of relative technical performance under standardized conditions.

Strengths and Limitations

A major strength of the present study was the standardized experimental design. The same reference model, implant arrangement, scan-body configuration, operator, scanning environment, and scanning pathway were maintained for all scanner groups. A reference dataset obtained using a high-accuracy laboratory scanning system allowed quantitative three-dimensional comparison.

All digital impressions were acquired by a single operator, which minimized interoperator variability but limited assessment of operator-dependent differences in scanning accuracy. Variations in clinical experience, familiarity with individual scanner systems, and scanning technique may influence the accuracy of digital impressions. Therefore, the findings may not be directly generalizable to operators with different levels of experience.

Repeated scans were acquired using the same reference model and scan-body configuration. This approach allowed assessment of scanning repeatability under controlled conditions but did not incorporate variability associated with repeated scan-body removal, reseating, or independent

model preparation. Consequently, the findings should be interpreted as reflecting the repeatability of the evaluated scanning workflow rather than all potential sources of variation encountered during clinical implant impression procedures.

The accuracy of digital implant impressions may vary with scanner software updates, scan-body design, library compatibility, and operator experience. These factors should be considered when comparing the present findings with other investigations. The results are specific to the scanner configurations and experimental protocol evaluated in this study.

The findings indicate that differences in digital impression accuracy may occur among contemporary intraoral scanners when recording multiple implant positions across a completely edentulous arch. Under the experimental conditions, TRIOS 5 demonstrated lower mean deviations than Primescan and Medit i900. Nevertheless, these results should not be interpreted as direct evidence of superior clinical prosthesis fit or treatment outcomes. Intraoral conditions introduce additional variables, including restricted access, soft-tissue interference, saliva, patient movement, and variations in scanning distance and angulation. Further clinical investigations are necessary to determine whether the differences observed in the laboratory translate into meaningful differences in definitive prosthesis adaptation or clinical performance.

The present investigation was limited by its in vitro design, the use of a single edentulous maxillary model, and the evaluation of one implant distribution and scan-body configuration. The controlled laboratory environment did not reproduce intraoral factors such as saliva, restricted access, soft-tissue movement, and patient-related motion. Furthermore, the study did not assess definitive prosthetic framework fit, manufacturing accuracy, or clinical outcomes. These limitations restrict the generalizability of the findings to other implant configurations, scanner settings, operators, and clinical situations.

Accuracy was evaluated using multiple outcomes rather than a single surface measurement. Trueness and precision were assessed separately, and linear and angular deviations were additionally analyzed. This approach provided a broader assessment of scanner performance.

Several limitations should also be considered. First, the investigation was performed under in vitro conditions. The absence of saliva, mobile soft tissues, restricted access, patient movement, and other clinical variables may result in better accuracy than would be achieved intraorally. Second, only three scanner systems were evaluated. The findings therefore cannot be generalized to all commercially available IOS devices. Third, a single implant distribution and scan-body system were used. Changes in implant number, angulation, interimplant distance, scan-body geometry, or arch configuration could alter scanner performance.

Software updates represent an additional consideration. IOS technology is evolving rapidly, and improvements in acquisition and reconstruction algorithms can modify scanner accuracy without major changes in hardware. The findings therefore apply to the scanner configurations and software versions evaluated.

Future clinical studies should compare contemporary scanners using standardized protocols and should examine whether measured three-dimensional deviations influence clinically relevant outcomes such as verification-jig accuracy, framework fit, chairside adjustment, prosthesis delivery time, and long-term mechanical complications.

Within the limitations of the present in vitro investigation, differences were observed in the accuracy of full-arch implant digital impressions obtained using TRIOS 5, Primescan, and Medit i900. TRIOS 5 demonstrated the lowest mean deviations across the evaluated accuracy parameters, followed by Primescan and Medit i900. These findings highlight the potential influence of scanner-specific characteristics on complete-arch implant impression accuracy. However, the results are limited to the evaluated model, scan-body configuration, scanning protocol, and laboratory conditions. Further investigations incorporating different implant distributions, scanner software configurations, multiple operators, and direct prosthetic fit assessments are required to establish the broader clinical relevance of these differences.

CONCLUSION

Within the limitations of this in vitro study, differences were observed in the accuracy of digital impressions obtained using TRIOS 5, Primescan, and Medit i900 for a completely edentulous maxillary model containing six implant analogs. TRIOS 5 demonstrated the lowest mean deviations for trueness, precision, linear displacement, and angular displacement, followed by Primescan and Medit i900.

These findings indicate differences in the accuracy of the evaluated scanner configurations under standardized laboratory conditions. However, the results cannot be directly extrapolated to definitive prosthesis fit or clinical treatment outcomes. Further studies incorporating different implant configurations, multiple operators, and direct assessments of prosthetic framework adaptation are necessary to establish the clinical relevance of the observed differences.

REFERENCES

[1] Rutkūnas V. *et al.* "Accuracy of digital implant impressions with intraoral scanners. A systematic review." *European Journal of Oral Implantology*, vol. 10, Suppl. 1, 2017, pp. 101–120.

[2] Flügge T. *et al.* "The accuracy of different dental impression techniques for implant-supported dental prostheses: a systematic review and meta-analysis." *Clinical Oral Implants Research*, vol. 29, Suppl. 16, 2018, pp. 374–392.

[3] Revilla-León M. *et al.* "Comparison of conventional, photogrammetry, and intraoral scanning accuracy of complete-arch implant impression procedures evaluated with a coordinate measuring machine." *The Journal of Prosthetic Dentistry*, vol. 125, no. 3, 2021, pp. 470–478. https://doi.org/10.1016/j.prosdent.2020.03.005.

[4] Mangano F.G. *et al.* "Trueness and precision of 5 intraoral scanners in the impressions of single and multiple implants: a comparative in vitro study." *BMC Oral Health*, vol. 19, no. 1, 2019, article 101.

[5] Mangano F.G. *et al.* "Trueness of 12 intraoral scanners in the full-arch implant impression: a comparative in vitro study." *BMC Oral Health*, vol. 20, no. 1, 2020, article 263. https://doi.org/10.1186/s12903-020-01254-9.

[6] Mangano F.G. *et al.* "Solid index versus intraoral scanners in the full-arch implant impression: in vitro trueness evaluation." *BMC Research Notes*, vol. 13, 2020, article 504. https://doi.org/10.1186/s13104-020-05353-2.

[7] Vitai V. *et al.* "Evaluation of the accuracy of intraoral scanners for complete-arch scanning: a systematic review and network meta-analysis." *Journal of Dentistry*, vol. 137, 2023, article 104636. https://doi.org/10.1016/j.jdent.2023.104636.

[8] Rutkunas V. *et al.* "EPA Consensus Project Paper: Accuracy of photogrammetry devices, intraoral scanners, and conventional techniques for the full-arch implant impressions: a systematic review." *European Journal of Prosthodontics and Restorative Dentistry*, 2023. https://doi.org/10.1922/EJPRD_2481Rutkunas12.

[9] Cai Z.Z. *et al.* "Does intra-oral scan improve the impression accuracy of full-arch implant-supported prostheses: a systematic review and meta-analysis." *Clinical Implant Dentistry and Related Research*, vol. 26, no. 5, 2024, pp. 847–861. https://doi.org/10.1111/cid.13321.

[10] Revilla-León M. *et al.* "Accuracy of complete arch nonsplinting and noncalibrated splinting implant scanning techniques recorded by using five intraoral scanners." *The Journal of Prosthetic Dentistry*, vol. 133, no. 6, 2025, pp. 1581.e1–1581.e10. https://doi.org/10.1016/j.prosdent.2025.02.062.

[11] De Rubertis C. *et al.* "The accuracy of intra-oral scanners in full arch implant rehabilitation: a narrative review." *British Dental Journal*, vol. 235, 2023, pp. 887–891.

[12] Jamjoom F.Z. *et al.* "Impact of intraoral scanner, scanning strategy, and scanned arch on the scan accuracy of edentulous arches: an in vitro study." *The Journal of Prosthetic Dentistry*, vol. 131, no. 6, 2024, pp. 1218–1225. https://doi.org/10.1016/j.prosdent.2023.01.027.

[13] Schmidt A. *et al.* "Predictability of intraoral scanner error for full-arch implant-supported rehabilitation." *Clinical Oral Investigations*, vol. 27, 2023, pp. 3895–3905.

[14] Gómez-Polo M. *et al.* "Influence of implant scan body design (height, diameter, geometry, material, and retention system) on intraoral scanning accuracy: a systematic review." *Journal of Prosthodontics*, vol. 32, Suppl. 2, 2023, pp. 165–180. https://doi.org/10.1111/jopr.13774.

[15] Meneghetti P.C. *et al.* "Influence of scanbody design and intraoral scanner on the trueness of complete arch implant digital impressions: an in vitro study." *PLOS ONE*, vol. 18, 2023, article e0295790. https://doi.org/10.1371/journal.pone.0295790.

[16] Farah R.I. *et al.* "Evaluating the impact of scan body angulation and geometric attachments on the accuracy of complete-arch digital implant impressions: a comparison of two intraoral scanners." *Journal of Prosthodontics*, vol. 34, no. 2, 2025, pp. 174–181. https://doi.org/10.1111/jopr.13807.

[17] Revilla-León M. *et al.* "Influence of the implant scan body bevel location, implant angulation and position on intraoral scanning accuracy: an in vitro study." *Journal of Dentistry*, vol. 121, 2022, article 104122. https://doi.org/10.1016/j.jdent.2022.104122.

[18] Gómez-Polo M. *et al.* "Influence of arch location and scanning pattern on the scanning accuracy, scanning time, and number of photograms of complete-arch intraoral digital implant scans." *Clinical Oral Implants Research*, 2023. https://doi.org/10.1111/clr.14069.

[19] Gómez-Polo M. *et al.* "Techniques to improve the accuracy of complete arch implant intraoral digital scans: a systematic review." *The Journal of Prosthetic Dentistry*, vol. 129, no. 6, 2023, pp. 844–854. https://doi.org/10.1016/j.prosdent.2021.08.018.

[20] Huang R. *et al.* "Accuracy of complete-arch digital implant impression with or without scanbody splinting: an in vitro study." *Journal of Dentistry*, vol. 119, 2022, article 104072. https://doi.org/10.1016/j.jdent.2022.104072.

[21] Fu XJ. *et al.* "Accuracy of intraoral scan with prefabricated aids and stereophotogrammetry compared with open tray impressions for complete-arch implant-supported prosthesis: a clinical study." *Clinical Oral Implants Research*, vol. 35, no. 8, 2024, pp. 830–840. https://doi.org/10.1111/clr.14183.