INFLUENCE OF SCANNABLE HEALING ABUTMENT DIAMETER ON THE TRUENESS OF INTRAORAL SCANS: AN IN VITRO STUDY

Gaewalee LEEHASATEAN[1], Wacharasak TUMRASVIN[2],
Trakol MEKAYARAJJANANONTH[2], Supaboon PURNAVEJA[2]
and Awat THEERACHAIWARAKUL[2]

1 Postgraduate student, Department of Prosthodontics, Faculty of Dentistry Chulalongkorn University, Thailand
2 Department of Prosthodontics, Faculty of Dentistry Chulalongkorn University, Thailand

ABSTRACT

This in vitro study evaluated the effect of scannable healing abutment (SHA) diameter on the trueness of intraoral scanning. Three SHA diameters, 4 mm (D4), 5 mm (D5), and 6 mm (D6), were scanned under controlled conditions with a constant supramucosal height. Reference data were obtained using a laboratory scanner. Ten repeated intraoral scans were performed for each group. The scan datasets were superimposed onto the reference dataset using three-dimensional analysis software. Trueness was assessed using root mean square (RMS), linear, and angular deviations. RMS, linear and angular deviation was analyzed using one-way ANOVA ($\alpha = 0.05$). Significant differences among the diameter groups were observed for all outcomes ($p < 0.001$). RMS deviation decreased significantly from D4 (61.11 ± 4.93 μm) to D5 (47.62 ± 7.91 μm) and D6 (32.90 ± 4.75 μm). Linear deviation showed a similar decrease from D4 (81.07 ± 6.04 μm) to D5 (62.42 ± 7.50 μm) and D6 (39.44 ± 11.38 μm). Angular deviation was significantly greater in D4 (0.75 ± 0.12°) than in D5 (0.47 ± 0.11°) and D6 (0.40 ± 0.08°), with no significant difference between D5 and D6. Increasing the SHA diameter improved RMS and linear scanning trueness, whereas angular trueness did not significantly improve with an increase in diameter from 5 to 6 mm.

Keywords: Intraoral Scanners, Trueness, Implant, Scannable Healing Abutment

CITATION INFORMATION: Leehasatean, G., Tumrasvin, W., Mekayarajjananonth, T., Purnaveja, S., & Theerachaiwarakul, A. (2026). Influence of Scannable Healing Abutment Diameter on the Trueness of Intraoral Scans: An in Vitro Study. *Procedia of Multidisciplinary Research, 4*(10), 60.

INTRODUCTION

Accurate transfer of three-dimensional implant position is essential for the fit and long-term success of implant-supported restorations. Intraoral scanners have increasingly been used as alternatives to conventional implant impressions because they improve patient comfort, reduce chairside time, facilitate digital data management, and eliminate dimensional changes associated with impression materials and stone casts. Scanning accuracy may be influenced by scanner technology, scanning strategy, scan range, operator experience, implant position and angulation, and scan component geometry. (Mizumoto & Yilmaz, 2018; Sanda et al., 2021; Talesara et al., 2023). Scannable healing abutments combine the functions of a healing abutment, impression coping, and scan body, allowing digital implant impressions without removing the healing component and potentially reducing soft-tissue irritation and chairside procedures (Çakmak et al., 2021; Ender & Mehl, 2013; Moron-Conejo et al., 2025). Although several factors affecting implant scanning trueness have been investigated, evidence regarding the effect of scannable healing abutment diameter remains limited. Therefore, this in vitro study evaluated the effect of scannable healing abutment diameter on intraoral scanning trueness using root mean square, linear, and angular deviations.

LITERATURE REVIEWS

The accuracy of digital implant impressions obtained using intraoral scanners is influenced by both patient-related and operator-related factors.

Patient-related factors include implant position and characteristics of the scan body or SHA. Operator-related factors include the scanning pattern and ambient lighting conditions. Among patient-related variables, implant position within the dental arch has been shown to affect scanning accuracy. Scan Body Characteristics provide geometric information that enables software to determine implant position, depth, and angulation. Scan body geometry can affect accuracy. Spherical designs may inadequately transfer implant angulation, whereas diameters greater than 4.8 mm and lengths exceeding 8 mm may provide more distinctive geometry for accurate software alignment (Ender & Mehl, 2013). PEEK scan bodies generally demonstrate lower accuracy than titanium components (Çakmak et al., 2021). SHAs integrate the functions of a healing abutment, impression coping, and scan body, allowing intraoral scanning without removing the healing component. This approach may simplify clinical procedures, reduce patient discomfort, and preserve peri-implant soft-tissue architecture. However, its accuracy depends on the optical readability and geometric features of the SHA, including its shape, height, surface texture, reflectivity, indexing features, and connection stability. Accurate transfer of implant position requires the intraoral scanner to capture the coded geometry of the SHA and align it correctly with the corresponding digital library. A systematic review reported that intraoral scanning of SHAs generally produced greater accuracy than elastomeric impressions of SHAs and, in some studies, achieved accuracy comparable to conventional implant scan bodies (Sanda et al., 2021). Distinctive geometric landmarks, including grooves, notches, indexing surfaces, and surface characteristics, may improve scanner recognition and library matching. Research demonstrated that different SHA designs resulted in significant variations in linear and angular deviations, confirming that SHA geometry affects impression accuracy (Lee et al., 2026). SHA height may also influence scanning outcomes, particularly in posterior regions. Batak et al. (2020) found that implant position affected distance deviation and that greater SHA height could increase angular deviation posteriorly, whereas both short and long SHAs performed similarly in anterior sites when sufficient geometry was visible. For operator-related factors, Ambient light intensity may influence the accuracy and consistency of intraoral scanning. Controlled lighting conditions, such as scanning in a windowless room, may reduce fluctuations in illumination; however, the optimal light intensity appears to depend on the intraoral scanner system used (Sanda et al., 2021). Scanning strategy is another

important determinant of accuracy. An irregular or interrupted scan path may increase stitching errors, particularly around implants and scannable healing abutments, where accurate acquisition of coded geometric features is required. (Mizumoto & Yilmaz, 2018).

Implant Accuracy Measurements

Impression accuracy is described in terms of trueness and precision. Trueness refers to the closeness of a measurement to the actual dimensions of an object, whereas precision represents the reproducibility of repeated measurements (ISO, 1994). The present study focuses on trueness, which is commonly evaluated using root-mean-square (RMS), linear, and angular deviations. RMS deviation represents the overall magnitude of discrepancy between a test scan and a superimposed reference dataset, with lower values indicating greater trueness (Mizumoto & Yilmaz, 2018; Sanda et al., 2021). Linear deviation quantifies the positional difference between corresponding points in the test and reference datasets. Angular deviation represents the difference between the long-axis orientations of the scan component in the test and reference datasets (Mizumoto & Yilmaz, 2018).

Clinically Acceptable Deviations

RMS deviation misfits of approximately 150-200 µm have been considered clinically acceptable for extensive or complete-arch prostheses, whereas lower values are generally preferred for single-unit and short-span restorations (Moron-Conejo et al., 2025). Linear deviation, values between 70 and 120 µm have been proposed as clinically acceptable in previous studies (Goujat et al., 2019; Jung et al., 2022). Mizumoto et al. (2019) reported angular deviations ranging from 0.21° to 0.78°, depending on scan body position and scanning technique, whereas Batak et al. (2020) reported values ranging from 0.4° to 0.8°, depending on SHA position and height. Based on previous studies, it can be implied that angular deviations ranging from approximately 0.21° to 0.8° may be considered clinically acceptable

Research Hypothesis

There are significant differences in the trueness of intraoral digital implant scans with different diameters of the scannable healing abutment

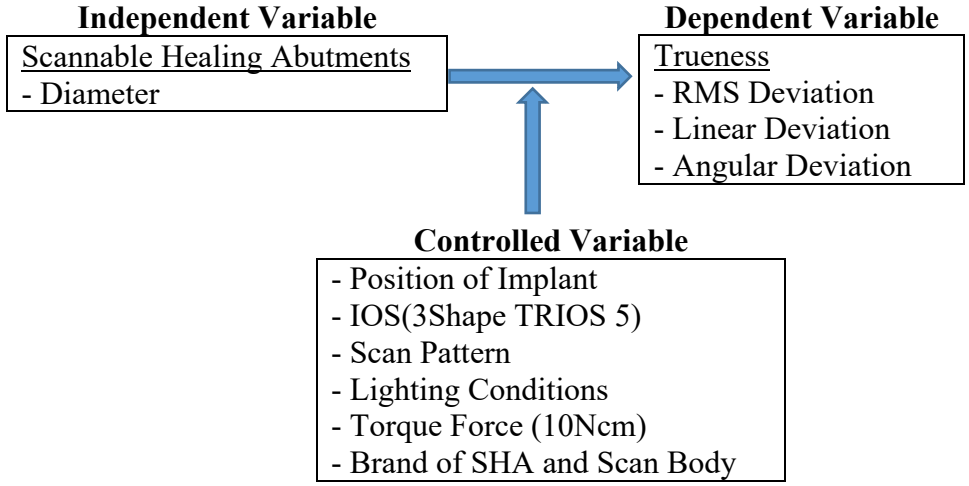


Figure 1 Conceptual Framework

RESEARCH METHODOLOGY

Study Design and Sample Size Estimation

Partially edentulous mandibular model with a missing right mandibular first molar was used. A digital implant analog was positioned 2 mm below the gingival margin of the adjacent teeth. scannable healing abutments with three different diameters were sequentially connected and scanned using an intraoral scanner. The resulting datasets were compared with reference scans obtained using a desktop scanner. All scans were performed by a single investigator, and

trueness was evaluated using RMS, linear, and angular deviations. Sample size was determined from a pilot study using G*Power version 3.1.9.4 (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). Five scans per group (n = 5) were obtained using a TRIOS 5 intraoral scanner, and angular deviations from the reference scans were used for sample size estimation. The calculated effect size was 1.340. A sample size of 10 scans per group was considered sufficient to achieve a two-sided type I error rate of 5% and statistical power greater than 80%. The numbers of reference and experimental scan datasets are shown in Table 1.

Table 1 Number of Scan Datasets for Each Experimental Group

		Group	**Number (n)**
Scan Body		Control (Desktop Scanner)	10
SHA	D4 H4	Experimental Group	10
	D5 H4	(Intraoral Scanner)	10
	D6 H4		10

A mandibular dentoform model was duplicated using a 3D-printed resin (Ultraprint-Dental Model E UV 3.0; HeyGears).Tooth 46 was removed to create the implant site. A digital laboratory analog (Osstem, Korea) was positioned 2 mm apical to the gingival margin of the adjacent teeth, and artificial gingiva (Gingiva 2.0 UV; HeyGears) was fabricated around the implant site.



Figure 2 Resin Model and Artificial Gingiva

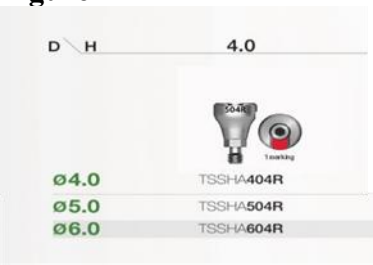


Figure 3 Scannable Healing Abutments Evaluated In This Study (Osstem Implant Co., Seoul, Korea).



A B C

Figure 4 Experimental Model with Different Diameters of SHAs
(A: diameter 4 mm, B: diameter 5 mm, C: diameter 6 mm)

Scanning Strategies

The master model was scanned using an intraoral scanner (TRIOS 5; 3Shape, Copenhagen, Denmark) with a field of view of 15.9 × 15.3 mm and a reported accuracy of 6 µm. The reference dataset was obtained using a laboratory scanner (inEos X5; Dentsply Sirona, Bensheim, Germany) with a reported accuracy of 2 µm. All scans were performed under

standardized environmental conditions, including controlled dark light conditions, temperature, and humidity.Three scannable healing abutments (SHAs) (Osstem Implant Co., Seoul, Korea) with different diameters (Figure 4) were connected to the implant analog and tightened to 10 Ncm using a universal torque wrench (Medentika), according to the manufacturer's recommendations. The model was checked radiographically before each scan to confirm that the component was fully seated in the implant analog and remained connected to the analog without removal or repositioning until all scans for the corresponding experimental group had been completed.

Scanning Protocol

A half-arch scanning extent was selected to minimize errors associated with long-span intraoral scanning (Revilla-León et al., 2023). All intraoral scanning procedures were performed using 3Shape Implant Studio software. For the initial half-arch scan, scanning began at the occlusal surface of the most posterior tooth on the ipsilateral side of the implant site. The scan path proceeded anteriorly along the occlusal surfaces of the second and first premolars, followed by acquisition of the lingual and buccal surfaces of the half-arch model. After completion of the initial scan, the region corresponding to the scannable healing abutment (SHA) at the mandibular right first molar site (tooth 46) was digitally removed from the dataset. The resulting scan served as the base dataset for subsequent SHA scanning.

For each SHA scan, scanning began from the buccal surface of the abutment. The scanner tip was positioned to simultaneously capture the SHA and the proximal portions of the adjacent teeth, including the distal half of tooth 45 and the mesial half of tooth 47. The scanning sequence then proceeded from the buccal to the occlusal and subsequently to the lingual surface.

This standardized scanning strategy was maintained throughout the experiment to facilitate image stitching between the SHA and adjacent teeth and to minimize local scanning distortion. All scan datasets were exported as standard tessellation language (STL) files and imported into Medit Link software. Each scanned SHA was aligned with its corresponding component in the implant library. Based on the position and orientation of the scanned SHA, the software determined the virtual implant position and replaced the SHA geometry with the corresponding scan body from the implant library. The resulting datasets were subsequently imported into three-dimensional analysis software for further evaluation.

Trueness Evaluation

The scan body library dataset generated from each intraoral SHA scan and the corresponding reference dataset obtained using the laboratory scanner were imported into reverse-engineering software (Geomagic Control X; 3D Systems, Rock Hill, South Carolina, USA) for three-dimensional deviation analysis. Trueness was evaluated using root mean square (RMS), linear, and angular deviations. According to ISO 5725-1 (1994), trueness was defined as the degree of deviation between measurements obtained using the intraoral scanner and the reference data obtained using the desktop scanner.

For linear and angular deviation analyses, the outer cylindrical surface of the scan body was manually selected to generate a fitted cylinder. The upper horizontal surface of the scan body was then selected to construct a reference plane. The longitudinal axis of the fitted cylinder was calculated by the software, and the intersection between the cylinder axis and the reference plane was defined as the reference point.

Linear deviation was calculated as the three-dimensional Euclidean distance between the reference points obtained from the intraoral scan and the corresponding reference scan. Angular deviation was defined as the angular difference between the longitudinal axes derived from the intraoral and reference datasets. For the 3D comparison analysis, the region of interest was defined as the coronal approximately one-third of the scan body surface. This selected surface area was used to calculate the root mean square (RMS) deviation.

Statistical Analysis

Data were analyzed using statistical software (IBM SPSS Statistics version 30 IBM Corp, Armonk, NY, USA). Normal distribution was tested using the Shapiro-Wilk test. One way analysis of variance (ANOVA) was used to evaluate the effects of diameter of SHA on trueness of intraoral scanning since data were normally distributed. The significance level for all statistical analyses was set at $\alpha = 0.05$.

RESEARCH RESULTS

The mean and standard deviation (SD) of RMS, linear, and angular deviations obtained from 10 repeated scans in each diameter group are presented in Table 2. Significant differences among the diameter groups were observed for all three outcomes (all $p < 0.001$). RMS deviation decreased from 61.11 ± 4.93 µm in D4 to 47.62 ± 7.91 µm in D5 and 32.90 ± 4.75 µm in D6, with significant differences among all three groups. A similar pattern was observed for linear deviation, which decreased from 81.07 ± 6.04 µm in D4 to 62.42 ± 7.50 µm in D5 and 39.44 ± 11.38 µm in D6, with significant differences among all groups. For angular deviation, D4 exhibited a significantly greater deviation (0.75 ± 0.12°) than D5 (0.47 ± 0.11°) and D6 (0.40 ± 0.08°), whereas no significant difference was observed between D5 and D6.

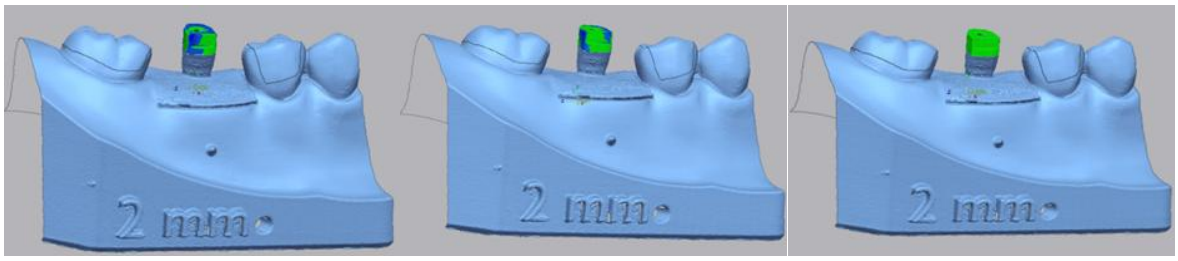
Table 2 Comparison of Trueness among Different Scannable Healing Abutment Diameters

Outcome	D4 (n = 10)	D5 (n = 10)	D6 (n = 10)	*p*-value
RMS deviation (µm)	61.11 ± 4.93[a]	47.62 ± 7.91[b]	32.90 ± 4.75[c]	<0.001
Linear deviation (µm)	81.07 ± 6.04[a]	62.42 ± 7.50[b]	39.44 ± 11.38[c]	<0.001
Angular deviation (°)	0.75 ± 0.12[a]	0.47 ± 0.11[b]	0.40 ± 0.08[b]	<0.001

Table 2 presented data as mean ± standard deviation. Different superscript lowercase letters within the same row indicate statistically significant differences between groups ($p < 0.05$).

Overall, increasing the scannable healing abutment diameter was associated with lower RMS and linear deviations, while angular deviation decreased significantly from D4 to D5 but showed no further significant reduction between D5 and D6. All measurements were within the clinically acceptable limits for RMS, linear, and angular deviations.

RMS deviation was also visualized using a color-coded deviation map, as shown in Figure 5. Deviations within ±150 µm were considered clinically acceptable and were displayed in green. Positive deviations greater than +150 µm, indicating that the scanned surface was positioned outward relative to the reference surface, were displayed in red. Negative deviations less than −150 µm, indicating that the scanned surface was positioned inward relative to the reference surface, were displayed in blue. It can be observed that as the diameter increased, the proportion of the green area, representing deviations within the clinically acceptable range, progressively increased.



A B C

Figure 5 Color-Coded Deviation Map of a Representative Specimen from Each Experimental Group (A: diameter 4 mm, B: diameter 5 mm, C: diameter 6 mm)

DISCUSSION & CONCLUSION

The present in vitro study evaluated the effect of scannable healing abutment diameter on the trueness of intraoral scanning. The results demonstrated that abutment diameter significantly affected RMS, linear, and angular deviations. Overall, larger scannable healing abutment diameters resulted in lower deviation values, indicating improved scanning trueness. Therefore, the hypothesis that there are significant differences in the trueness of intraoral digital implant scans with different diameters of the scannable healing abutment was accepted.

A clear diameter-dependent trend was observed for RMS deviation. The D4 group exhibited the highest RMS deviation (61.11 ± 4.93 μm), followed by D5 (47.62 ± 7.91 μm), whereas D6 demonstrated the lowest value (32.90 ± 4.75 μm). All pairwise comparisons were statistically significant. Since RMS deviation represents the overall three-dimensional discrepancy between the test scan and the reference dataset, these findings suggest that increasing the diameter of the scannable healing abutment may improve the overall accuracy with which its geometry is captured and reproduced by the intraoral scanner.

A similar pattern was observed for linear deviation. The mean linear deviation progressively decreased from 81.07 ± 6.04 μm in D4 to 62.42 ± 7.50 μm in D5 and 39.44 ± 11.38 μm in D6, with significant differences among all diameter groups. These results indicate that a larger abutment diameter may facilitate more accurate reproduction of the three-dimensional position of the implant-related component. Accurate spatial positioning is particularly important in digital implant workflows because positional discrepancies introduced during intraoral scanning may subsequently be transferred to the virtual implant position and ultimately affect the accuracy of the definitive prosthesis (Mizumoto & Yilmaz, 2018)

The improvement in RMS and linear deviations with increasing diameter may be related to the amount of scannable surface and geometric information available to the intraoral scanner. A larger-diameter abutment provides a greater surface area within the scanner's field of view and may generate a more extensive point cloud during image acquisition. This may provide the scanning and registration algorithms with additional geometric information for image matching and reconstruction, thereby reducing errors during alignment. In contrast, a smaller-diameter abutment provides a more limited scannable surface, which may increase the relative contribution of adjacent structures to image registration and make accurate reconstruction of the abutment geometry more challenging (Mizumoto & Yilmaz, 2018; Revilla-León et al., 2023)

Angular deviation showed a slightly different pattern. D4 demonstrated the greatest angular deviation (0.75 ± 0.12°) and was significantly different from both D5 (0.47 ± 0.11°) and D6 (0.40 ± 0.08°). However, no statistically significant difference was observed between D5 and D6. This finding suggests that increasing the diameter from D4 to D5 may provide sufficient geometric information to improve the estimation of the implant axis, whereas a further increase in diameter may provide limited additional benefit for angular orientation. In other words, the influence of diameter on angular trueness may not be linear across the entire range evaluated in this study. Previous studies have demonstrated that characteristics affecting the amount of scan body exposed to the scanner, including clinical scan body height and implant angulation, can influence linear and angular accuracy during intraoral implant scanning (Gómez-Polo et al., 2024)

The difference between the behavior of linear and angular deviations may be related to the manner in which the digital geometry is reconstructed. Linear positioning is influenced by the spatial localization of the entire scanned component and therefore may continue to benefit from an increase in the available scannable surface. In contrast, determination of the long axis may require only a sufficient amount of geometric information to establish orientation reliably. Once this amount of information is available, as may have occurred in the D5 group, further increases in diameter may not substantially improve angular reconstruction. This could explain

why D6 produced a numerically lower angular deviation than D5 but without a statistically significant difference. The importance of scan body geometry and the amount of exposed scan surface for accurate digital implant position transfer has also been emphasized in previous investigations of intraoral implant scanning (Mizumoto & Yilmaz, 2018; Revilla-León et al., 2023)

Another important aspect of the present study was that the visible height of the scannable healing abutment was maintained consistently among the experimental groups. Consequently, the observed differences can be primarily attributed to variations in abutment diameter rather than differences in supramucosal height. Controlling the exposed height is particularly relevant because the amount of visible scan geometry may independently influence the ability of an intraoral scanner to identify and reconstruct an implant-related component. The standardized scanning protocol, scanning extent, scanner, environmental conditions, and reference dataset further reduced potential confounding factors. The influence of clinical scan body height on digital implant scan accuracy has been previously demonstrated, with reduced exposed scan body height being associated with changes in scanning accuracy, particularly when combined with implant angulation. Scannable healing abutments have been introduced to integrate healing and digital impression procedures and may reduce the need for repeated component manipulation during restorative treatment. Previous studies evaluating scannable or coded healing abutments have demonstrated their feasibility for transferring implant position within digital restorative workflows (Yilmaz & Abou-Ayash, 2020; Jung et al., 2022). Jung et al. evaluated the accuracy of implant impression techniques using a scannable healing abutment, while Yilmaz and Abou-Ayash described a digital intraoral implant scan technique using a combined healing abutment and scan body system. The present findings further suggest that, in addition to the concept of using a healing abutment as a scanning component, its geometric dimensions may also influence the accuracy of digital implant position transfer. (Jung et al., 2022; Yilmaz et al., 2024)

From a clinical perspective, the present findings suggest that the dimensions of a scannable healing abutment should be considered when selecting components for a digital implant workflow. Larger diameters may provide more favorable scanning trueness, particularly in terms of overall three-dimensional and linear positional accuracy. Nevertheless, the absence of a significant difference in angular deviation between D5 and D6 indicates that selecting the largest possible diameter may not necessarily provide additional improvement for every accuracy parameter. Component selection must therefore also consider anatomical limitations, available restorative space, peri-implant soft tissue conditions, and the compatibility of the healing abutment with the planned restoration. Several limitations should be considered when interpreting these findings. First, this study was performed under in vitro conditions, which allowed variables to be tightly controlled but did not reproduce clinical factors such as saliva, blood, patient movement, limited mouth opening, tongue interference, variable ambient lighting, or subgingival soft-tissue conditions. Differences between laboratory and intraoral scanning conditions have previously been reported and may influence the accuracy of intraoral implant digitization (Flügge et al., 2016). Second, only one intraoral scanner, one scannable healing abutment design, and a limited range of diameters were evaluated. Differences in scanner technology, scan-body geometry, surface characteristics, and software algorithms may produce different results (Mizumoto & Yilmaz, 2018; Revilla-León et al., 2020). Third, the present study evaluated trueness under a standardized scanning protocol and did not assess precision between repeated scans as a separate outcome. Finally, although statistically significant differences were identified, the clinical relevance of the magnitude of these differences should be further investigated in relation to the fit and performance of definitive implant-supported restorations.

Future studies should therefore evaluate different scannable healing abutment geometries, diameters, and supramucosal heights using multiple intraoral scanning systems. Clinical studies are also required to determine whether the improvements in scanning trueness observed with larger diameters translate into meaningful improvements in definitive prosthesis accuracy and clinical outcomes.

Within the limitations of this in vitro study, the diameter of the scannable healing abutment significantly influenced the trueness of intraoral scanning. Increasing the abutment diameter resulted in progressively lower RMS and linear deviations, with significant differences among all diameter groups. Angular deviation was significantly greater in D4 than in D5 and D6; however, no significant difference was observed between D5 and D6. Therefore, larger scannable healing abutment diameters generally improved scanning trueness, particularly in terms of overall three-dimensional and linear positional accuracy, whereas the improvement in angular accuracy appeared to plateau beyond D5.

REFERENCES

Batak, B., Yilmaz, B., Shah, K., Rathi, R., Schimmel, M., & Lang, L. (2020). Effect of coded healing abutment height and position on the trueness of digital intraoral implant scans. *The Journal of prosthetic dentistry, 123*(3), 466-472.

Çakmak, G., Donmez, M. B., Atalay, S., Yilmaz, H., Kökat, A. M., & Yilmaz, B. (2021). Accuracy of single implant scans with a combined healing abutment-scan body system and different intraoral scanners: An in vitro study. *Journal of dentistry, 113*, 103773.

Ender, A., & Mehl, A. (2013). Accuracy of complete-arch dental impressions: a new method of measuring trueness and precision. *The Journal of prosthetic dentistry, 109*(2), 121-128.

Flügge, T. V., Att, W., Metzger, M. C., & Nelson, K. (2016). Precision of Dental Implant Digitization Using Intraoral Scanners. *The International journal of prosthodontics, 29*(3), 277-283.

Gómez-Polo, M., Sallorenzo, A., Ortega, R., Gómez-Polo, C., Barmak, A. B., Att, W., & Revilla-León, M. (2024). Influence of implant angulation and clinical implant scan body height on the accuracy of complete arch intraoral digital scans. *The Journal of Prosthetic Dentistry, 131*(1), 119-127.

Goujat, A., Abouelleil, H., Colon, P., Jeannin, C., Pradelle, N., Seux, D., & Grosgogeat, B. (2019). Marginal and internal fit of CAD-CAM inlay/onlay restorations: A systematic review of in vitro studies. *The Journal of prosthetic dentistry, 121*(4), 590-597.

Jung, H. T., Kim, H. Y., Song, S. Y., Park, J. H., & Lee, J. Y. (2022). Accuracy of implant impression techniques with a scannable healing abutment. *The Journal of Prosthetic Dentistry, 128*(4), 729-734.

Lee, H. N., Park, Y. K., Shim, J. S., & Lee, J. Y. (2026). Impact of Scannable Healing Abutment Type on the Accuracy of Implant Impression. *BioMed Research International, 2026*(1), 1061741.

Mizumoto, R. M., Alp, G., Özcan, M., & Yilmaz, B. (2019). The effect of scanning the palate and scan body position on the accuracy of complete-arch implant scans. *Clinical implant dentistry and related research, 21*(5), 987-994.

Mizumoto, R. M., & Yilmaz, B. (2018). Intraoral scan bodies in implant dentistry: A systematic review. *The Journal of prosthetic dentistry, 120*(3), 343-352.

Moron-Conejo, B., Stran-Lo Giudice, A. F., Salido, M. P., Berrendero, S., Madrigal, C., & Pradies, G. (2025). Influence of three coded healing abutment design on intraoral scan accuracy: a comparative in vitro study. *Journal of Dentistry, 163*, 106180.

Revilla-León, M., Gohil, A., Barmak, A. B., Zandinejad, A., Raigrodski, A. J., & Alonso Pérez-Barquero, J. (2023). Best-Fit Algorithm Influences on Virtual Casts' Alignment Discrepancies. *Journal of Prosthodontics, 32*(4), 331-339.

Sanda, M., Miyoshi, K., & Baba, K. (2021). Trueness and precision of digital implant impressions by intraoral scanners: a literature review. *International Journal of Implant Dentistry, 7*(1), 97.

Talesara, V., Bennani, V., Aarts, J., Ratnayake, J., Khurshid, Z., & Brunton, P. (2023). Accuracy of digitally coded healing abutments: A systematic review. *The Saudi dental journal, 35*(8), 891-903.

Yilmaz, H., Arinc, H., Cakmak, G., Atalay, S., Donmez, M. B., Kokat, A. M., & Yilmaz, B. (2024). Effect of scan pattern on the scan accuracy of a combined healing abutment scan body system. *The Journal of prosthetic dentistry, 131*(1), 110-118.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.



Copyright: © 2026 by the authors. This is a fully open-access article distributed under the terms of the Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0).