EVALUATION OF THE INFLUENCE OF IMPLANT SCAN BODY SURFACE ROUGHNESS ON INTRAORAL SCANNING ACCURACY: AN IN VITRO STUDY

Polykarpos M. Athanasius[1*], Mohamed Sherine El Attar[2], Ingy S. Soliman[3]

ABSTRACT

INTRODUCTION: Precise and reliable digital impressions obtained through intraoral scanning techniques are crucial for ensuring accurate prosthetic fit and optimal patient outcomes. Advancements in technology and scanning methodologies have significantly improved the accuracy of intraoral scanning, allowing for enhanced clinical efficiency and better treatment planning in dental procedures.

OBJECTIVE: The aim of the study is to assess how various levels of surface roughness of scan body and the scanning direction affects the accuracy of intraoral scanning.

METHODS: 3D Printed cast with 4 implant analogs placed parallel was fabricated. A total of 40 scans was subdivided equally into four groups based on the scan body surface roughness; Smooth, Rough 1 (R1), rough 2 (R2), and combination (smooth & rough). Cast was scanned using a laboratory scanner (reference) and an intraoral scanner will be used to scan each group. Superimposition of extraoral scan and intraoral scan of each group was done using best fit algorithm.

RESULTS: The two-way ANOVA results indicate that both scan body roughness and scan direction significantly affect trueness ($p < 0.001$), with partial eta squared values of 0.513 and 0.468, respectively. Additionally, there is a statistically significant interaction between scan body roughness and scan direction ($p = 0.037$, partial $\eta^2 = 0.230$)

CONCLUSION: Smoother surfaces enhance data acquisition by reducing optical distortions caused by light scattering, while rougher textures introduce errors that compromise clinical outcomes

KEYWORDS: Roughness, Scan body, Intraoral scanning (IOS), Accuracy.

RUNNING TITTLE: Influence Of Surface Roughness Of Scanbody On Intraoral Scanning Accuracy.

1-Master's Student, Department of Prosthodontics, Faculty of Dentistry, Alexandria University, Alexandria, Egypt.
1-Teaching Assistant of Prosthodontics, Department of Prosthodontics, College of Dentistry, Arab Academy for Science, Technology and Maritime Transport (AASTMT), El-Alamein, Egypt
2-Professor, Department of Prosthodontics, Faculty of Dentistry, Alexandria University, Alexandria, Egypt
3- Associate Professor, Department of Prosthodontics, Faculty of Dentistry, Alexandria University, Alexandria, Egypt

Corresponding Author:
bolykarbos.mimi.dent@alexu.edu.eg

INTRODUCTION

The latest developments in digital dentistry have significantly improved the planning and rehabilitation process for patients suffering from partial or complete edentulism (1).

The transition from traditional impression techniques to digital intraoral scanning has led to significant benefits, such as increased comfort for patients, eliminating the discomfort associated with impression materials and techniques- the elimination of material-related inaccuracies like shrinkage and expansion, reduced clinical chair time, and improved accuracy in prosthetic design[(2)].

Although IOS technology has shown reliable performance in scanning partially edentulous patients, its application to completely edentulous cases presents unique challenges. Factors such as the absence of fixed anatomical landmarks, the intricacy of scanning protocols, and operator expertise significantly influence outcomes. Additionally, discrepancies in precision and accuracy between various IOS systems emphasize the importance of evaluating their performance under diverse clinical scenarios[(3)].

Scan bodies are crucial in the digital workflow, acting as a bridge between the intraoral environment and CAD software. They accurately transfer the 3D position of dental implants to the digital realm, enabling precise digital impressions.

Several factors affect intraoral scanning regarding the scan body itself include material composition, surface texture, shape and geometry, size and dimensions, positioning and stability, compatibility with the scanner, markings and features, and wear and contamination. The accuracy of intraoral scanning is significantly affected by the surface roughness of the scan body. The surface characteristics of the scan body can directly impact the precision of the digital impression, potentially affecting the overall fit and functionality of the final restoration[(4)].

This study aimed to assess how scan body surface roughness affects the accuracy of intraoral scans for edentulous arches. By employing a comprehensive research methodology, including experimental studies and data analysis, we aim to uncover the effect of different surface roughness levels on scanning accuracy.

The null hypothesis states that there is no significant effect of implant scan body surface roughness on the trueness and precision of the intraoral scanning systems under evaluation.

MATERIALS AND METHODS

1- Sample preparation

A-Fabrication of the model

A maxillary completely edentulous virtual model was designed using Exocad software, in which four Neobiotech implant analogs were virtually situated in the dental arch at the following positions: right first molar (implant 1), right canine (implant 2), left canine (implant 3), and left first molar (implant 4)[5].

The 3D virtual model was printed using 3D-printer (Creality Halot-Mage Pro CL-103 - 3D-printer) and gingival mask was printed to resemble the soft tissue. Digital analogues (Neobiotech analog)) were inserted in pre-determined positions in the printed model and four scan bodies were attached to them and the model was scanned with (Medit T710; Medit Corp, Seoul, Korea) to obtain reference scans.

B-Modification of scan body (sandblasting)

For group (R1), Sandblasting was performed on the polished surface of the PEEK scan body using an airborne particle abrader with 90-110 µm alumina particles at a pressure of 0.2 MPa. for ten strokes in one direction per each surface starting from the bevel surface. The same for group (R2) with 20 strokes for each surface[6]. (Figure 1)

2-Intra oral scanning

Digital scans were done using (Medit i700 Corp, Seoul, Korea) IOS. Ten scans were done for completely edentulous model with the smooth scan bodies in position twice (once from left quadrant to the right quadrant and once from right to left). The scanning sequence followed the manufacturer's guidelines as outlined in the IOS manual. With average time 7 seconds for each scan

Then the roughened scan bodies(R1&R2) will be placed and ten scans will be made in both directions.

Then two smooth scan bodies will be placed in right side and two roughened will be placed in left side and ten scans will be made in both directions. (Figure 2)

3-Outcome assessment

For analysis, STL files were generated from the scan data. Using Geomagic Control X 2018 (3D Systems Corp), all the scans were aligned with a reference scan using a best-fit alignment method (Figure 3)

Angular and overall deviations were quantified by superimposing computer-aided design (CAD) models onto the scanned surfaces of the scan bodies. Angulation was determined as the angular difference between the vectors defining the scan bodies' longitudinal axes in three-dimensional space. Trueness and precision were evaluated for all measured variables and analyzed across groups with differing scan body surface roughness levels.[2, 7]. (Figure 4) (Figure 5)

4-Statistical analysis

Normality of variables was checked using Shapiro Wilk test and Q-Q plots. Data were presented using mean and standard deviation (SD) in addition to 95% Confidence intervals (CI). To assess the effect of scan body surface roughness and scan direction on trueness, precision and angular deviation. Pairwise comparisons were done with Bonferroni correction to adjust type I error.

All tests were two tailed and the significance level was set at p value<0.05. Data was analyzed using IBM SPSS version 23 for Windows, Armonk, NY, USA

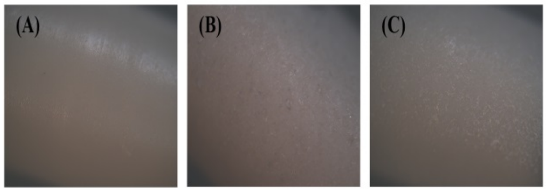

Figure 1: Representative implant scan body used on each group. A, Smooth group. B, R1 group. C, R2 group.

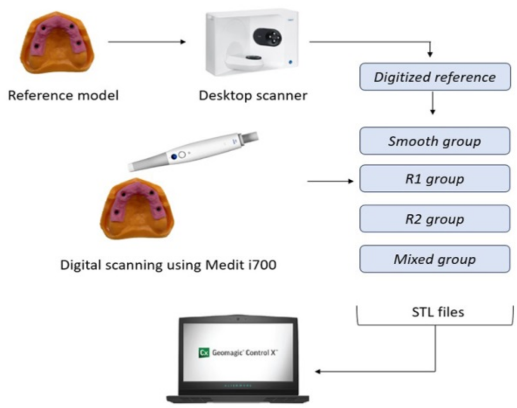

Figure 2: Research methodology.

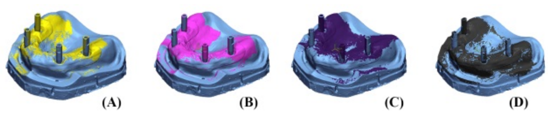

Figure 3: Representative best-fit algorithm of each group where blue model is reference file. A, Smooth group. B, R1 group. C, R2 group. D, Mixed group.

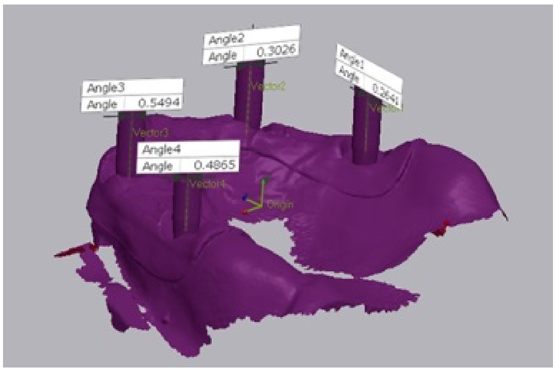

Figure 4: Angular measurement discrepancies measured on implant scan bodies between reference file and experimental scans.

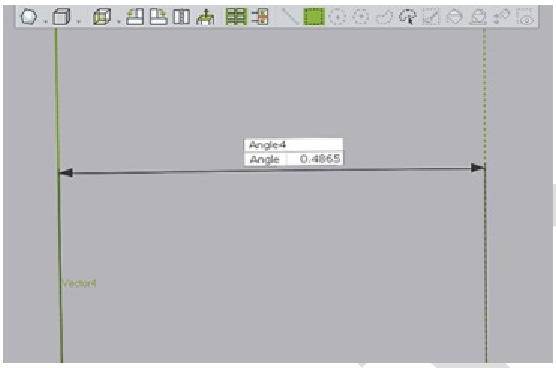

Figure 5: Angulation measurement between scan bodies.

RESULTS

Table 1 shows Descriptive trueness ±precision values (µm) between the study groups in which Smooth group showed the lowest mean and standard deviation (0.09 ±0.02), for group R1(0.19 ±0.09), for group R2 (0.18 ±0.08) and for mixed group (0.20 ±0.06).

The two-way ANOVA results indicate that both scan body roughness and scan direction significantly affect trueness ($p < 0.001$), with partial eta squared values of 0.513 and 0.468, respectively. Additionally, there is a statistically significant interaction between scan body roughness and scan direction ($p = 0.037$, partial $\eta^2 = 0.230$)

Means, standard deviations, and 95% confidence intervals are presented in Table 2. In the angular deviation analysis. Smooth group showed the least mean and standard deviation (0.23 ±0.08) followed by mixed group (0.28 ±0.10) but both R1&R2 showed higher angular deviation (0.35 ±0.05) & (0.31 ±0.05) respectively

The two-way ANOVA results indicate that scan body roughness significantly affect angular deviation ($p < 0.001$), with partial eta squared values of 0.273. Additionally, results indicate that both scan direction and interaction between scan body roughness and scan direction has no statistically significant effect on angular deviation ($p = 0.369$, partial $\eta^2 = 0.025$) and ($p = 0.979$, partial $\eta^2 = 0.006$) respectively. (figure 6)

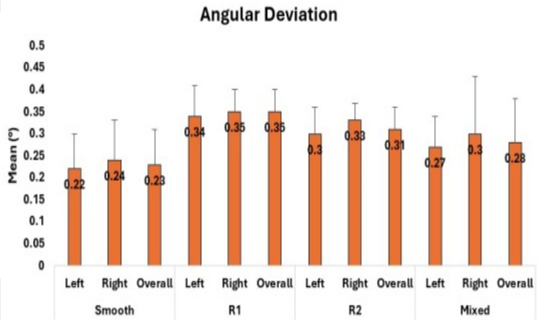

Figure 6: Descriptive angular deviation values (°) between the study groups.

Table 1: Descriptive trueness ±precision values (µm) between the study groups

Scan bodies	Scan direction	Mean ±SD	95% CI	*p* value
Smooth	Left	0.09 ±0.03	0.04, 0.13	0.702
	Right	0.09 ±0.02	0.05, 0.14	
	Overall	0.09 ±0.02	0.07, 0.11	
R1	Left	0.13 ±0.08	0.09, 0.18	0.041*
	Right	0.25 ±0.07	0.20, 0.29	
	Overall	0.19 ±0.09	0.12, 0.26	
R2	Left	0.11 ±0.04	0.07, 0.16	0.001*
	Right	0.24 ±0.04	0.20, 0.29	
	Overall	0.18 ±0.08	0.12, 0.23	
Mixed	Left	0.17 ±0.04	0.12, 0.21	0.015*
	Right	0.24 ±0.04	0.20, 0.29	
	Overall	0.20 ±0.06	0.16, 0.24	
p value	Smooth vs R1<0.001*, Smooth vs R2=0.002*, Smooth vs mixed<0.001*			

*Statistically significant difference at *p* value<0.05

Table 2: Descriptive angular deviation values (°) between the study groups

Scan bodies	Scan direction	Mean ±SD	95% CI	*p* value
Smooth	Left	0.22 ±0.08	0.15, 0.29	NS
	Right	0.24 ±0.09	0.17, 0.31	
	Overall	0.23 ±0.08	0.17, 0.29	
R1	Left	0.34 ±0.07	0.27, 0.42	NS
	Right	0.35 ±0.05	0.28, 0.42	
	Overall	0.35 ±0.05	0.31, 0.39	
R2	Left	0.30 ±0.06	0.23, 0.37	NS
	Right	0.33 ±0.04	0.26, 0.40	
	Overall	0.31 ±0.05	0.28, 0.35	
Mixed	Left	0.27 ±0.07	0.20, 0.34	NS
	Right	0.30 ±0.13	0.23, 0.37	
	Overall	0.28 ±0.10	0.21, 0.36	
p value	Smooth vs R1=0.002*, Smooth vs R2=0.025*			

*Statistically significant difference at *p* value<0.05, NS: Not significant

DISCUSSION

This study aimed to evaluate the impact of different surface roughness levels of scan bodies on the accuracy of intraoral scanning. The findings led to the rejection of the null hypothesis that surface roughness does not affect the trueness and precision of the intraoral scanner tested. Significant angular and 3D surface differences were quantified among the complete arch digital scans obtained using rough scan bodies. The results showed that more deviation has occurred when increasing the surface roughness of the scan body. Also, the scanning direction affects the accuracy of the IOS tested.

To the authors' knowledge, no prior study has examined the impact of implant scan body surface roughness on the accuracy of full arch digital scans. Previous research has primarily focused on assessing other modifications in scan bodies in relation to complete arch digital accuracy.[8, 9].

The highest discrepancies were observed in the R1 and R2 groups. These errors likely resulted from acute angles and overlaps introduced by implant scan body (ISB) modifications, creating data noise that resisted standard postprocessing correction[10].

The findings of this research demonstrate a significant relationship between the surface roughness of implant scan bodies and the accuracy of intraoral scanning (IOS). Surface roughness, a critical physical property, directly affects the interaction between light and the scan body during digital impression acquisition. Smooth surfaces allow for uniform light reflection, reducing optical distortions and noise during scanning. In contrast, rough surfaces scatter light unpredictably, leading to incomplete or imprecise data acquisition. This phenomenon was particularly evident in the present study, where scan bodies with higher surface roughness exhibited greater deviations in distance and angular measurements compared to those with smoother finishes[10].

Intraoral scanner Medit i700, rely on triangulation-based scanning technology, which utilizes structured light patterns to detect geometric features of scan bodies. However, irregularities in surface texture can disrupt these systems, leading to inaccuracies in data capture and impacting the precision of digital models used for implant placement and prosthetic design[11, 12].

For the Medit i700, surface roughness exceeding 50 µm can create light scattering that disrupts the projected grid pattern recognition essential for accurate scanning. When the surface of the scan body is too rough, it interferes with the scanner's ability to effectively triangulate the position of points on the surface. This disruption can lead to inaccuracies in the digital model generated by the scanner, resulting in potential misfit restorations or prosthetics. Studies have shown that smoother surfaces facilitate more accurate data acquisition by reducing light scattering and noise during scanning[11, 13, 14].

The Medit i700 has demonstrated high precision and trueness in several studies. For instance, Verniani et al. found that while it performed well on supragingival preparations, its accuracy was affected when scanning subgingival margins due to increased complexity in capturing light reflections from less accessible areas. This suggests that while the Medit i700 offers advanced features and rapid scanning capabilities, it remains sensitive to surface irregularities.

From a clinical perspective, The present study reinforces the necessity of selecting suitable scan bodies with optimized surface characteristics to ensure accurate digital impressions. Clinicians should prioritize using scan bodies with smoother surfaces to minimize potential inaccuracies caused by light scattering. Additionally, understanding that rougher surfaces could compromise scanning performance allows practitioners to make informed decisions about materials and techniques used in digital workflows.

The study showed that angular deviation of smooth group has no statistically significance compared to that of the mixed group so it is recommended to combine the use of new (smooth) scan bodies with old scratched ones to minimize potential inaccuracies and enhance scanning performance.
Moreover, manufacturers should consider refining their scan body designs to reduce surface roughness while maintaining optimal bonding properties. For example, slight micro-roughness may be necessary for bonding but should not exceed thresholds that interfere with scanning accuracy. Providing detailed specifications regarding scan body surface properties would further assist clinicians in optimizing their workflows.

The results obtained may have been influenced by certain limitations, including the assessment of only one IOS[8, 15], The reference scan was generated with the aid of a laboratory-based scanner [9], and reliance on reverse engineering software rather than dental-specific software. Additionally, a single operator conducted the cast scanning to maintain standardization[16], This research used a protocol lacking validation for completely edentulous patients. Results are specific to the tested ISB type and cannot be generalized to other manufacturers or materials, yet they emphasize the ISB's critical impact on accuracy. Future *in vivo* studies are essential to validate these findings and ensure consistency in prosthetic precision.

CONCLUSION

From the data obtained in this in vitro study, we can conclude the following:
1. Smoother surfaces enhance data acquisition by reducing optical distortions caused by light scattering, while rougher textures introduce errors that compromise clinical outcomes
2. Combination between rough and smooth scan bodies enhance scanning performance and minimize potential inaccuracies

CONFLICT OF INTEREST

The authors confirm that they are free from conflicts of interest.

ACKNOWLEDGEMENTS

We extend our gratitude to Dr. Hams Abdelrahman for her assistance with data interpretation.

FUNDING

This study did not receive funding from any public, commercial, or not-for-profit organizations

REFERENCES

1. Pereira ALC, Curinga MRS, Segundo HVM, Carreiro AdFP. Factors that influence the accuracy of intraoral scanning of total edentulous arches rehabilitated with multiple implants: A systematic review. JPD. 2023;129(6):855-62.
2. Rutkūnas V, Gedrimienė A, Husain NA-H, Pletkus J, Barauskis D, Jegelevičius D, et al. Effect of additional reference objects on accuracy of five intraoral scanners in partially and completely edentulous jaws: An in vitro study. JPD. 2023;130(1):111-8.
3. Lawand G, Ismail Y, Revilla-León M, Tohme H. Effect of implant scan body geometric modifications on the trueness and scanning time of complete arch intraoral implant digital scans: an in vitro study. JPD. 2024;131(6):1189-97.
4. Arcuri L, Pozzi A, Lio F, Rompen E, Zechner W, Nardi A. Influence of implant scanbody material, position and operator on the accuracy of digital impression for complete-arch: A randomized in vitro trial. J Prosthodont Res. 2020;64(2):128-36.
5. Gómez-Polo M, Álvarez F, Ortega R, Gómez-Polo C, Barmak AB, Kois JC, 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. 2022;121:104122.
6. Hata K, Komagata Y, Nagamatsu Y, Masaki C, Hosokawa R, Ikeda H. Bond strength of sandblasted PEEK with dental methyl methacrylate-based cement or composite-based resin cement. Polymers (Basel). 2023;15(8):1830.
7. Schimmel M, Akino N, Srinivasan M, Wittneben J-G, Yilmaz B, Abou-Ayash S. Accuracy of intraoral scanning in completely and partially edentulous maxillary and mandibular jaws: an in vitro analysis. Clin Oral Investig. 2021;25:1839-47.
8. Amornvit P, Rokaya D, Sanohkan S. Comparison of accuracy of current ten intraoral scanners. Biomed Res Int. 2021;2021(1):2673040.
9. Bohner LOL, Canto GDL, Marció BS, Laganá DC, Sesma N, Neto PT. Computer-aided analysis of digital dental impressions obtained from intraoral and extraoral scanners. JPD. 2017;118(5):617-23.
10. Mizumoto RM, Yilmaz B, McGlumphy Jr EA, Seidt J, Johnston WM. Accuracy of different digital scanning techniques and scan bodies for complete-arch implant-supported prostheses. JPD. 2020;123(1):96-104.
11. Verniani G, Casucci A, Ferrero E, Gaeta C, Cagidiaco EF. Accuracy evaluation of digital impressions on horizontal finish line designs. Journal of Osseointegration. 2023;15(4):276-83.
12. Osman RB, Alharbi NM. Influence of scan technology on the accuracy and speed of intraoral scanning systems for the edentulous maxilla: An in vitro study. Journal of Prosthodontics. 2023;32(9):821-8.
13. Sorrentino R, Ruggiero G, Leone R, Cagidiaco EF, Di Mauro MI, Ferrari M, et al. Trueness and precision of an intraoral scanner on abutments with subgingival vertical margins: an in vitro study. Journal of Dentistry. 2024;144:104943.
14. Alkadi L. A comprehensive review of factors that influence the accuracy of intraoral scanners. Diagnostics. 2023;13(21):3291.
15. Richert R, Goujat A, Venet L, Viguie G, Viennot S, Robinson P, et al. Intraoral scanner technologies: a review to make a successful impression. Journal of healthcare engineering. 2017;2017(1):8427595.
16. Giménez B, Özcan M, Martínez-Rus F, Pradíes G. Accuracy of a digital impression system based on parallel confocal laser technology for implants with consideration of operator experience and implant angulation and depth. International Journal of Oral & Maxillofacial Implants. 2014;29(4).