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Influence of Preparation Height on Digital Impression Trueness: A Comparative Study of 2 Intraoral Scanners

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Abstract

Background: This study aims to evaluate the effect of crown preparation height on the trueness of intraoral scanners (IOS) by comparing 2 different scanners at varying preparation heights.

Methods: A typodont model was prepared with a chamfer finish line at 2 different crown heights (7 mm and 5 mm). A laboratory scanner (E1, 3Shape, Copenhagen, Denmark) was used to obtain a reference scan. Intraoral scanners, Trios 3 (3Shape, Copenhagen, Denmark) and iTero Element 5D Plus (Align Technologies, San Jose, USA), were used for digital impressions. Ten scans were taken for each preparation height per scanner, resulting in a total of 40 scans. The trueness was assessed using Geomagic Control X software by calculating root mean square (RMS) error values between IOS scans and the reference model. Statistical analysis was performed using IBM SPSS v29. An independent sample *t*-test was applied ($\alpha = 0.05$).

Results: The iTero scanner exhibited significantly lower RMS values (0.040 ± 0.005 mm) compared to the Trios 3 scanner (0.049 ± 0.006 mm, $P < .001$), indicating higher overall trueness. The Trios 3 scanner showed a significant difference in trueness between 5 mm (0.051 ± 0.005 mm) and 7 mm (0.046 ± 0.006 mm) preparations ($P = .043$), demonstrating improved trueness with greater preparation height. In contrast, the iTero scanner maintained consistent trueness across both preparation heights ($P = .451$).

Conclusion: The trueness varies depending on the intraoral scanner used. Crown height is a factor that affects trueness depending on the scanner.

Keywords: Intraoral scanner, preparation height, trueness

What is already known on this topic?

- *Digital impressions using intraoral scanners are widely used in prosthodontics due to their high trueness and patient comfort.*
- *The trueness of intraoral scanners is influenced by multiple factors, including scanning distance, ambient lighting, operator experience, and patient-related factors (saliva, restorations, edentulous space).*
- *Although preparation geometry and scanning distance are believed to affect intraoral scanner trueness, the specific impact of preparation height has not been fully investigated.*

What does this study add on this topic?

- *This study provides new insights into how preparation height affects the trueness of intraoral scanners.*
- *The findings indicate that preparation height influences the trueness of intraoral scans, depending on the scanner.*
- *These results contribute to improving digital workflows by addressing a critical gap in the literature regarding preparation geometry and scanning trueness.*

INTRODUCTION

In recent years, digital dentistry has emerged as a transformative approach providing a compelling alternative to conventional workflows, particularly through the use of intraoral scanners for digital impressions. This technology offers various benefits, including a reduction in patient visits and enhanced comfort during the impression process.[1] Digital impressions yield highly accurate restorations, minimizing errors and improving outcomes.[2] The ability to archive data digitally also streamlines treatment planning and record-keeping.[3]

The trueness of digital scanners is paramount in the realm of digital dentistry, as it directly influences the fit of restorations produced from digital impressions. High

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trueness in scanning ensures that the resulting crown exhibits precise marginal adaptation on the prepared finish line, which is crucial for both functional and esthetic outcomes.[4] Restorations exhibiting marginal discrepancies can lead to various complications, including secondary caries and periodontal problems, difficulties in oral hygiene maintenance, and compromised esthetics.[5] Moreover, accurately manufactured restorations enhance the overall success of dental procedures, as they are less likely to require adjustments or replacements. Ultimately, the reliability of intraoral scanners not only impacts the technical aspects of dental work but also plays a vital role in patient satisfaction and oral health.[6]

The trueness of intraoral scanners is influenced by various factors, including operator-related considerations such as experience, scanning pattern, and rescanning or overlapping images.[7,8] Additionally, the technology of the scanner itself plays a crucial role, with aspects like calibration quality and the size of the scanning head impacting performance. Environmental conditions, particularly ambient lighting, can also affect accuracy.[8] Furthermore, patient-specific factors, including tooth type, existing restorations, surface characteristics, humidity in the oral cavity, diastemas, edentulous areas, and the presence of implant scan bodies, contribute to the overall accuracy of the scanning process.[9] Each of these elements must be carefully considered to optimize the trueness of intraoral scanning.

In addition to these factors, previous studies suggest that the geometric characteristics of the preparation, along with the scanner's distance from the preparation, are thought to have a significant impact on trueness.[10-12] It is important to understand how these variables interact, as they can potentially affect the quality of intraoral scans and the resulting restorations.

This study will specifically address the preparation geometry, with a particular emphasis on the height of the preparation. The height of the dental preparation is crucial for retention; however, shorter preparations can be made in certain cases where specific material thickness is required to achieve optimal esthetics and functionality for the restoration. When determining the ideal preparation height, several factors must be considered. Firstly, the type of restoration plays a significant role; for instance, if the underlying tooth is discolored or has undergone endodontic treatment, it may need to be assessed for how much remaining tooth structure is available. If the underlying tooth needs to be masked, a thicker material may be necessary, which could dictate the need for a shorter preparation height to accommodate this. Additionally, different types of materials can require varying preparation dimensions.

Although it is believed that the scanning distance and the geometry of the preparation affect the intraoral scanners (IOS) trueness, there have not been sufficient studies in the literature regarding the relationship between preparation height and the trueness of intraoral scanners. In this study, the trueness of intraoral scanners will be evaluated using different intraoral scanner technologies across various preparation heights.

The aim of this study is to evaluate the performance of 2 different intraoral scanners at varying preparation heights and to investigate the effect of preparation height on IOS trueness. The null hypothesis is defined as "Differences in preparation height do not affect the trueness of intraoral scanners." The second hypothesis of the study is that "There is no difference in trueness between the intraoral scanners."

MATERIALS AND METHODS

This study does not require ethics committee approval or informed consent as it does not involve human or animal subjects.

This in vitro study investigated the effect of preparation height on the trueness of intraoral scanners. A typodont tooth (Frasaco, Frasaco GmbH, Tettnang, Germany) corresponding to tooth number 15 (maxillary right second premolar) was prepared with a chamfer finish line. Two crown preparations of varying heights were done to evaluate the trueness of 2 different intraoral scanners. Both preparations were performed on the same typodont consecutively to eliminate other factors that could potentially influence trueness.

Initially, the preparation height was set to 7 mm (Figure 1). The preparation was standardized using a silicone index to guide reduction and a suitable depth gauge bur to ensure uniform reduction. The preparation height of the prepared typodont was measured using a periodontal probe to confirm the final reduction. A silicone index of the unprepared typodont was created, sectioned along the midline, and used to visually inspect and verify the adequacy of the preparation by observing the cross-section. The preparations were performed by a single experienced operator, and all scans were also conducted by the same individual. This approach eliminated potential errors arising from variability between different operators performing the preparations and scans.

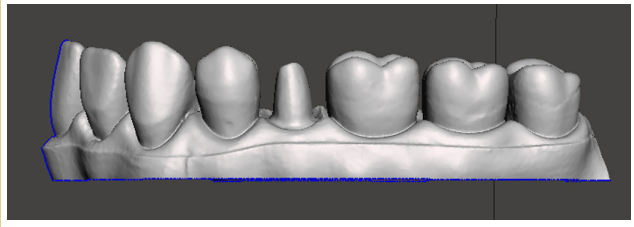

Figure 1. Prepared tooth model with 7 mm preparation height.

The prepared typodont tooth to a height of 7 mm was positioned in a master model (Frasaco, Frasaco GmbH, Tettnang, Germany) representing a full arch, and a reference scan was obtained with a high-precision laboratory-grade desktop scanner (E1, 3Shape, Copenhagen, Denmark). The images were then exported as standard tessellation language files. Following the scanning of the master model, intraoral scans were performed using 2 different intraoral scanners.

Intraoral scans were performed for half-jaw sections using 2 different intraoral scanners: Trios 3 (3Shape, Copenhagen, Denmark) and iTero Element 5D (Align Technologies, San Jose, California, USA). Ten scans were performed for the 7 mm preparation height with each intraoral scanner. Subsequently, the preparation height was reduced to 5 mm freehand and compared to the silicone index obtained from the initially unprepared tooth (Figure 2). The preparation depth and dimensions were measured using a periodontal probe. The same scanning procedures were repeated for the 5 mm preparation. In total, 40 intraoral scans were collected (n=40; 20 scans per scanner, divided equally between the 2 preparation heights).

The trueness of the intraoral scans was evaluated using Geomagic Control X software. Superposition and mapping were performed for each preparation height (7 mm and 5 mm) by comparing the intraoral scans to their respective master model reference scans (Figure 3). Within Geomagic software, the scans underwent initial alignment in the primary stage. Following this, all regions except the prepared tooth were designated as reference areas for subsequent best fit alignment. Root mean square (RMS) error values were used as the primary measure of trueness. Trueness was assessed specifically at the crown preparation finish line to determine the deviation between the scanned data and the reference model (Figure 4).

Statistical analyses were performed using IBM SPSS v29 software (IBM Corp., Armonk, NY, USA). The normality of data distribution was evaluated through visual (histograms, Q-Q plots) and analytical methods (Shapiro–Wilk test). Descriptive statistics were presented as mean ± SD. Initial comparisons between groups were conducted using Independent Samples *t*-tests. Additionally, a two-way ANOVA was performed to examine the main effects of scanner type and preparation height, as well as their interaction effect on RMS values. Pair-wise *t*-test results are presented in Tables 1 and 2, while factorial effects were evaluated with two-way ANOVA. The significance level was set at $\alpha = 0.05$ for all tests.

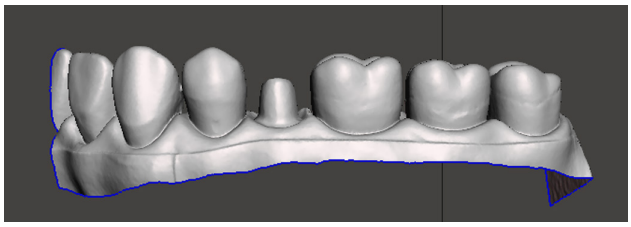

Figure 2. Prepared tooth model with 5 mm preparation height.

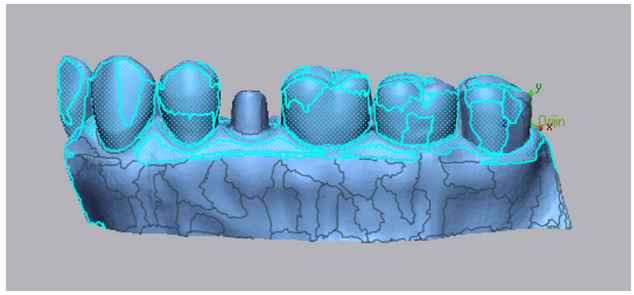

Figure 3. Best fit alignment of the reference data with intraoral scans.

RESULTS

The iTero scanner exhibited significantly lower overall RMS values (mean ± SD: 0.040 ± 0.005 mm) compared to the Trios 3 scanner (mean ± SD: 0.049 ± 0.006 mm) (Table 1), indicating higher overall trueness ($P < .001$, confirmed by two-way ANOVA main effect for scanner type: ($F(1,36) = 26.541$, $P < .001$). The two-way ANOVA also revealed a statistically significant interaction effect between scanner type and preparation height on RMS values ($F(1,36) = 4.516$, $P = .041$). This interaction indicates that the influence of preparation height on scanning trueness was dependent on the specific intraoral scanner used.

When analysing trueness by preparation height, reflecting this interaction, the Trios 3 scanner showed a significant difference between 5 mm (mean ± SD: 0.051 ± 0.005 mm) and 7 mm (mean ± SD: 0.046 ± 0.006 mm) preparations ($P = .043$), with improved trueness observed for the 7 mm preparation height (Table 2). In contrast, the iTero scanner showed no statistically significant difference in trueness between the 5 mm (mean ± SD: 0.039 ± 0.005 mm) and 7 mm (mean ± SD: 0.041 ± 0.005 mm) preparations ($P = .451$), maintaining consistent trueness across both preparation heights (Table 2, Figure 5). The main effect for preparation height in the two-way ANOVA was not statistically significant overall ($F(1,36) = 1.169$, $P = .287$).

DISCUSSION

The present study aimed to evaluate the impact of preparation height on the trueness of IOS and to determine whether different IOS devices exhibit comparable trueness. The null hypothesis, which stated that differences in preparation height do not affect the trueness of intraoral scanners, was partially accepted. While no significant trueness loss was

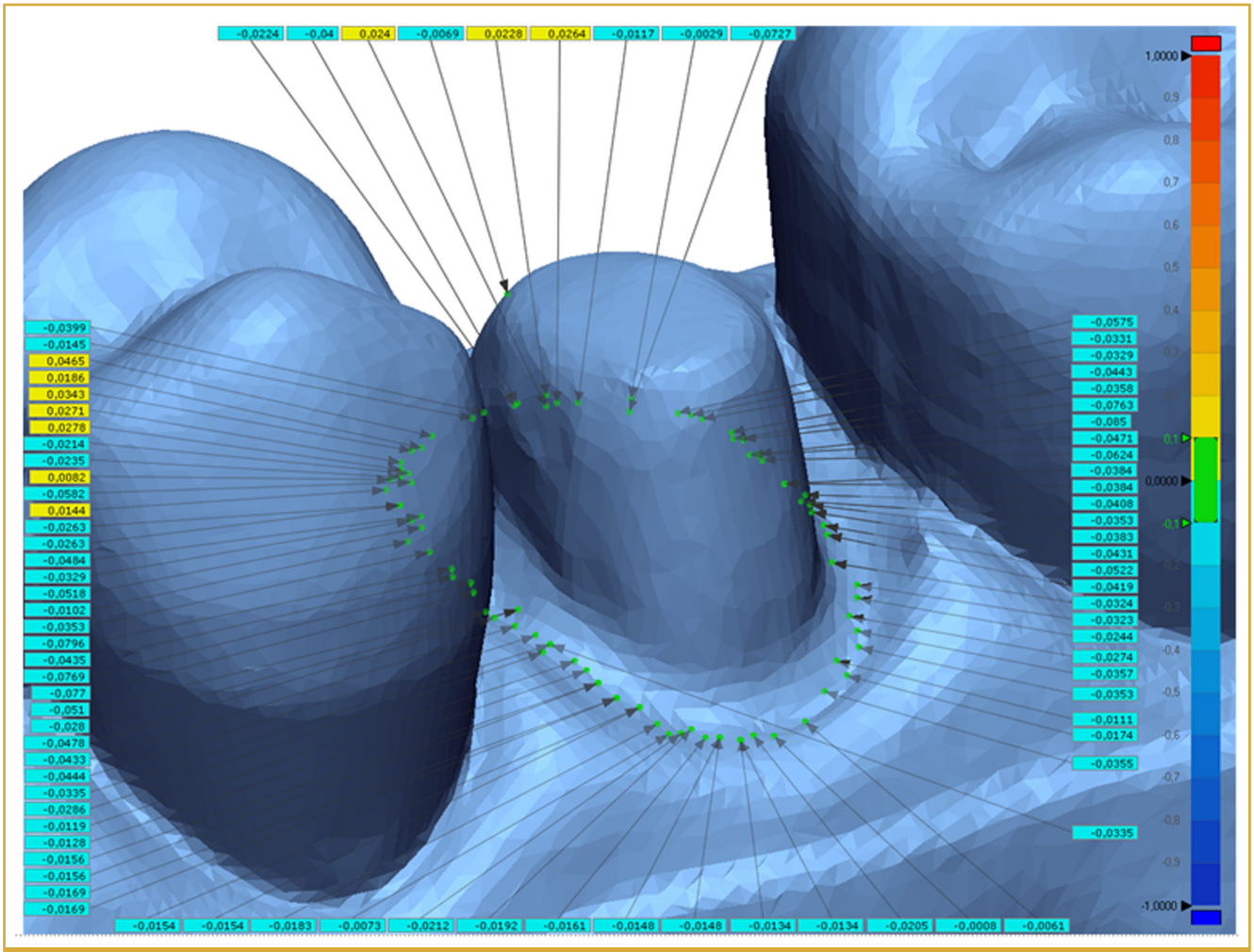

Figure 4. Selected points for root mean square measurement.

observed in the iTero scanner due to variations in preparation height, the Trios 3 scanner demonstrated an increase in trueness as preparation height increased. This finding suggests that scanner-specific differences may influence the trueness of digital impressions to variations in tooth morphology. Conversely, the second hypothesis, which proposed that there is no difference in trueness between the intraoral scanners, was rejected. The results indicated a statistically significant difference in trueness between the iTero and Trios 3 scanners, suggesting that scanner technology and algorithmic processing may contribute to variations in digital impression trueness. These findings emphasize the need for a critical assessment of IOS performance in clinical scenarios where morphological variations, such as differences in preparation height, may affect scanning trueness.

Previous studies have reported that the accuracy of intraoral scanners tends to decrease as the scanning area increases.[13,14]

Table 1. Distribution of Root Mean Square Values by Device and Preparation Length (Lab, 2024)

	Mean ± SD	*P**
Scanner		
Trios 3 (n=20)	0.049 ± 0.006	**<.001**
iTero Element 5D (n=20)	0.040 ± 0.005	
Preparation length		
5 mm (n=20)	0.045 ± 0.008	.421
7 mm (n=20)	0.043 ± 0.006	

*Independent sample t-test.

Table 2. Distribution of Root Mean Square Values by Crown Length and Scanner Type (Lab, 2024)

	Mean ± SD	*P**
iTero Element 5D		
5 mm (n=10)	0.039 ± 0.005	.451
7 mm (n=10)	0.041 ± 0.005	
Trios 3		
5 mm (n=10)	0.051 ± 0.005	**.043**
7 mm (n=10)	0.046 ± 0.006	

*Independent samples t-test.

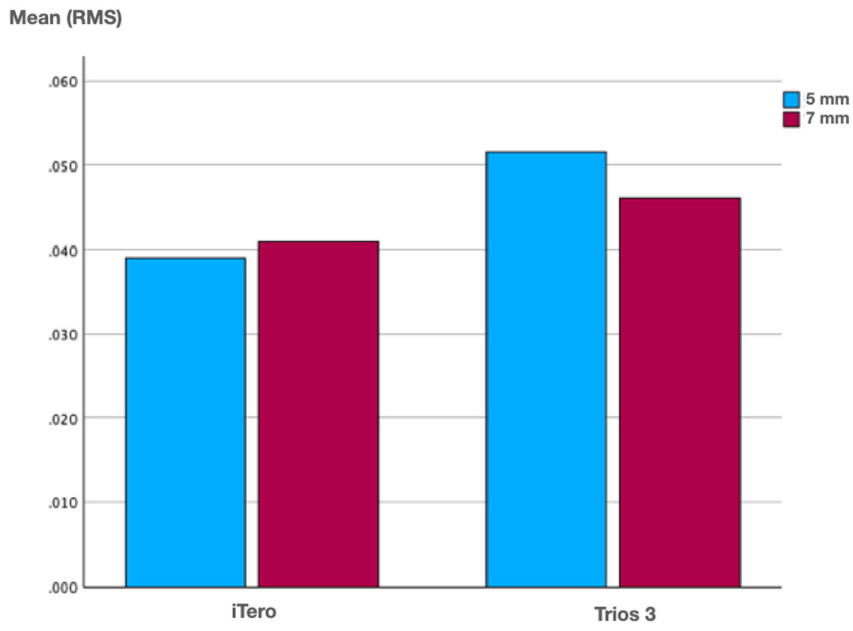

Figure 5. The distribution of the mean root mean square values by intraoral scanners and preparation height.

Therefore, in this study, partial scans were performed using intraoral scanners in order to minimize the influence of this factor on the study outcomes. In contrast, since such an effect is not observed with laboratory-grade scanners, full arch scans were deemed appropriate for acquiring the reference data.

Since there is no direct literature study investigating the effect of preparation height on the trueness of intraoral scanners, no existing study in the literature allows for a direct comparison with the findings of the present study. However, preparation height indirectly influences factors such as scanning distance and preparation geometry, which are known to affect scanning trueness. The geometric characteristics of the preparation have been shown to influence scanning trueness in various restorative procedures. In restorations such as overlay, endocrown, inlay, and onlay, preparation depth and, consequently, the distance to the scanner tip have been reported as factors affecting scanning trueness. The depth of the preparation and its distance from the scanner tip are critical factors affecting scanning trueness.[12] Greater depth can lead to decreased accuracy due to increased distance from the scanner tip, which affects the scanner's ability to capture precise details.[4,11,15] Gürpınar et al[11] evaluated the performance of 6 different intraoral scanners at 3 different endocrown cavity depths (2 mm, 3.5 mm, and 5 mm) and reported a general decrease in scanner accuracy at a depth of 5 mm. Similarly, Rotar et al[12] concluded that in overlay-type restorations, increased scanning distances can reduce the accuracy of digital impressions.

As preparation height decreases, the presence of adjacent teeth limits the ability to position the scanner tip closer to the preparation. Consequently, the scanning distance increases. Supporting this finding, Ashraf et al[10] reported that scanning accuracy is higher in extracoronal restorations compared to intracoronal restorations. This outcome is consistent with the fact that in extracoronal restorations, the distance to the scanner tip is shorter than in intracoronal restorations. In the present study, a similar trend was observed. The RMS value at the margin area of a prepared maxillary premolar with a 5 mm preparation height was higher compared to a prepared tooth with a 7 mm preparation height, indicating that as preparation height decreases, scanner trueness declines.

The question of which intraoral scanner exhibits the best performance remains a debated topic in the literature. Studies comparing different devices under varying experimental conditions have reported conflicting results. Although intraoral scanner technology has reached clinically applicable levels, research has demonstrated that numerous factors can influence scanner trueness. As a result, each experimental condition may affect scanner performance differently depending on the device being tested. While factors such as ambient lighting intensity, operator influence, the size of the scanned area, scanning strategy, and even room temperature have been standardized in experimental settings, their potential effects may vary between scanners. This variability should always be considered when interpreting results. Nevertheless, within the experimental conditions of this study, iTero Element 5D (mean ± SD:

0.040 ± 0.005) provided more accurate measurements than Trios 3 (mean ± SD: 0.049 ± 0.006) regardless of preparation height.

Preparation height is often a fixed clinical parameter that cannot be altered. However, in certain cases, such as post-core applications, the preparation height may be intentionally reduced to create additional space for restorative material, provided that retention is not compromised. In such scenarios, the findings of this study are significant in guiding clinicians by offering insight into the balance between potential benefits and drawbacks related to scanning trueness and restoration success. On the other hand, when evaluating the study results within the scope of the existing experimental conditions, certain limitations can be identified. One such limitation is that the assessment was conducted on only a single premolar tooth at 2 different preparation heights. Another limitation of this study is that, although desktop scanners were used for reference scans in previous studies, a reference scan was not performed with a much more precise industrial-type scanner.[16-18] In future studies, the number of intraoral scanners can be increased, and experimental groups can be expanded by incorporating different teeth and evaluating the effect of the presence or absence of adjacent teeth on scanning trueness.

CONCLUSION

The findings demonstrated that preparation height has a variable effect on IOS trueness depending on the scanner used. While iTero Element 5D maintained consistent trueness regardless of preparation height, the Trios 3 exhibited a significant decrease in trueness at the lower preparation height.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: This study does not require ethics committee approval as it does not involve human or animal subjects.

Informed Consent: This study does not require informed consent as it does not involve human or animal subjects.

Peer-review: Externally peer-reviewed.

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Declaration of Interests: The authors declare that they have no competing interests.

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REFERENCES

1. Eggmann F, Blatz MB. Recent advances in intraoral scanners. *J Dent Res*. 2024;103(13):1349-1357. [CrossRef]
2. Khurshid Z. Digital dentistry: transformation of Oral Health and dental education with technology. *Eur J Dent*. 2023;17(4):943-944. [CrossRef]
3. Mangano F, Gandolfi A, Luongo G, Logozzo S. Intraoral scanners in dentistry: a review of the current literature. *BMC Oral Health*. 2017;17(1):149. [CrossRef]
4. Ozden YE, Ozkurt-Kayahan Z, Kazazoglu E. Effect of intraoral scanning distance on the marginal discrepancy of milled interim crowns. *J Prosthodont*. 2024;33(1):41-45. [CrossRef]
5. Srimaneepong V, Heboyan A, Zafar MS, et al. Fixed prosthetic restorations and periodontal health: a narrative review. *J Funct Biomater*. 2022;13(1):15. [CrossRef]
6. Suese K. Progress in digital dentistry: the practical use of intraoral scanners. *Dent Mater J*. 2020;39(1):52-56. [CrossRef]
7. Revilla-León M, Kois DE, Kois JC. A guide for maximizing the accuracy of intraoral digital scans. Part 1: Operator factors. *J Esthet Restor Dent*. 2023;35(1):230-240. [CrossRef]
8. Thongma-Eng P, Amornvit P, Silthampitag P, Rokaya D, Pisitanusorn A. Effect of ambient lights on the accuracy of a 3-dimensional optical scanner for face scans: an in vitro study. *J Healthc Eng*. 2022;2022:2637078. [CrossRef]
9. Revilla-León M, Kois DE, Kois JC. A guide for maximizing the accuracy of intraoral digital scans: Part 2-Patient factors. *J Esthet Restor Dent*. 2023;35(1):241-249. [CrossRef]
10. Ashraf Y, Sabet A, Hamdy A, Ebeid K. Influence of preparation type and tooth geometry on the accuracy of different intraoral scanners. *J Prosthodont*. 2020;29(9):800-804. [CrossRef]
11. Gurpinar B, Tak O. Effect of pulp chamber depth on the accuracy of endocrown scans made with different intraoral scanners versus an industrial scanner: an in vitro study. *J Prosthet Dent*. 2022;127(3):430-437. [CrossRef]
12. Rotar RN, Faur AB, Pop D, Jivanescu A. Scanning distance influence on the intraoral scanning accuracy-an in vitro study. *Materials (Basel)*. 2022;15(9):3061. [CrossRef]
13. Chen Y, Zhai Z, Watanabe S, Nakano T, Ishigaki S. Understanding the effect of scan spans on the accuracy of intraoral and desktop scanners. *J Dent*. 2022;124:104220. [CrossRef]
14. Mourouzis P. Critical methodological factors influencing the accuracy of intraoral scanners in digital dentistry research. *Comput Biol Med*. 2025;187:109780. [CrossRef]
15. Pachiou A, Zervou E, Tsirogiannis P, Sykaras N, Tortopidis D, Kourtis S. Characteristics of intraoral scan bodies and their influence on impression accuracy: a systematic review. *J Esthet Restor Dent*. 2023;35(8):1205-1217. [CrossRef]
16. Giannetti L, Apponi R, Mordini L, Presti S, Breschi L, Mintrone F. The occlusal precision of milled versus printed provisional crowns. *J Dent*. 2022;117:103924. [CrossRef]
17. Yilmaz B, Dede DÖ, Donmez MB, et al. Comparison of intraoral and laboratory scanners to an industrial-grade scanner while analyzing the fabrication trueness of polymer and titanium complete-arch implant-supported frameworks. *J Dent*. 2023;138:104697. [CrossRef]
18. Huynh NCN, Tran ATV, Truong TNT, et al. Correlation of resin composite translucency and IOS accuracy: an in-vitro study. *J Clin Exp Dent*. 2024;16(6):e678-e684. [CrossRef]