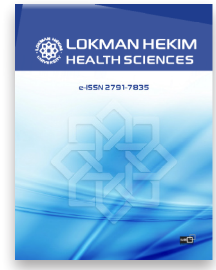
LOKMAN HEKIM HEALTH SCIENCES

DOI: 10.14744/lhhs.2025.34004
Lokman Hekim Health Sci 2026;6(1):102–108



lokmanhekimhs.com

ORIGINAL ARTICLE

The Evaluation of the Effectiveness of Intraoral Scanning Systems in the Detection and Classification of Caries Lesions

Arda Büyüksungur[1], Zehra İrem Öztürk Barut[2], Seyide Tuğçe Gökdeniz[2*], Mehmet Eray Kolsuz[2]

[1]Department of Basic Medical Sciences, Ankara University Faculty of Dentistry, Ankara, Türkiye
[2]Department of Dentomaxillofacial Radiology, Ankara University, Faculty of Dentistry, Ankara, Türkiye

Abstract

Introduction: This study aims to evaluate the effectiveness of intraoral scanning systems in the detection and classification of caries lesions using the International Caries Detection and Assessment System (ICDAS) and the presence of fissure sealant on the tooth.

Methods: Six molar teeth in different classes according to ICDAS classification were randomly placed in the prepared mandibular model. The model was scanned using three different intraoral scanners (3shape Trios 5, 3shape Trios 3, and Eighteeth Helios 600). Fissure sealant was applied to the tooth, and the same scanning procedures were performed again. Training on the ICDAS classification was given to five oral and maxillofacial radiology assistants. After training, observers evaluated three different data sets, and the main model obtained from different scanners recorded their scores on the training card.

Results: Model within-observer consistencies and within-observer model consistencies were excellent in reliability with each other. When the success rates are compared according to the model and devices, it is determined after clinical observation of the model that the highest success rate is achieved with the 3Shape Trios 3 scanner (66.7%). In contrast, the lowest success rate is observed with the Eighteeth Helios 600 scanner (53.3%). When teeth were examined individually, all observers made correct predictions for teeth 36 (ICDAS 6) and 48 (ICDAS 0) in the clinical observation of the model and all devices. The fissure sealant was also detected by all observers.

Discussion and Conclusion: The study demonstrates that intraoral scanners can be used to diagnose dental cavities with respect to ICDAS. Additionally, it seems to be useful for identifying the presence of fissure sealant.

Keywords: Biomaterials; Caries; ICDAS, Intraoral scanner; Tissue determination

The use of 3D intraoral scanners in different areas, such as caries, periodontal disease, tooth abrasion, etc., is among the research topics of interest.[1] The use of intraoral scanners for the detection and monitoring of oral diseases shows high success rates.[2] Owing to the developments in intraoral scanners, detecting and monitoring diseases in the oral region in the clinical environment or via remote access is supported.[1,3]

Clinical radiography methods are insufficient for detecting early occlusal enamel caries.[4] Techniques that facilitate

Cite this article as: *Büyüksungur A, Özturk Barut ZI, Gökdeniz ST, Kolsuz ME. The Evaluation of the Effectiveness of Intraoral Scanning Systems in the Detection and Classification of Caries Lesions. Lokman Hekim Health Sci 2026;6(1):102–108.*

***The current affiliation of the author:** Department of Dentomaxillofacial Radiology, Aksaray University, Faculty of Dentistry, Ankara, Türkiye

Correspondence: Arda Büyüksungur, M.D. Ankara Üniversitesi Diş Hekimliği Fakültesi, Temel Tıp Bilimleri Anabilim Dalı, Ankara, Türkiye
E-mail: abuyuksungur@ankara.edu.tr **Submitted:** 16.06.2025 **Revised:** 09.07.2025 **Accepted:** 06.11.2025 **Available Online:** 16.03.2026

the identification of incipient enamel caries significantly enhance clinical assessment. Establishing the diagnostic precision of caries lesion identification with an intraoral scanner for occlusal caries detection is a significant study domain in this discipline.[5] Nevertheless, the number of studies assessing the precision of caries lesion detection on 3D models derived from intraoral scanners is scarce, necessitating further research.[2,5] It states that today intraoral scanners of different brands provide caries diagnostic tools for the detection of occlusal and/or proximal caries lesions integrated into their scanners.[6] However, there is not much data on these uses. Caries diagnosis with intraoral scanners may not be possible in restored teeth, as additional features such as light transmission or fluorescence technology are required.[7] Schlenz et al.[8] reported that intraoral scanners can help clinical practice for caries diagnosis but are not suitable for universal use. Improved caries detection and classification of intraoral scanners may add further clinical value to these devices. With these devices, dentists can make more accurate clinical diagnoses.

The International Caries Detection and Assessment System (ICDAS) criteria are mostly employed in studies evaluating the detection accuracy of caries lesions on 3D models obtained from intraoral scanners.[2,5,9] It is regarded as more beneficial than other indices for classifying caries lesions, as it supports epidemiological assessments, assesses lesion progression, aids in planning preventive measures for initial non-cavitated enamel caries lesions, and ensures the standardization of clinical diagnoses by healthcare professionals.[10]

The definition of the diagnostic index is crucial for the standardization of clinical diagnoses by professionals.[5] In this context, ICDAS demonstrates several advantages over other indices, as it supports epidemiological analyses, assesses lesion stages, and aids in planning preventive strategies for initial non-cavitated enamel caries lesions, particularly through the implementation of non-surgical treatment approaches.

Although the potential benefits of intraoral scanners in caries diagnosis have been mentioned, there is room for improvement, as the number of studies in this area is quite limited.[8] Consequently, this study aims to compare the caries detection performance of three different intraoral scanner systems with visual inspection using ICDAS criteria. The depth and stage of lesions were also compared by employing this criterion study. The aim was also to evaluate the detectability of biomaterial use with an intraoral scanner, such as a fissure sealant.

Table 1. Tooth number and caries

Tooth number	ICDAS
38	2
37	5
36	6
48	0
47	3
46	4

ICDAS: International Caries Detection and Assessment System.

Materials and Methods

This study was conducted *in vitro* using intraoral scanners at the Ankara University Faculty of Dentistry Integrated Clinic.

Ethical Statement

The study received approval from the ethics committee of the Ankara University Faculty of Dentistry. (Approval number 10/5, decision date 26.05.2025). Written informed consents were obtained from the patients. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Preparation of the Model

Carious/non-carious mandibular left and right third molars, second molars, first molars, canines, lateral teeth, central teeth, and left first premolars that were extracted for various reasons were collected, washed with water, disinfected with 5% sodium hypochlorite, and stored in water until use. Six molar teeth of different classes, which were confirmed visually according to the ICDAS classification, were randomly placed on the prepared mandibular edentulous wax model. Table 1 presents the tooth number and ICDAS scores for the caries. Inspired by previous studies using models consisting of extracted teeth, the phantom model was employed specifically for this study.[8,11]

Table 1 displays the teeth used to determine the intraoral scanners' efficiencies. The remaining cavities of the model were filled with extracted teeth, and an implant scanning head (C-Tech Implant, Bologna, Italy) was placed in the right mandibular premolar region. Fissure sealant application with 3M Clinpro sealant (3M, Minnesota, USA) was performed on tooth number 47.

Scanning of the Model with 3D Intraoral Scanners

Three intraoral scanners (3shape Trios 5 (Copenhagen, Denmark), 3shape Trios 3 (Copenhagen, Denmark), and Eighteeth Helios 600 (Changzhou City, Jiangsu Province,

Figure 1. Images of intraoral scan data from PLY files. **(a)** Eighteeth Helios 600 scan model, **(b)** 3SHape Trios 3 scan model, **(c)** 3Shape Trios 5 scan model.

China)) were employed to obtain a digital scan of the main model (Fig. 1). The scanning sequence was determined according to the manufacturer's instructions for full scanning and in accordance with published literature on scanning strategies for optimal results.[12] An oral and maxillofacial radiologist with at least 3 years of experience performed the scans after a learning phase with the scanning devices over a period of 1 week. Each scan was performed with standardized illumination of the treatment unit (25,000 lx) at an ambient temperature of 23±2 °C. The scan was initiated from the occlusal surface of the right third molar, and the tip of the scanner moved from the vestibule to the lingual and slowly forward in an arc motion. Thus, all surfaces of the teeth, the scanning body, the gums, and the wax layer and the wax layer were scanned instead of the mucosa. The scan was completed on the distal surface of the left third molar. The operator performed a total of three scans with each intraoral scanner and saved them as PLY files. With the use of the polygon file format (PLY), the advantage of adding features such as color and transparency, surface normal, and texture coordinates of an object to the image is provided. Fissure sealant application with 3M Clinpro sealant (3M, Minnesota, USA) was performed on tooth number 47 with an ICDAS score of 3 (lack of substance in enamel, without affecting dentin). Then, tooth number 47 was added to the model, and the same scanning process was performed again.

Evaluation of the Performance

Education cards briefly pointing out the ICDAS classification were provided to five oral and maxillofacial radiologists with at least three years of experience. Classification was explained accordingly. One hour after training, observers evaluated three data sets obtained from different scanners in random order. Which devices the observer was evaluating was known only to the operator.

ICDAS Scores***(Directly from Ţuculină et. al., 2025)	
Code	Description
0	healthy tooth
1	visible demineralization in enamel, only after prolonged drying
2	visible color changes in the enamel
3	lack of substance in enamel, without affecting dentin
4	pigmented dentin
5	visible cavity in the dentin
6	enlarged and visible cavity in the dentin

Model Image	Evaluated Tooth					
	36	37	38	46	47	48
1. Model Image						
2. Model Image						
3. Model Image						

Figure 2. Training card for observers about the ICDAS system.

Observers scored the occlusal surfaces in the area below the training card to detect carious lesions on each molar (Fig. 2). Then, observers scored the teeth according to the ICDAS classification on the model without scan data. The observers employed a 22" NEC MD213MG LCD monitor (NEC, Tokyo, Japan) set to a screen resolution of 2048 × 1536 pixels and 32-bit color depth to examine and evaluate the images in a dimly lit room.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics version 22.0 (IBM Corp., Armonk, NY, USA). Inter-rater reliability for quantitative (ICDAS) scores was assessed using the intraclass correlation coefficient (ICC) based on a two-way mixed-effects model with absolute-agreement definition, appropriate for fixed raters evaluating the same cases. Associations between categorical variables were examined using the chi-square (χ^2) test, and Monte Carlo simulation (10.000 samples) was applied to ensure accurate significance estimation when

Table 2. Table of observer consistency statistics within the model (ICC correlation)

Model	ICC	95% Confidence interval		Inter-item correlations	p
		Lower bound	Upper bound		
EIGHTEETH HELIOS 600	0.991	0.970	0.999	0.956	0.0001
3SHAPE TRIOS 3	0.989	0.964	0.998	0.949	0.0001
3SHAPE TRIOS 5	0.980	0.934	0.997	0.909	0.0001

ICC: intraclass correlation coefficient.

Table 3. Table of model consistency statistics within observers (ICC correlation)

Observer	ICC	95% Confidence interval		Inter-item correlations	p
		Lower bound	Upper bound		
Observer 1	0.958	0.849	0.993	0.854	0.0001
Observer 2	0.99	0.965	0.998	0.963	0.0001
Observer 3	0.997	0.990	1.000	0.99	0.0001
Observer 4	0.994	0.979	0.999	0.997	0.0001
Observer 5	0.986	0.948	0.998	0.948	0.0001

ICC: intraclass correlation coefficient.

Table 4. Success rates by scanning model and devices

Success	Model		Eighteeth Helios 600		3Shape Trios 3		3Shape Trios 5	
	n	%	n	%	n	%	n	%
Successful	28	93.3	16	53.3	20	66.7	18	60.0
Unsuccessful	2	6.7	14	46.7	10	33.3	12	40.0
Total	30	100.0	30	100.0	30	100.0	30	100.0

expected cell frequencies were low. The effect size for chi-square analyses was reported using Cramer's V. A $p < 0.05$ threshold was considered statistically significant for all analyses.

Results

ICC values were interpreted according to determined threshold values (<0.5 poor, 0.5–0.75 moderate, 0.75–0.9 good, ≥0.9 excellent). Interpretations were made according to determined thresholds for Cohen's kappa values (<0.00 poor, 0.00–0.20 Slight, 0.21–0.40 Fair, 0.41–0.60 Moderate, 0.61–0.80 Substantial, 0.81–1.00 Almost perfect).

Significant differences in success rates were found among intraoral scanners. The HELIOS model exhibited a lower success rate compared to the other models. The TRIOS 3Shape 3 model stands out with its clinically preferable higher success rate.

The agreement between the scores obtained using the HELIOS model and the gold standard scores was found to be moderate and significant (Kappa=0.601; p=0.0001). The agreement between the scores obtained using the TRIOS 3Shape 3 model and the gold standard scores was found to be high and significant (Kappa=0.801; p=0.0001). The agreement between the scores obtained using the TRIOS 3Shape 5 model and the gold standard scores was found to be moderate and significant (Kappa=0.601; p=0.0001).

Caries Detection Level

The model prepared was scanned with different intraoral scanners. Table 2 presents the consistency of the observers within the model when the scanning data obtained from the main model, and three different devices are evaluated (ICC correlation). As a result of these data, it is observed that the scores obtained by the five observers are highly consistent with each other.

Table 3 presents the model consistency statistics for each observer (ICC correlation). It is observed that the scores obtained by evaluating the main model and the scanning data obtained from three different devices by five observers are highly consistent with each other.

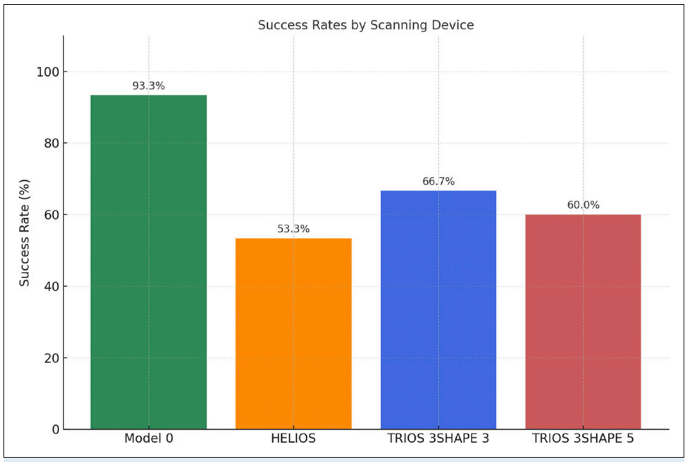


Figure 3. Success rates by scanning devices.

ICDAS Detection Level

Table 4 presents the comparison of the ICDAS scores obtained from the scan data of the main model and three devices from each observer with the actual ICDAS scores of the teeth. After the clinical observation of the main model, it was determined that the highest success rate is in the 3Shape Trios 3 device (66.7%). The Eighteeth Helios 600 device displays the lowest success rate (53.3%) (Fig. 3).

Table 5 presents the accuracy rates for correctly determining ICDAS scores based on individual tooth evaluations, as derived from both the primary model and the scanning data obtained from the devices. A statistically significant difference was found between the success rates of correctly identifying ICDAS scores across the evaluated teeth ($\chi^2 = 34.5$, df = 5, $p < 0.05$). All observers made correct classifications for tooth 36 (ICDAS 6 = large and distinct cavity with visible dentin) and tooth 48 (ICDAS 0 = no visual change in enamel when air dried) across all scanning devices. The lowest success rate was observed for tooth 38 (ICDAS 2 = distinct visual change in enamel), with only 35% of correct determinations. The fissure sealant restoration applied to tooth 47 (ICDAS 3 = localized enamel breakdown without dentin involvement) was also correctly identified by all observers. These findings suggest that intraoral scanners can effectively detect dentin tissue, as observers were able to differentiate the fissure sealant from the dentin area with high precision. The strength of the association between the evaluated tooth and the accuracy of ICDAS score determination was large (Cramer's V = 0.54), indicating a strong effect size.

Discussion

Various methods that do not use ionizing radiation in the detection and evaluation of the presence of caries in teeth continue to be investigated.[13] The most important of these is the detection of caries with three-dimensional (3D) intraoral scanners (IOS). Promising results have been obtained in *in vivo* and *in vitro* studies using 3D intraoral scanners for caries detection.[8,14] In this study, the use of 3D intraoral scanners in caries detection was investigated with a similar approach. The results indicate that intraoral scanners provide successful results in detecting dental caries (ICC: 0.991- (≥0.9 excellent)). This ICC value means excellent reliability.

In a study, the effectiveness of three different intraoral scanners in caries detection was compared.[8] In this study, using three different intraoral scanners, intra-observer and inter-observer agreement were found to be similarly high (ICC: 0.991- (≥0.9 excellent)). In addition, in this study, the detectability of restored teeth with an intraoral scanner was examined. In this way, it has been determined that it can be detected in restored teeth.

In a study using an oral camera, the use of intraoral images as part of remote patient screening methods was used for patient populations that do not have access to a dentist improved oral health care.[15] The findings of this current study indicate that the use of intraoral scanners in the detection of both dental caries and restored teeth with remote access displays successful results.

Table 5. The rates of correct determination of ICDAS scores

Succes	Evaluated tooth														Chi-square analysis	
	36		37		38		46		47		48		Total			
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	Chi-square	p
Successful	20	100.0	9	45.0	7	35.0	12	60.0	14	70.0	20	100.0	82	68.3	34.5	0.0001*
Unsuccessful	0	0.0	11	55.0	13	65.0	8	40.0	6	30.0	0	0.0	38	31.7		
Total	20	100.0	20	100.0	20	100.0	20	100.0	20	100.0	20	100.0	120	100.0		

*There is a significant difference (P=0.0001<0.05; Cramer's V = 0.54). **df=5 ***Montecarlo simulation technique was applied. ICDAS: International Caries Detection and Assessment System.

In a study, intraoral scanners were employed for the structural problems in the oral cavity for orthodontic diagnostics, such as the width of the dental arches.[16] The measurements were carried out with the model files for 10 months before and after treatment.

Two studies employed intraoral scanners for the detection of plaque. The first one used planimetric measurements with a special program.[17] The other study employed 3D models for plaque measurements.[18] Both studies indicated that intraoral scanners can be employed for plaque measurements. These two studies also found the use of the intraoral scanner useful.

All observers accurately identified teeth with large, distinct cavities exposing visible dentin, corresponding to an ICDAS score of 6, across all devices. Similarly, they correctly identified teeth with no visible enamel changes when air-dried, corresponding to an ICDAS score of 0. This study demonstrates that intraoral scanners can detect both decay-free teeth and those with the most severe decay (highest scores) with high accuracy. It is observed that there are significant differences between the scanners in the scores between ICDAS 0 and ICDAS 6. All intraoral scanners displayed very high and successful results in teeth with the highest and lowest scores, in accordance with the ICDAS classification. On the other hand, in caries with intermediate scores, the detectability is greatly reduced, regardless of the depth of the caries.

This indicates that intraoral scanners detect the presence or absence of dental caries with high accuracy but are less successful in classifying caries depth. Both the fissure sealant and the implant (scanning head) are biomaterials. The scanners are generally used to scan the scanning head of the implant, but both biomaterials were employed in this study to determine the effectiveness.

When the results of this current study were compared, the most successful device in detecting caries was the 3Shape Trios 3 device. There were also differences in device success. Since intraoral scanners are computer-aided systems, it should be kept in mind that all situations that may affect the computer system (system being up-to-date, background work intensity, etc.) may also affect scanning accuracy. The devices used in this study were each used in clinics with different usage intensities. Since the 3Shape Trios 3 device was used in the clinic with the least usage intensity, this can be considered one of the important reasons for the improvement in its performance.

All observers made correct predictions for the tooth with the highest ICDAS score and the tooth with the lowest ICDAS score across all instruments. The lowest success rate was detected in the tooth with an ICDAS score of 2. It has been observed that success rates do not increase in direct proportion to the ICDAS score. As a result, it is observed that the highest and lowest ICDAS scores have the highest success rate, and there is no proportion between the remaining intermediate scores. This situation may have occurred because the ICDAS classification is based on caries depth. This may be an indication that intraoral scanners are less successful in determining caries depth.

This study contributes to the *in vitro* performance of intraoral scanning devices for caries detection. In clinical use, visualization of caries, in addition to examination, can contribute to improving patient communication. The ability to visualize caries lesions and incompatible restorations via a screen may increase patients' acceptance of invasive interventions. With recent advances in technology for the analysis of dental images, it is hypothesized that artificial intelligence can be employed to detect and classify dental caries using intraoral scan data.[19] Therefore, the existence of studies examining the accuracy of intraoral scanning data is important for future studies.

Limitations

Since the working principle of intraoral scanners is based on an optical system, many external factors affect their accuracy.[1] Since the *in vitro* study design used in this study cannot fully reflect real clinical conditions (saliva, movement, patient-specific factors, etc.), further clinical research is needed.

Conclusion

The study demonstrates the potential use of intraoral scanners in caries diagnosis. It also appears that it can be employed to detect the presence of fissure sealant. All intraoral scanners displayed high success rates in teeth with the highest and lowest scores according to the ICDAS classification, making them suitable for clinical use. However, in caries with intermediate scores, the detectability decreases regardless of the depth of the caries. Therefore, the detection of caries with moderate scores with intraoral scanners should be supported by clinical and radiographic examination.

Ethics Committee Approval: The Ankara University Faculty of Dentistry Ethics Committee granted approval for this study (date: 26.05.2025, number: 10/5).

Informed Consent: Written informed consent was obtained.

Conflict of Interest: None declared.

Financial Disclosure: The authors declared that this study has received no financial support.

Use of AI for Writing Assistance: The authors declared that artificial intelligence (AI) supported technologies were not used in the study.

Authorship Contributions: Concept: AB, MEK; Design: AB, ZİÖB, STG; Supervision: AB; Materials: ZİÖB, STG, AB; Data Collection or Processing: ZİÖB, STG, AB, MEK; Analysis or Interpretation: ZİÖB, AB, STG; Literature Search: AB, ZİÖB, STG; Writing: AB, ZİÖB, STG; Critical Reviews: AB, MEK.

Peer-review: Double blind peer-reviewed.

References

1. Michou S, Lambach MS, Ntovas P, Benetti AR, Bakhshandeh A, Rahiotis C, et al. Automated caries detection *in vivo* using a 3D intraoral scanner. Sci Rep 2021;11(1):21276. Erratum in: Sci Rep 2021;11(1):23951. Erratum in: Sci Rep 2022;12(1):13240. [CrossRef]
2. Michou S, Tsakanikou A, Bakhshandeh A, Ekstrand KR, Rahiotis C, Benetti AR. Occlusal caries detection and monitoring using a 3D intraoral scanner system. An *in vivo* assessment. J Dent 2024;143:104900. [CrossRef]
3. Michou S, Benetti AR, Vannahme C, Hermannsson PG, Bakhshandeh A, Ekstrand KR. Development of a fluorescence-based caries scoring system for an intraoral scanner: An *in vitro* study. Caries Res 2020;54(4):324-35. Erratum in: Caries Res 2022;56(3):234-5. [CrossRef]
4. Kühnisch J, Ekstrand KR, Pretty I, Twetman S, van Loveren C, Gizani S, et al. Best clinical practice guidance for management of early caries lesions in children and young adults: an EAPD policy document. Eur Arch Paediatr Dent 2016;17(1):3-12. [CrossRef]
5. Sá G, Michou S, Bönecker M, Mendes F, Amarante B, Ekstrand K. Diagnostic validity of ICDAS clinical criteria on digital 3D models. J Dent 2024;149:105274. [CrossRef]
6. Suese K. Progress in digital dentistry: The practical use of intraoral scanners. Dent Mater J 2020;39(1):52-6. [CrossRef]
7. Abdelaziz M, Krejci I. DIAGNOcam--a Near Infrared Digital Imaging Transillumination (NIDIT) technology. Int J Esthet Dent 2015;10(1):158-65.
8. Schlenz MA, Schupp B, Schmidt A, Wöstmann B, Baresel I, Krämer N, et al. New caries diagnostic tools in intraoral scanners: a comparative *in vitro* study to established methods in permanent and primary teeth. Sensors (Basel) 2022;22(6):2156. [CrossRef]
9. Pitts NB, Ekstrand KR; ICDAS Foundation. International Caries Detection and Assessment System (ICDAS) and its International Caries Classification and Management System (ICCMS) - methods for staging of the caries process and enabling dentists to manage caries. Community Dent Oral Epidemiol 2013;41(1):e41-52. [CrossRef]
10. Ekstrand KR, Gimenez T, Ferreira FR, Mendes FM, Braga MM. The international caries detection and assessment system - ICDAS: A Systematic Review. Caries Res 2018;52(5):406-19. [CrossRef]
11. Siadat H, Chitsaz F, Zeighami S, Esmaeilzadeh A. Accuracy of maxillary full-arch digital impressions of tooth and implant models made by two intraoral scanners. Clin Exp Dent Res 2024;10(2):e857. [CrossRef]
12. Müller P, Ender A, Joda T, Katsoulis J. Impact of digital intraoral scan strategies on the impression accuracy using the TRIOS Pod scanner. Quintessence Int 2016;47(4):343-9.
13. Ntovas P, Michou S, Benetti AR, Bakhshandeh A, Ekstrand K, Rahiotis C, et al. Occlusal caries detection on 3D models obtained with an intraoral scanner. A validation study. J Dent 2023;131:104457. [CrossRef]
14. Metzger Z, Colson DG, Bown P, Weihard T, Baresel I, Nolting T. Reflected near-infrared light versus bite-wing radiography for the detection of proximal caries: A multicenter prospective clinical study conducted in private practices. J Dent 2022;116:103861. [CrossRef]
15. Kopycka-Kedzierawski DT, McLaren SW, Billings RJ. Advancement Of teledentistry at the university of Rochester's Eastman Institute for oral health. Health Aff (Millwood) 2018;37(12):1960-6. [CrossRef]
16. Pałka J, Gawda J, Byś A, Zawadka M, Gawda P. Assessment of growth changes in the width of dental arches caused by removable appliances over a period of 10 months in children with malocclusion. Int J Environ Res Public Health 2022;19(6):3442. [CrossRef]
17. Jung K, Giese-Kraft K, Fischer M, Schulze K, Schlueter N, Ganss C. Visualization of dental plaque with a 3D-intraoral-scanner-A tool for whole mouth planimetry. PLoS One 2022 26;17(10):e0276686. [CrossRef]
18. Giese-Kraft K, Jung K, Schlueter N, Vach K, Ganss C. Detecting and monitoring dental plaque levels with digital 2D and 3D imaging techniques. PLoS One 2022;17(2):e0263722. [CrossRef]
19. Jones B, Chen T, Michou S, Kilpatrick N, Burgner DP, Vannahme C, et al. Diagnostic agreement between visual examination and an automated scanner system with fluorescence for detecting and classifying occlusal carious lesions in primary teeth. J Dent 2024;149:105279. [CrossRef]