Validity of Panoramic Multilayer Imaging Program in the Diagnosis of Proximal Caries: An Ex-vivo Study

Weam Ibrahim[1], Mona Mahmoud[2], Mostafa SaadEl-Dein[2], Tarek M Ibrahim[3]

Aim: To verify the validity of panoramic multilayer imaging program in the diagnosis of proximal caries.

Material and methods: Formic acid was used to create artificial caries in 80 individual sound molars and premolars with various levels of decalcification. Multilayer imaging program and Extraoral bitewing were done using Vatech pax-I Insight machine (Vatech Co., Hwaseung Si, Korea). In total, 160 proximal surfaces were evaluated by two oral and maxillofacial radiologists twice. Area under the ROC curve for each image type, observer and reading were compared. For every observer and reading, calculations were made of sensitivity, specificity, PPV, and NPV.

Results: The period of demineralization and the histological classification of carious surfaces of teeth exhibited a significant positive connection, according to Kendall's tau test. Both intraobserver reliability and interobserver agreement were moderate to strong for the two radiography procedures. P>0.05 indicates that there was no statistically significant difference between the two methods. When it came to detecting early proximal caries, extra-oral bitewing had the highest sensitivity and multilayer imaging program the highest specificity.

Conclusion: The two methods' differences in diagnostic accuracy were negligible within the confines of ex-vivo design. When intraoral radiography is not an option, multilayer imaging programs show promise in detecting proximal caries. Their results are equivalent to those of EO bitewing in terms of their capacity to decrease superimpositions.

Keywords: Proximal Caries, Multilayer, panoramic radiography.

1. Master candidate Oral and Maxillofacial Radiology, Faculty of Dentistry, Ain Shams university, Cairo, Egypt.
2. Professor of Oral and Maxillofacial Radiology, Faculty of Dentistry, Ain Shams University, Cairo, Egypt.
3. Professor of Oral& Maxillofacial Radiology, Oral Basics& Clinical Sciences Department, Taibah University, Saudi Arabia.
   Corresponding author: Weam Ibrahim, email: Weka.elfallal.93@gmail.com

Introduction

Dental caries is a dynamic condition characterized by ultrastructural and biochemical changes that can lead to symptoms such as pulp infection, periapical abscess, and tooth loss if not detected early. It is a common dental disease that can lead to higher treatment costs and delayed diagnosis if not addressed promptly.[1,2]

There are several means of conventional caries detection including visual examination& tactile exploration [3,] Transillumination[4] , ECM (Electronic caries monitor [5], Quantitative Light Induced Fluorescence[6] , The VistaProof intraoral camera system [7], The DIAGNOdent device [8], OCT (Dental Optical Coherence Tomography) [8] and radiographic examination. [9]

When diagnosing caries lesions on clinically inaccessible surfaces, like proximal surfaces, radiographic evaluation is a commonly advised supplementary technique.9 Among various methods used nowadays for the detection of proximal caries, extraoral bitewing proved its high performance, especially in patients with a gag reflex and uncooperative ones.[10]

For the premolar and molar regions— which include portions of the maxilla, mandible, and rami—this technique produces bitewing-like images. Because it provides better interproximal separation between contacts, it uses Selective Compliance Assembly Robot Arm (SCARA) technology to overcome the drawbacks of panoramic radiography in identifying caries[11,12]

Panoramic radiography provides a comprehensive view of the maxillofacial structures, such as the dental arches, alveolar bones, temporomandibular joints, and facial bones, all captured in a single image. [13] However, it may experience issues with overlapping teeth and reduced sharpness, making it less reliable for detecting early-stage proximal caries, which require high-resolution imaging. [14]

A novel method for acquiring panoramic radiography images has emerged recently, providing multilayer imaging in an ordered manner spanning from the buccal to the lingual planes. Similar to the panoramic reconstructed view of CBCT images, this approach offers a layered picture of the buccolingual depth [15,16]

To the best of our knowledge, few researches in the literature discussed multilayer imaging program. Thus, the current research aimed to check the validity of multilayer imaging program and to compare it with extraoral bitewing in caries detection.

Material and Methods

The study was approved by the ethical committee (No: FFDASU-RecIM022160) at the Faculty of Dentistry, Ain Shams University.

Skull, mandible assembly, and teeth were borrowed from the Department of Anatomy faculty of Medicine, Ain Shams University. Eighty human teeth were scaled to remove calculus and debris, then disinfected for twenty minutes with 2% sodium hypochlorite and kept in distilled water.

Sample preparation and grouping

With forty surfaces per, the teeth were split into three experimental groups and one control group. The surfaces of the control group were not altered (Table 1) .

Table 1: sample groups

Group	Number of surfaces	Time of demineralization
Control group	40	0 Hours
Experimental group 1	40	10 Hours
Experimental group 2	40	20 Hours
Experimental group 3	40	30 Hours

Utilizing a rubber dam punch, circular rubber pieces were formed and placed slightly below the contact region on the proximal surfaces of the test teeth to produce typical circular windows for the application of acid. After that, the teeth were covered in an acid-resistant, quick-drying nail varnish, exposing nothing except the rubber circle. Each tooth had two-millimeter-wide areas of exposed enamel when the rubber circles were taken off after the varnish had dried. Each experimental group's specimens were submerged separately in 8 milliliters of 5% formic acid, and they were left in the acid for varying amounts of time—10, 20, and 30 hours.

After the teeth underwent acid treatment for a set amount of time, only the lead investigator knew the duration for each tooth, they were thoroughly cleaned with acetone to remove the protective nail polish. Each skull and mandible was fitted with 16 teeth, resulting in the placement of two premolars and two molars in each quadrant. A softened pink wax was used to hold the teeth securely in their designated alveolar sockets which were widened slightly for accommodation (figure 1).

Figure1: Teeth preparation.

Image acquisition
Panoramic multilayer radiographs were taken using Vatech Pax-I Insight, Green (Vatech Co., Hwaseung Si, Korea). and operating at 69 kVp, 6mA, and the exposure

time selected was 14.1 s. This multilayer imaging application offers 41 multilayer images in total, spanning the buccal to lingual aspects of the ROI. To bring the structures of a particular plane into focus or alignment, the reconstruction technique involved shifting and adding the individual projection images. Extra-oral bitewing images were taken with the Bitewing Program of Vatech digital panoramic machine (Vatech, Pax-I, Green) (Vatech Co., Hwaseung Si, Korea). The exposure variables were modified to 7 mA, 14.1 sec, and 73 KV.

The type of detector incorporated was CMOS.

Image evaluation
Utilizing the same computer display, two calibrated observers—oral and maxillofacial radiologists with ten years of experience—evaluated every digital image as a consensus-based gold standard. During the observations, the lights were kept low. To reduce weariness and the likelihood of remembering past judgments on comparable images, they separately scored the proximal surfaces of each tooth at one-week intervals. Two weeks later, the assessment of the images was conducted via a four-graded scale[11]:

- R0: radiolucency is absent
- R1: radiolucency in the enamel's outer layer
- R2: the inner enamel portion up to the dentinoenamel junction (DEJ) is radiolucent.
- R3: radiolucency in the dentin's outer half and beyond the DEJ.

Each observer assessed ten radiographs (five panoramic and five extraoral bitewing radiographs) totaling 160 proximal surfaces twice for each system.

Microscopic examination
The gold standard for validation was histological. Following the completion of the

radiographic evaluations, a diamond disc on NX201 micromotor mesiodistally sectioned each tooth so that it was parallel to the crown's long axis. A stereomicroscope (Olympus DP 10, SZ-PT; Olympus Corporation, Tokyo, Japan) with a 15× magnification was used to examine both sides of each segment at the oral pathology department of Ain Shams University. By consensus, two assessors who were blind to the surfaces' radiographic appearance assessed the sections.

The following Russell and Pitts [11] criteria were used to score the caries level:

- H0: no visible caries
- H1: solely carious lesions in the enamel's outer half;
- H2: a variety of lesions in the enamel's inner half up to the DEJ
- H3: carious lesions extending into the outer half of dentin and the DEJ

Statistical Analysis

Every piece of information was gathered, tallied, and then statistically examined. SPSS (version 20) is generally utilized for statistical analysis, whereas Microsoft Office Excel is utilized for data management and graphical presentation.

The agreement of two qualitative ordinal variables was assessed by percentage of agreement, Cohen Kappa and weighted Kappa with its 95% confidence limits while Kendall's tau-b correlation coefficient is applied for correlation analysis of such variables. The area under the ROC curve is reported with its 95% confidence limits.

For dichotomous variables, diagnostic tables were presented with the sensitivity; specificity, Positive Predictive Value PPV, Negative Predictive Value NPV, and total test accuracy together with their 95% confidence limits. Phi correlation coefficient was used for the two by two tables. Cohen Kappa with its 95% confidence limits was used of inter

and intra-observer reliability analysis for these dichotomous variables.

P>0.05 was used as the significance level (S); P>0.01 was used as the highly significant (HS) threshold. For all statistical tests used in the analysis, two-tailed testing was applied.

Results

The histological grading of caries teeth surface and the period of demineralization exhibited a strong positive connection, as demonstrated by Kendall's tau test Table (2). For the two radiography methods, the intraobserver agreement ranged from moderate to strong table (3). Table (4) shows that there was moderate to strong interobserver agreement between the two methodologies. Kandall's tau showed strong agreement between panoramic machine scoring and the histology (0.674) table (5). Kandall's tau showed strong agreement between Extraoral bitewing program scoring and the histology (0.624) table(6). Az values for caries graded by EO BW and Panoramic multilayer were almost identical, at 0.863 and 0.864, respectively. Table (7) displays the two observers' readings' sensitivity, specificity, positive predictive value, and negative predictive value. Figures 2 and 3 show the multilayer program.

Table 2: Correlation between duration of demineralization and histological grading of caries using kendall's tau and phi correlation coefficient.

		Duration of demineralization	
		Correlation coefficient	P Value
Kendall's tau-b		0.982	.000
Nominal by Nominal	Phi	1.000	.000
Measure of Agreement	Kappa	1.000	.000

Kendall's tau and Phi tests revealed a strong positive association between duration of

demineralization and histological grading of caries teeth surface

Table 3: Shows the intra-observer kappa coefficients calculated by comparing 1st and 2nd readings of each observer for each radiographic programs.

Score		Histology				Total	Kendall's tau	P value
		0	1	2	3			
Panoramic ML program	0	23	7	4	0	34		
	1	12	21	8	2	43		
	2	3	7	26	6	42	0.674	0
	3	0	3	8	30	41		
Total		38	38	46	38	160		

Intra-observer kappa statistics for the 2 radiographic programs ranged from 0.566 to 0.775 suggesting moderate to strong intra-observer agreement

Table 4: Shows the inter-observer kappa coefficients calculated by comparing 1st and 2nd observers of each reading for each radiographic programs.

Radiographic program	Observer 1 &2			Observer 1&2		
	Reading 1			Reading 2		
	WK	SE	CI	WK	SE	CI
Panoramic multilayer program	0.747	0.035	0.816-0.678	0.595	0.049	0.691-0.499
Extraoral bitewing	0.7	0.042	0.782-0.618	0.599	0.051	0.699-0.498

Inter-observer kappa statistics for the 2 radiographic programs ranged from 0.595 to 0.747 suggesting moderate to strong inter-observer agreement.

Table 5: Kandall's tau test was used to assess the relationship between caries grading by panoramic multilayer program and the histologic gold standard.

Score		Histology				Total	Kendall's tau	P value
		0	1	2	3			
Panoramic ML program	0	23	7	4	0	34		
	1	12	21	8	2	43		
	2	3	7	26	6	42	0.674	0
	3	0	3	8	30	41		
Total		38	38	46	38	160		

Kandall's tau showed strong agreement between panoramic program scoring and the histology (0.674)

Table 6: Kandall's tau test was used to assess the relationship between caries grading by extraoral bitewing program and the histologic gold standard.

Score		Histology				Total	Kendall's tau	P Value
		0	1	2	3			
Extraoral Bitewing	0	20	12	2	0	34		
	1	6	26	11	0	43		
	2	0	10	26	6	42	0.624	0
	3	3	4	13	21	41		
Total		29	52	52	27	160		

Kandall's tau showed strong agreement between extraoral bitewing program scoring and the histology (0.624).

Table 7: Specificity, Sensitivity, Negative predictive value, and Positive predictive value test accuracy of the 2 tested imaging programs.

Radiographic program		Observer 1		Observer 2	
		1st Reading	2nd Reading	1st Reading	2nd Reading
Panoramic multilayer Program	sensitivity	0.88	0.86	0.9	0.78
	specificity	0.68	0.44	0.85	0.76
	PPV	0.91	0.85	0.96	0.92
	NPV	0.61	0.45	0.69	0.48
	Test accuracy	0.84	0.77	0.89	0.78
Extraoral bitewing Program	sensitivity	0.93	0.91	0.84	0.84
	specificity	0.59	0.53	0.62	0.62
	PPV	0.89	0.88	0.89	0.89
	NPV	0.69	0.62	0.51	0.51
	Test accuracy	0.86	0.83	0.79	0.79

Extraoral bitewing got the highest record in sensitivity and the panoramic multilayer program got the highest specificity.
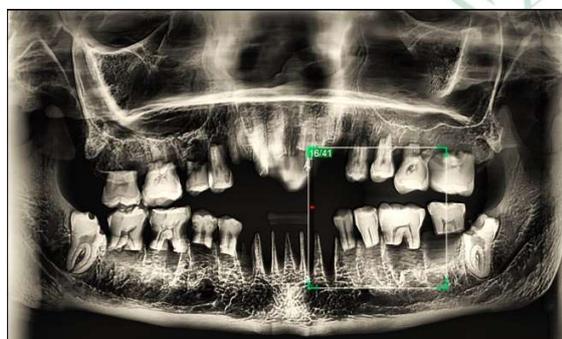
Figure 2: After using multilayer program: in section number 16 lower left 2nd premolar revealing mesial caries graded as R1 where caries is confined to the outer half of enamel.
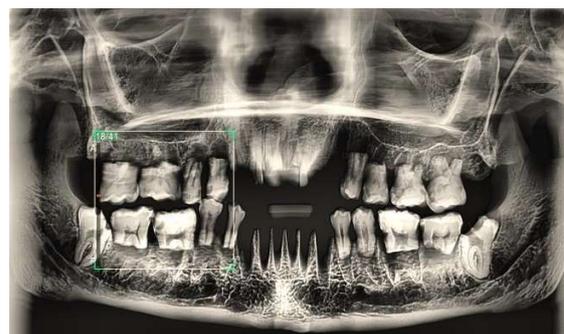
Figure 3: After using multilayer program in section number 18 lower right 1st molar revealing distal caries graded as R3 where caries extended beyond DEJ reaching 2nd half of dentine.

Discussion

Dental caries is among the most widespread health issues globally, with 2.3 billion people having untreated and progressive cavities in their permanent teeth.[17–19] It is a prevalent bacterial infection that gradually deteriorates tooth enamel and is the primary cause of tooth loss. This disease can seriously affect the quality of life for many people. Factors like social and economic conditions, demographics, and individual behaviors influence the development of tooth decay.[18,20]

Although panoramic X-rays are a valuable diagnostic and screening tool for dentists, they have certain limitations. Despite advantages such as low radiation exposure and cost-effectiveness, they produce images with less detail than other dental X-rays and may not clearly display specific features.

This study's objective was to confirm using a multilayer imaging program of panoramic radiography, and we further sought to determine if there is any variation between it and extraoral bitewing in the ability of caries detection and its evaluation.

With the identical radiation dosage, the multilayer imaging acquisition system provides a multilayer view of buccolingual depth. As a result of the shifting rotation center movement, high-speed detectors take multiple strip images at somewhat varied

angles, adding this information in a single rotation [16.] According to earlier research, the extraoral bitewing approach was just as effective as the intraoral bitewing technique at detecting proximal caries, outperforming traditional panoramic radiography in this regard. [17]

It may appear as though caries is present on the proximal surface of the sound tooth when advanced proximal caries is limited to one side of two neighboring teeth. A multilayer imaging program lowers the possibility of outcomes that are falsely positive.

Since extracted human premolars and first and second molars are known to contain 90% of all radiographic caries lesions, Abu El-Ela et al. 2016 [12] considered these teeth in our research sample. In order to closely mimic a natural dental arch, a dried human skull and mandible were utilized, with the teeth inserted into the empty sockets. This method is in line with Kamburoglu et al. [21] approach, which involved inserting tooth sample crowns into the alveolar sockets of a mandible and skull. We utilized healthy human premolar and molar teeth to particularly create artificial proximal caries of varying depths. This allowed us to assess the accuracy of radiographic grading and the detection of proximal caries [12,21] The proximal surfaces were positioned to contact each other, simulating their normal anatomical placement, as done by Abesi et al. 2012. [22] As conducted by Rahmel et al. 2019[23], four layers of pink wax, each 1.5 mm thick, were placed buccally around the teeth, resulting in a total thickness of 6 mm. This simulation aimed to replicate the influence of oral soft tissues in the experimental setup.

According to Kamburoglu et al. 2012[21], while panoramic radiography with a multilayer program has proven beneficial for detecting proximal caries, additional intraoral radiography, specifically bitewing radiography, is still recommended for accurate diagnosis. When it came to diagnosing proximal caries in premolars and molars, intraoral bitewing radiography outperformed traditional radiography and panoramic radiography combined with extraoral bitewing.

By employing multilayer imaging, the repeatability of proximal caries detection was improved. Considering that CBCT is more expensive and has a larger radiation dosage, multilayer imaging programs may eventually take the place of CBCT in certain cases.

The concept of extraoral bitewing imaging is not novel, and several authors have previously investigated this approach. Terry et al. 2016 [24], provided evidence that extraoral bitewing images obtained using a panoramic machine were slightly less effective than intraoral bitewing images in detecting interproximal carious lesions, although this difference was not statistically significant.

Intra-observer agreement was evaluated by each radiologist examining the images twice, with a two-week interval between sessions to minimize memory bias. This methodology was also employed by Senel et al. 2010. [25]

Studies that have used histopathological data as the gold standard for detecting caries have produced more reliable results AbuAla et al. 2016 [12], Dias da Silva et al. 2010 [26] and histological data were utilized as gold standard in the majority of published researches. In this work, histological data were used as the gold standard, chosen for its reproducibility and scientific acceptance in vitro research. Simulating what was done by Zayet et al. 2014 [27], sectioning was made at the contact point because it's the starting point of interproximal caries. The section was made in a mesiodistal direction to access both the buccal and lingual halves, enabling examiners to assess the extent of

interproximal caries through enamel, dentin, and pulp layers. Although Ferreira et al 2007[1] by extracted human teeth, they determined that the experimentally induced enamel demineralization could be validated by Knoop cross-sectional micro-hardness profiling. This technique provides information about the degree of demineralization and the physical feature of enamel hardness.

In this study, a significant positive correlation was found between the duration of demineralization and the histological grading of caries, Similar to a study done by Ferreira et al. 2007 [1] and AbuAla et al. 2016 [12] They noticed that when demineralization lasted longer, the depth of enamel caries grew. It was not a precise connection, though; H1, H2, and H3 histological caries depth were produced by 20-hour demineralization. This could be explained by the variation in the thickness of the proximal enamel.

The kappa values for intra- and inter-observer agreement were higher when utilizing the multilayer program, according to the two radiologists by Kug Jin Jeon et al. 2020 [17,] it was 0.96 and 0.461 respectively while Rahmel et al. 2019 [23] reported that 0.55 and 0.47 for the intra and inter-observer reliability. Our study revealed that intra-observer reliability was 0.566 and interobserver reliability was 0.747.

According to Yeler et al. 2017 [28], they found that standard panoramic images exhibited the lowest sensitivity due to increased superimposition. Extraoral bitewing and orthogonal programs showed reduced levels of superimposition (0.59, 0.51), resulting in fewer false-negative results and higher sensitivity compared to the standard program. Our study showed that multilayer imaging program has sensitivity of 0.88 and specificity of 0.68. in another study done by Kug Jin Jeon et al. 2020 [17] sensitivity was .914 and specificity was 0.931.

Rahmel et al. 2019 [23] noted the effectiveness of panoramic radiography in diagnosing artificial root resorption, using a method involving 41 layers similar to our study's equipment. They found that tomosynthesis panoramic radiography had slightly higher mean sensitivity (0.54) compared to standard PAN (0.50), while average specificity remained equally high (0.96). On the other hand, the sensitivity for extraoral bitewing for Kamburoglu et al. 2012 [21] and AbuAla et al. 2016 [12] was 0.64 and 0.75 respectively, while in our study sensitivity was 0.93.

Kamburoglu et al. 2012 [21] found that the specificity of extraoral bitewing was 0.97, whereas AbuAla et al. 2016 [12] found it 0.95 but in our study specificity was 0.59.

Conclusion

For proximal caries detection, panoramic radiography combined with a multilayer imaging program may yield outcomes similar to those of an extraoral bitewing program. This program may be helpful to individuals who find it challenging to take intraoral radiographs and is anticipated to decrease the number of unnecessary radiographs.

Moreover, the difference in diagnostic accuracy in detecting of proximal caries between the two techniques was insignificant. Multilayer imaging program had the highest specificity in detection of proximal caries, whereas extraoral bitewing had the highest sensitivity in detection of proximal caries.

Funding
No funding is subjected to the research reported in this manuscript.
Availability of data and materials
All data included in this study are available from the corresponding author upon request.
Declarations
Ethical approval

Ethical approval was granted by the local Ethics Committee of the faculty of dentistry, Ain Shams University (No: FFDASU-RecIM022160)

Competing interests

The authors declare they have no conflict of interest.

References

1. Ferreira RI, Haiter-Neto F, Tabchoury CPM, Bóscolo FN. In vitro induction of enamel subsurface demineralization for evaluation of diagnostic imaging methods. J Appl Oral Sci. 2007 Oct;15(5):392–8.
2. Elhady A, Obeid M, Yehia T. Efficiency of different irrigation protocols on Cleanliness and disinfection of root canal (An In-vitro study). Ain Shams Dent J. 2024 Mar 1;33(1):114–20.
3. Braga MM, Mendes FM, Ekstrand KR. Detection Activity Assessment and Diagnosis of Dental Caries Lesions. Dent Clin North Am. 2010 Jul;54(3):479–93.
4. Caries detection and diagnostics with near-infrared light transillumination: Clinical experiences. Quintessence Int. 2014 Apr 3;45(6):531–8.
5. Gomez J. Detection and diagnosis of the early caries lesion. BMC Oral Health. 2015 Dec;15(S1):S3.
6. Khandelwal A, Jose J, Ajitha P. Early detection of dental caries—A review. Drug Invent. Today. 2020;13:139-43.
7. Jablonski-Momeni A, Heinzel-Gutenbrunner M, Klein SMC. In vivo performance of the VistaProof fluorescence-based camera for detection of occlusal lesions. Clin Oral Investig. 2014 Sep;18(7):1757–62.
8. Iranzo-Cortés JE, Montiel-Company JM, Almerich-Torres T, Bellot-Arcís C, Almerich-Silla JM. Use of DIAGNOdent and VistaProof in diagnostic of Pre-Cavitated Caries Lesions—A Systematic Review and Meta-Analysis. J Clin Med. 2019 Dec 19;9(1):20.
9. Shimada Y, Sadr A, Sumi Y, Tagami J. Application of Optical Coherence Tomography (OCT) for Diagnosis of Caries, Cracks, and Defects of Restorations. Curr Oral Health Rep. 2015 Jun;2(2):73–80.
10. Wenzel A. Radiographic modalities for diagnosis of caries in a historical perspective: from film to machine-intelligence supported systems. Dentomaxillofacial Radiol. 2021 Jul 1;50(5):20210010.
11. Khan EA, Tyndall DA, Caplan D. Extraoral imaging for proximal caries detection: Bitewings vs scanogram. Oral Surg Oral Med Oral Pathol Oral Radiol Endodontology. 2004 Dec;98(6):730–7.
12. Abu El-Ela WH, Farid MM, Mostafa MSED. Intraoral versus extraoral bitewing radiography in detection of enamel proximal caries: an ex vivo study. Dentomaxillofacial Radiol. 2016 Apr;45(4):20150326.
13. Naduvakattu B, Chatra L, Shenai Kp, Ashir K, Veerabhadrappa S, Shetty D. Evaluation of diagnostic efficacy of improved interproximal program and bitewing program in proximal caries detection- an extraoral radiographic comparative study. J Indian Acad Oral Med Radiol. 2022;34(4):456.
14. Assiri H, Estrugo-Devesa A, Roselló-Llabrés X, Egido-Moreno S, López-López J. The Accuracy of Bone Assessment Distal to Lower Second Molars Using Panoramic Radiography: A Systematic Review and Meta-Analysis. Dent J. 2024 Mar 11;12(3):73.
15. Møystad A, Svanaes DB, Risnes S, Larheim TA, Gröndahl HG. Detection of approximal caries with a storage phosphor system. A comparison of enhanced digital images with dental X-ray film. Dentomaxillofacial Radiol. 1996 Sep;25(4):202–6.
16. Martins LAC, Nascimento EHL, Gaêta-Araujo H, Oliveira ML, Freitas DQ. Mapping of a multilayer panoramic radiography device. Dentomaxillofacial Radiol. 2022 May 1;51(4):20210082.
17. Jeon KJ, Han SS, Lee C, Choi YJ, Jung HI, Kim YH. Application of panoramic radiography with a multilayer imaging program for detecting proximal caries: a preliminary clinical study. Dentomaxillofacial Radiol. 2020 Dec 1;49(8):20190467.
18. Elmesellawy MY, Fahd A, Nasr M. Assessment of Mesiobuccal Root Canal Curvature in Maxillary Molars of Egyptian Population: A Standardized CBCT-Based Radiographic Protocol. Ain Shams Dent J. 2024 Jun 1;34(2):195–202.
19. Hussein M, Mostafa M, Abo Fotouh M, Adel-Khattab D. Intra Oral Digital Radiography versus Cone Beam Computed Tomography for Detection of Infra Bony Periodontal Defects. Ain Shams Dent J. 2021 Dec 1;24(4):87–94.
20. Giacaman RA, Fernández CE, Muñoz-Sandoval C, León S, García-Manríquez N, Echeverría C, et al. Understanding dental caries as a non-communicable and behavioral disease: Management implications. Front Oral Health. 2022 Aug 24;3:764479.
21. Kamburoğlu K, Kolsuz E, Murat S, Yüksel S, Özen T. Proximal caries detection accuracy using intraoral bitewing radiography, extraoral bitewing radiography and panoramic radiography. Dentomaxillofacial Radiol. 2012 Sep;41(6):450–9.
22. Abesi F, Mirshekar A, Moudi E, Seyedmajidi M, Haghanifar S, Haghighat N, et al. Diagnostic Accuracy of Digital and Conventional Radiography

in the Detection of Non-Cavitated Approximal Dental Caries. Iran J Radiol. 2012 Mar 25;9(1):17–21.

23.   Rahmel S, Schulze RKW. Accuracy in Detecting Artificial Root Resorption in Panoramic Radiography versus Tomosynthetic Panoramic Radiographs. J Endod. 2019 May;45(5):634-639.e2.
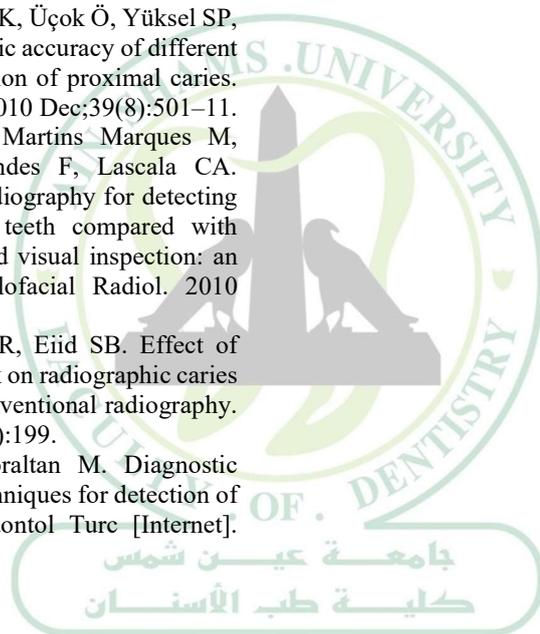
24.   Terry GL, Noujeim M, Langlais RP, Moore WS, Prihoda TJ. A clinical comparison of extraoral panoramic and intraoral radiographic modalities for detecting proximal caries and visualizing open posterior interproximal contacts. Dentomaxillofacial Radiol. 2016 Apr;45(4):20150159.

25.   Şenel B, Kamburoğlu K, Üçok Ö, Yüksel SP, Özen T, Avsever H. Diagnostic accuracy of different imaging modalities in detection of proximal caries. Dentomaxillofacial Radiol. 2010 Dec;39(8):501–11.

26.   Dias Da Silva PR, Martins Marques M, Steagall W, Medeiros Mendes F, Lascala CA. Accuracy of direct digital radiography for detecting occlusal caries in primary teeth compared with conventional radiography and visual inspection: an *in vitro* study. Dentomaxillofacial Radiol. 2010 Sep;39(6):362–7.

27.   Zayet MK, Helaly YR, Eiid SB. Effect of changing the kilovoltage peak on radiographic caries assessment in digital and conventional radiography. Imaging Sci Dent. 2014;44(3):199.

28.   Yalçın Yeler D, Koraltan M. Diagnostic accuracy of five different techniques for detection of approximal caries. Acta Odontol Turc [Internet]. 2017 Sep 12.

ASDJ

Ain Shams Dental Journal

Validity of Panoramic Multilayer Imaging Program in the Diagnosis of Proximal Caries: An Ex-vivo Study| Weam Ibrahim et al. MARCH2025.