In vitro effect of changing the horizontal angulation of X-ray beam on the detection of proximal enamel caries in bitewing radiographs

Wpływ zmian poziomego kąta padania promienia centralnego X na wykrywanie próchnicy szkliwa na powierzchniach stycznych na zdjęciach skrzydłowo-zgryzowych – badania in vitro

Abbas Shokri[1,A], Shahin Kasraei[2,B], Elham Shokri[3,C], Maryam Farhadian[4,E], Bahareh Hekmat[1,D,F]

[1] Dental Implant Research Center, Department of Oral and Maxillofacial Radiology, Dental School, Hamedan University of Medical Science, Iran
[2] Department of Restorative Dentistry, Dental School, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[3] Dental Research Center, Department of Oral and Maxillofacial Radiology, Dental School, Hamedan University of Medical Science, Iran
[4] Modeling of Noncommunicable Diseases Research Center, Department of Epidemiology, School of Public Health, Hamedan University of Medical Sciences, Iran

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2018;55(1):29–34

Address for correspondence
Bahareh Hekmat
E-mail: bahar_hekmat70@yahoo.com

Funding sources
None declared

Conflict of interest
None declared

Received on November 21, 2017
Reviewed on December 27, 2017
Accepted on January 28, 2018

Abstract

Background. Bitewing radiography is an important modality useful for the evaluation of teeth in patients of various ages and in different stages of tooth eruption. Clinical examination of proximal surfaces for caries may result in false negative results, especially in tight contact areas. Thus, radiography, as an adjunct to clinical examination, is used as a routine diagnostic modality for caries detection.

Objectives. The objective of this study was to assess the in vitro effect of changing the horizontal angulation of X-ray beam on the detection of proximal enamel caries in bitewing radiographs.

Material and methods. This in vitro study was conducted on 150 caries-free human premolars (code: p/16/35/9/210). The teeth were randomly divided into 3 groups (n = 50). Group 1 served as the control group and no carious lesions were induced in this group. Teeth in groups 2 and 3 were immersed in demineralizing solution for 2 and 4 months, respectively. After induction of caries and its radiographic confirmation, the teeth were mounted in wax in groups of 3 and bitewing radiographs were obtained at 0°, 5°, 10° and 15° horizontal angles.

Results. The sensitivity values of bitewing radiographs at 0°, 5°, 10° and 15° horizontal angles were 88%, 90%, 88%, 92% in group 2 and 88%, 94%, 94% and 94% in group 3, respectively. The specificity values of bitewing radiographs at 0°, 5°, 10° and 15° horizontal angles were 92%, 86%, 84% and 76%. The accuracy of bitewing radiographs at 0°, 5°, 10° and 15° horizontal angles was 89.3%, 90%, 88.7% and 87.3%, respectively. The highest diagnostic accuracy was obtained at 5° horizontal angle for caries detection; however, the difference in this regard among the tested horizontal angles was not statistically significant (p = 0.846).

Conclusions. Based on the results of this study, changing the horizontal angulation has no significant effect on the detection of proximal enamel caries in bitewing radiographs.

Key words: bitewing radiography, approximal caries, angulation, X-ray beam

Słowa kluczowe: zdjęcie skrzydłowo-zgryzowe, próchnica na powierzchniach stycznych, kąt promienia centralnego, wiązka promieniowania rentgenowskiego

DOI
10.17219/dmp/84868

Introduction

Dental caries is a microbial infectious disease characterized by demineralization and destruction of the mineral structure of teeth. Carious lesions develop as a result of the activity of acidogenic bacteria since they provide a suitable environment for the demineralization of tooth structure.[1]

Carious lesions confined to the enamel are referred to as incipient caries. Incipient caries is characterized by an intact surface with an underlying porous structure, which is reversible and can be remineralized. Clinically, an incipient carious lesion appears as a white spot lesion detectable after drying the tooth surface.[1]

Proximal tooth surfaces are susceptible to caries. Proximal caries develops at the contact area between 2 adjacent teeth. Clinically, proximal carious lesions have an opaque appearance and decrease enamel translucency below the contact area and above the free gingival margin.[2]

Carious lesions are primarily detected by a clinical examination. Visual inspection is the first step in the clinical examination of teeth. A dental explorer can be used for tactile examination. However, inappropriate use of the sharp tip of an explorer can create a cavity on the sound surface of an incipient carious lesion. Radiography is another diagnostic modality for this purpose. Properly obtained radiographs can provide valuable diagnostic information as a supplement to a clinical examination.[1]

Bitewing radiography is an important modality useful for the evaluation of teeth in patients of various ages and in different stages of tooth eruption. Bitewing radiographs often visualize the crowns of maxillary and mandibular teeth as well as the alveolar crest; thus, they are suitable for visualization and inspection of proximal areas and the detection of approximal carious lesions, which have yet to manifest clinically.[3] In bitewing radiography, X-ray beams pass through the teeth parallel to the occlusal plane, and thus the contact area is well visualized (as an open contact) on radiographs.[4]

Clinical examination of proximal surfaces for caries may result in false negative results, especially in tight contact areas. Thus, radiography, as an adjunct to clinical examination, is used as a routine diagnostic modality for caries detection.[4,5] In order to visualize a carious lesion on a parallel radiograph (0° angle), it must have a minimum depth of 0.5 mm; a cavity has yet to be formed in 60% of such carious lesions.[1] The absence of a horizontal and vertical overlap is a primary requirement for an optimal bitewing radiograph, which is helpful for the correct detection of caries.[6]

Despite the fact that the contact area of teeth must be open and overlaps must be absent on bitewing radiographs, in the current study bitewing radiographs were obtained at 0°, 5°, 10° and 15° horizontal angles to evaluate the effect of changing the horizontal angulation on the accuracy of detecting proximal enamel caries, since early detection of caries is absolutely necessary to take measures to cease the progression of carious lesions. In other words, we hypothesized that we might be able to disregard some degrees of overlap (caused by changing the horizontal angulation) in favor of enhancing early detection of proximal carious lesions shallower than 0.5 mm.

Digital radiography was used in this study, since digital software programs allow easy manipulation of contrast to enhance visualization of a particular area; whereas, if the respective contact area is completely open (no overlap), increased contrast may cause burnout of enamel margins and, consequently, incipient caries may be masked and remain undetected. Thus, this study aimed to assess the effect of changing the horizontal angulation of X-ray beams for the detection of artificially induced proximal enamel caries on bitewing radiographs.

Objectives

The objective of this study was to assess the in vitro effect of changing the horizontal angulation of X-ray beam on the detection of proximal enamel caries in bitewing radiographs.

Material and methods

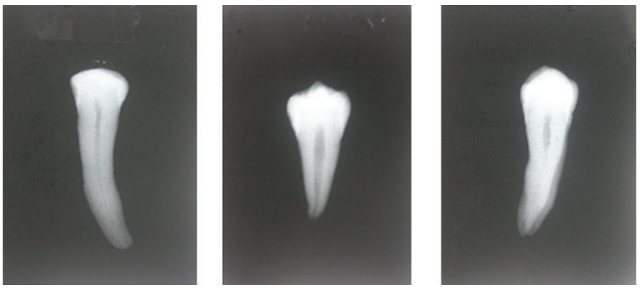
This in vitro, experimental study was conducted in Dr. Abbas Shokri Oral and Maxillfacial Radiology Clinic (Hamedan, Iran). The study was conducted on 150 sound (caries-free) extracted human premolar teeth (code: p/16/35/9/210). The teeth had been extracted for orthodontic or periodontal reasons. The teeth were cleaned and immersed in 0.2% sodium hypochlorite solution for 20 min for disinfection. Next, they were stored in saline solution until the experiment. The teeth were inspected visually and then with a dental explorer to ensure that there were no caries, enamel defects or cracks. The tooth surfaces were coated with 2 layers of nail varnish. Then, the nail varnish on the mesial/distal surface was randomly removed to create a varnish-free window measuring 2 × 2 mm (Fig. 1).

TenCate demineralizing solution with a pH of 4 was used to artificially create carious lesions. The chemical composition of this solution included 2.2 mM calcium chloride ($CaCl_2$), 2.2 mM potassium dihydrogen phosphate (KH_2PO_4), 0.05 M acetic acid and 1 M potassium hydroxide (KOH).[7] The teeth were randomly divided into 3 groups (n = 50). Group 1 served as the control group and artificial carious lesions were not induced in teeth in this group. Teeth in groups 2 and 3 were immersed in demineralizing solution for 2 and 4 months, respectively. Teeth in groups 2 and 3 were radiographed periodically every 30 days using Minray® intraoral X-ray unit (Tuusula, Helsinki, Finland) with the exposure set-

Fig. 1. Teeth coated with nail varnish with a varnish-free window on one of their proximal surfaces

tings of 60 kVp, 7 mA and 0.1 s time at 0° angle. Development of incipient caries was radiographically confirmed as such (Fig. 2).

After the formation of carious lesions and their radiographic confirmation, the teeth were coded and randomly mounted in wax (3 teeth in a row per each wax mold) such that the carious proximal surfaces were positioned in contact with the adjacent teeth (Fig. 3). Photostimulable phosphor plate (PSP) digital sensors (Optime®, Soredex, Helsinki, Finland) were used to take digital radiographs of the teeth. After placing a size 2 PSP sensor in the desired position, bitewing radiographs were obtained using Minray X-ray unit with the exposure settings of 60 kVp, 7 mA and 0.1 s time at 0° (perpendicular to tooth surface), 5°, 10° and 15° horizontal angles. To adjust the horizontal angle (since the horizontal angle of the X-ray unit was not adjustable and the tube could only be adjusted in different vertical angles), the X-ray tube was rotated such that the vertical angulation options were positioned horizontally. Horizontal angulation was adjusted as such and bitewing radiographs were taken at the aforementioned angles (Fig. 3, 4).



a b c

Fig. 2. Radiographs obtained at 30 (a), 60 (b) and 90 (c) days following immersion of teeth in demineralizing solution to ensure development of carious lesions

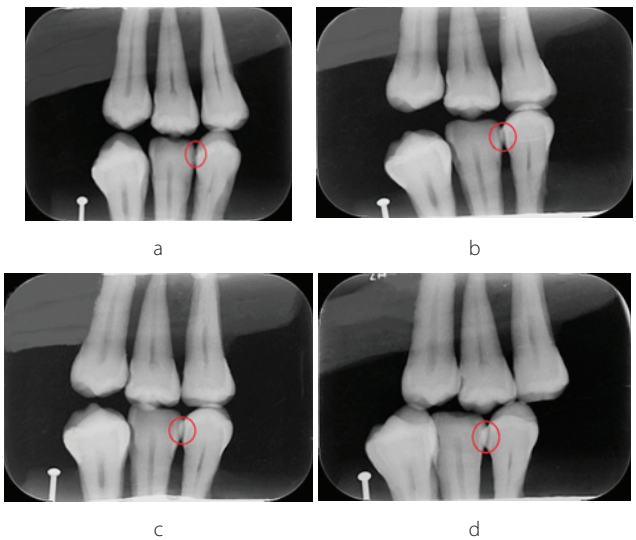
Fig. 3. Teeth mounted in wax

Fig. 4. Adjusting the X-ray tube angulation to take radiographs at different horizontal angles

All radiographs were evaluated by 2 oral and maxillofacial radiologists for the presence of proximal carious lesions and performed clear detection using a 1–4 scoring system as follows:

1. No carious lesion detectable,
2. Carious lesion not clearly visible (indefinite diagnosis),
3. Carious lesion clearly visible,
4. Presence/absence of carious lesion could not be determined due to significant overlap.[5]

Observers were blinded to the carious/sound state of teeth and the horizontal angulations at which the radiographs were taken (Fig. 5).



a b c d

Fig. 5. Bitewing radiographs taken at 0° (a), 5° (b), 10° (c) and 15° (d) horizontal angles

Fig. 6. Teeth longitudinally sectioned by a diamond disc for evaluation under a stereomicroscope for definite detection of carious lesions

The teeth were then sectioned parallel to their longitudinal axis in buccolingual direction (Fig. 6) and evaluated under a stereomicroscope (Olympus®, Hamburg, Germany) at ×20 magnification to determine the presence/absence of carious lesions.

Results

Table 1 shows the inter- and intraobserver agreements for detection of caries on bitewing radiographs taken at 0°, 5°, 10° and 15° horizontal angles. The highest interobserver agreement (93.5%) was noted for radiographs taken at 10° horizontal angle while the highest intraobserver agreement (78%) was noted in radiographs taken at 5° horizontal angle.

Table 1. Intra- and interobserver agreements for caries detection on bitewing radiographs taken at different horizontal angles by calculation of the kappa statistic

Interobserver agreement [%]	Intraobserver agreement [%]	Angle
85.4	73.9	0°
92.2	78.5	5°
93.5	76.5	10°
93.3	76.3	15°

Table 2 shows the sensitivity, specificity, accuracy, positive predictive value and negative predictive value of bitewing radiographs for detection of proximal enamel caries. In group 2, radiographs taken at 15° horizontal angle had the highest (94%) and those taken at 0° horizontal angle had the lowest sensitivity (86%). In group 3, radiographs taken at 10° and 15° horizontal angle had the highest (94%) and those taken at 0° horizontal angle had the lowest (80%) sensitivity. The difference in sensitivity values among different angulations was statistically significant (p = 0.026). Specificity values decreased by an increase in the horizontal angle. The highest specificity (94%) was noted at 0° horizontal angle, while the lowest specificity (84%) was noted at 15° horizontal angle. The difference in this respect was not statistically significant (p = 0.288). The highest accuracy (90%) was noted at 15° horizontal angle while the lowest accuracy (86%) was recorded at 0° horizontal angle. The difference in this regard among different horizontal angles was not statistically significant (p = 0.593).

Discussion

Nowadays, dental caries is a major health problem and one of the most common chronic diseases throughout the world. In has a great effect on the life quality and major indirect impact on the economy.[8,9] One of the most problematic parts of a dental examination is the detection of caries lesions on tooth surfaces which are hard to reach. Nowadays, in clinical practice, besides clinical examination, subsidiary methods, such as radiovisiography or laser in identifying proximal caries, are recommended.[10] Valid and reliable methods detecting proximal caries lesions are required for the appropriate treatment of dental caries.[11] Different techniques for detecting proximal caries have been studied and the bitewing radiography is reported as the most efficient modality for the detection of proximal caries.[2,10]

Early detection of incipient non-cavitated caries lesions is important since their progression can be stopped by preventive interventions with minimal invasion to the tooth structure and no need for restorative treatments.[5,11] Shallow carious lesions detected early (before forming a cavity) can be reversed by preventive measures such as fluoride therapy, oral hygiene instruction and decreasing the consumption of carbohydrates.

Table 2. Sensitivity, specificity, accuracy, positive predictive value and negative predictive value of bitewing radiographs taken at different angles for detection of proximal enamel caries

Angle	Sensitivity [%]		Specificity [%]	False positive [%]	False negative [%]		Accuracy [%]
	group 3	group 2			group 3	group 2	
0°	86	80	94	6	14	20	86.7
5°	90	90	90	10	10	10	90
10°	88	94	86	14	12	6	89.3
15°	94	94	84	16	6	6	90.7
p-value	0.593		–	–	0.288		0.026

Horizontal angles adjusted for taking bitewing radiographs from the premolar and molar areas are slightly different. In the clinical setting, incipient carious lesions confined to the enamel in premolar teeth are often better visualized on radiographs taken from the molar area. Thus, a question arises whether changing the horizontal angle when taking bitewing radiographs can enhance the detection of proximal enamel caries, or on the contrary, lesions detected on such radiographs are not caries and changing the horizontal angle may create a caries-like appearance and lead to false positive results.

The current study evaluated the effect of changing the horizontal angle when taking bitewing radiographs on the detection of proximal enamel caries. The results showed that the sensitivity of bitewing radiographs increased by an increase in horizontal angle (compared to 0° angle); however, the difference in this respect among the tested horizontal angles was not statistically significant. Chadwick et al. evaluated the effect of changing the horizontal angulation of X-ray beam and buccolingual cavity width on radiographic depth of approximal cavities and reported that alterations in the horizontal angle significantly affected the depth of a cavity such that an increase in horizontal angle led to an increase of the radiographic depth as well. By changing the horizontal angle of the X-ray beam, carious lesions are visualized to a greater extent.[12]

In our study, the sensitivity of bitewing radiographs for detecting proximal enamel caries was found to be 88%, which was higher than the values obtained by Pontual et al. and Abesi et al.[4,5] This difference in the results may be attributed to the following reasons:

1. The current study was conducted on extracted teeth collected from several centers. Three teeth were mounted next to each other in a row in wax, and a simulation of dental arch and natural contact of teeth in the oral cavity was not feasible. This might have increased the ability of observers for detecting caries.
2. In our study, soft tissue was not simulated when taking radiographs while in the oral cavity, gingival soft tissue and structures such as nasolabial fold may be superimposed on teeth and decrease the accuracy of detection of caries.
3. In the clinical setting, following several consecutive demineralization and remineralization cycles, enamel caries occurs due to the dominance of the demineralization process. Thus, enamel carious lesions in the clinical setting are irregular and have a relatively low contrast; as a result, they are not easily detectable radiographically. However, the current study had an in vitro design; the teeth were sound and only demineralizing solution was used to induce caries. Thus, the resultant carious lesions had a more regular structure, which enhanced their detection using radiographs.

In the current study, specificity was calculated to be 92%, which was similar to the results of Kamburoğlu et al., Pontual et al. and Abesi et al.[2,4,5] In our study, specificity decreased with an increase in the horizontal angle, although no statistically significant difference was noted in this regard among the tested horizontal angles. Changing the angle results in an overlap of adjacent structures and, due to superimposition of the enamel of the 2 adjacent teeth, this area appears more opaque on radiographs. Margins of the overlapped area absorb less X-ray beam due to the lower density and appear radiolucent on radiographs mimicking carious lesions. This decreases the ability of observers to detect sound surfaces. As a result, observers may misdiagnose sound surfaces as carious. In our study, vertical angle was 0° when taking radiographs and the highest diagnostic accuracy was noted in radiographs taken at a 5° horizontal angle; however, the difference in this respect among different horizontal angles was not statistically significant. Thus, if incipient carious lesions are not detected on standard bitewing radiographs but the patient complaints of tooth hypersensitivity at the area, horizontal angle can be changed when taking bitewing radiographs to better evaluate the area for possible caries. Moreira et al. evaluated the effect of vertical angle of X-ray beam on the detection of secondary caries developed under esthetic restorations and showed that 10° vertical angle yielded the highest diagnostic accuracy, although the difference among the tested angles was not statistically significant.[13] In the current study, the sensitivity for detecting carious lesions was higher in group 3 (longer immersion of teeth in demineralizing agent). This finding was in agreement with the results of previous studies reporting that a greater depth of caries results in the easier detection of carious lesions.[5,12,14] However, Pontual et al. reported results contrary to our findings and those of some other studies.[4] In our study, radiographs taken at 5° horizontal angle yielded the highest intraobserver agreement, while the highest interobserver agreement was noted in radiographs taken at 10° horizontal angle.

Conclusions

This study showed no statistically significant difference in the detection of proximal enamel caries in bitewing radiographs taken at different horizontal angles. However, based on the obtained results, in cases suspected of proximal caries which is not visualized in a standard bitewing radiograph taken at 0° angle in the clinical setting, horizontal angulation can be changed by 5° to 10° to enhance diagnosis.

References

1. Roberson T, Heymann H, Swift Jr E. *Art and Science of Operative Dentistry.* St. Louis, MO, Mosby Co; 2006:92–110.
2. Kamburoğlu K, Kolsuz E, Murat S, Yüksel S, Özen T. Proximal caries detection accuracy using intraoral bitewing radiography, extraoral bitewing radiography and panoramic radiography. *Dentomaxillofac Radiol.* 2012;41:450–459.

3. Dauer L, Branets I, Stabulas-Savage J, et al. Optimising radiographic bitewing examination to adult and juvenile patients through the use of anthropomorphic phantoms. *Radiat Prot Dosimetry.* 2014;158.
4. Pontual A, Melo DP, Almeida SM, Bóscolo FN, Haiter Neto F. Comparison of digital systems and conventional dental film for the detection of approximal enamel caries. *Dentomaxillofac Radiol.* 2010;39:431–436.
5. Abesi F, Mirshekar A, Moudi E, et al. Diagnostic accuracy of digital and conventional radiography in the detection of non-cavitated approximal dental caries. *Iran J Radiol*. 2012;9:17–21.
6. Stuart C. White MJP. *Oral Radiology: Principles and Interpretation*. 7th ed. Elsevier; 2014:95–100.
7. Onem E, Baksi BG, Sen BH, Sögüt O, Mert A. Diagnostic accuracy of proximal enamel subsurface demineralization and its relationship with calcium loss and lesion depth. *Dentomaxillofac Radiol.* 2012;41:285–293.
8. Hussein Abu El-Ela W, Medhat Farid M, Saad El-Din M. Intraoral versus extraoral bitewing radiography in detection of enamel proximal caries: An ex vivo study. *Dentomaxillofac Radiol.* 2016;45:18–23.
9. Zhang ZL, Li JP, Li G, Ma XC. Accuracy of computer aided measurement for detecting dental proximal caries lesions in images of cone-beam computed tomography. *Chin J Stomatol*. 2017;52:103–108.
10. Błażejewska A, Dacyna N, Niesiobędzki P, et al. Comparison of the detection of proximal caries in children and youth using DIAGNOcam and bitewing radiovisiography. *Dent Med Probl.* 2016;53:468–475.
11. Litzenburger F, Heck K, Pitchika V, et al. Inter- and intra-examiner reliability of bitewing radiography and near-infrared light transillumination for proximal caries detection and assessment. *Dentomaxillofac Radiol.* 2017. doi.org/10.1259/dmfr.20170292.
12. Chadwick BL, Dummer PM, VanderStelt PF. The effect of alterations in horizontal X-ray beam angulation and buccolingual cavity width on the radiographic depth of approximal cavities. *J Oral Rehabil.* 1999;26:292–301.
13. Moreira PL, Messora MR, Pereira SM, Almeida SM, Cruz AD. Diagnosis of secondary caries in esthetic restorations: Influence of the incidence vertical angle of the X-ray beam. *Braz Dent J.* 2011;22:129–133.
14. Castro VM, Katz JO, Hardman PK, Glaros AG, Spencer P. In vitro comparison of conventional film and direct digital imaging in the detection of approximal caries. *Dentomaxillofacial Radiol.* 2007;36:138–142.

.