Original Article

Interobserver Agreement in Proximal Caries Detection from a Smartphone Display

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Abstract

The aim of this study was to report an inter-observer agreement in proximal caries detection from digital bitewing radiographs viewed and evaluated on a smartphone display. A total of 200 proximal surfaces from digital bitewing radiographs stored in the Picture Archiving and Communication System (PACS) of Chulalongkorn University dental hospital were selected. Images of selected radiographs were exported in JPEG format and transferred to an iPhone 8 plus. Each proximal surface was viewed and evaluated by seven observers in a dimly lit room (ambient light intensity < 100 lux). The ratings were on a 5-point-scale. Weighted kappa test was used to determine agreement among observers. Inter-observer agreement among observers ranged from moderate to almost perfect (0.47 - 0.82). Images of digital bitewing radiographs viewed on a smartphone provided an acceptable result in terms of consistency between dentists and may be considered one of the methods used for proximal caries detection.

Keyword: Digital radiograph, Display, Proximal caries, Smartphone

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Introduction

Digital radiography is gradually becoming common in today's dental practice. The advantages, compared to conventional techniques, include easier processing, saving time, cost reduction in the long term and environmental friendliness. Moreover, the images can be stored for a very long time without quality changes.

One of the most important parts in a digital radiographic system is the display. As a final device that shows resultant images, an underqualified display can compromise the image quality and lead to misinterpretation and misdiagnosis. Also, well-calibrated monitors reduce eye strain and fatigue.[1] Medical-grade displays are invented as assisting tools in medical radiography assessment. These monitors can be adjusted to comply with a certain protocol, called the Digital Imaging and Communication in Medicine (DICOM) Part 14 Greyscale Standard Display

Function standard (GSDF).[2] This named guideline is developed by experts in the American Association of Physicists in Medicine (AAPM) and the National Electrical Manufacturers Association (NEMA). However, this type of display is very expensive and may not be affordable in community hospitals or small clinical settings. Therefore, cheaper off-the-shelf PC monitors are alternatively used. Tablet devices and smartphones are also selected, especially in case consulting, as they are portable, easy-to-use and more budget friendly.

A smartphone is a portable device that can perform many of the functions of a computer, and usually has a touchscreen interface, internet access, and an operating system capable of running downloaded applications. Nowadays, smartphone usage is near-universal. Many health-care providers use their smartphones to transmit patient-related information, including viewing and evaluating radiographs to come up with a proper treatment plan.[3]

Usually, proximal caries, especially incipient ones, are barely visible in visual examination. There are numerous tools invented for proximal caries detection. One of the widely accepted methods is using bitewing radiographs which reveal 88 % more proximal carious lesions when compared with visual inspection alone.[4]

Bitewing radiographs are the essential diagnostic tool in proximal caries diagnosis, especially for non-cavitated lesions. Commonly, radiolucency cannot be detected in a radiograph unless there are more than 30 – 40 % of demineralization in the affected areas.[5] As the true depths of proximal caries are always greater than those observed, it is recommended that this type of lesion be found as early as possible.[6] Still, this can be challenging because of indistinct radiolucency in incipient caries. Consequently, monitors with adequate quality should be used to show such precise details. The effectiveness among displays available in today's market, especially smartphones' displays, is not yet thoroughly studied and the results remain controversial.[7-13]

The aim of this study was to report an inter-observer agreement in proximal caries detection from digital bitewing radiographs viewed and evaluated on a smartphone display.

Materials and Methods

A total of 200 proximal surfaces from digital bitewing radiographs which were stored in the Picture Archiving and Communication System (PACS) of Chulalongkorn University dental hospital were selected. The number of sampled surfaces was mentioned in previous studies.[11,12] Proximal surfaces, starting from mesial surfaces of first premolars to mesial surfaces of third molars (if present) of each quadrant, were observed. Inclusion and exclusion criteria were as follows;

Inclusion criteria

- Acceptable quality: No overexposure or underexposure, no cone cutting and artifacts
- No overlapping between each proximal surface

Exclusion criteria

- Surfaces with proximal restorations, edentulous areas, retained roots, fixed prostheses or orthodontic appliances

Images of selected radiographs (Fig. 1) were exported in JPEG format and transferred to an iPhone 8 plus (Apple, Cupertino, CA, USA). The model has a color LCD monitor with IPS technology, 5.5" in display size and resolution of 1920 x 1080 pixels.

Figure 1 *An examples of the selected radiographs, only non-overlapping surfaces without any artifacts and filling material on proximal surfaces were evaluated.*

Each proximal surface was viewed and evaluated by seven observers in a dimly lit room (ambient light intensity < 100 lux). The observers consisted of three oral and maxillofacial radiologists, two dentists specialized in operative dentistry and two general practitioners with at least five years of experience. The number of observers was determined in accordance to previous studies.[11,12] All observers were calibrated and introduced to the device. After that, each observer was assigned to evaluate the images independently using the "Photos" application. Brightness, contrast and magnification could be subjectively adjusted. Each proximal surface of selected tooth was rated by a 5-point-scale (1 = caries definitely absent, 2 = caries probably absent, 3 = unsure if caries absent or present, 4 = caries probably present and 5 = caries definitely present).

Statistical analysis was performed in SPSS Software version 22. A weighted kappa test was used to determine agreement among observers. The strength of agreements were determined in accordance to Landis and Koch's guidelines[14] (Table 1). The significance level was set at 0.05.

Table 1 *Strength of agreement according to kappa value by Landis and Koch[14]*

Kappa value	Strength of agreement
<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

Results

Inter-observer agreement among seven observers ranged from "moderate" to "almost perfect", with the minimum value of 0.47 and maximum value of 0.82. Strength of agreements were mostly at the "substantial" level. The weighted kappa values with standard errors, 95% confidence interval as well as p-value between each pair of observers are shown in Table 2.

Table 2 *Weighted kappa values (± standard error) and 95% confidence interval for inter-observer agreement*

Observers	2	3	4	5	6	7
1	0.583 (±0.041)	0.531 (±0.045)	0.58 (±0.042)	0.503 (±0.045)	0.543 (±0.044)	0.47 (±0.048)
	(0.502 - 0.664)	(0.442 - 0.62)	(0.498 - 0.662)	(0.416 - 0.591)	(0.457 - 0.628)	(0.376 - 0.564)
2		0.782 (±0.038)	0.787 (±0.035)	0.73 (±0.043)	0.737 (±0.045)	0.682 (±0.053)
		(0.706 - 0.857)	(0.718 - 0.856)	(0.646 - 0.814)	(0.648 - 0.826)	(0.579 - 0.785)
3			0.746 (±0.038)	0.651 (±0.046)	0.632 (±0.05)	0.606 (±0.054)
			(0.672 - 0.82)	(0.560 - 0.741)	(0.534 - 0.73)	(0.501 - 0.711)
4				0.73 (±0.041)	0.731 (±0.041)	0.67 (±0.049)
				(0.651 - 0.81)	(0.651 - 0.812)	(0.574 - 0.767)
5					0.611 (±0.051)	0.82 (±0.037)
					(0.511 - 0.711)	(0.748 - 0.893)
6						0.613 (±0.055)
						(0.505 - 0.721)

p-value < 0.001 for all kappa volues[5]

Discussion

In our study, seven observers participating in our study and viewing selected bitewing radiographs on the same smartphone display showed "moderate" to "almost perfect" agreement on proximal caries detection. Most of the calculated values were at a "substantial" level. The result is similar to a previous study that reported inter-

observer agreements among three dentists evaluating conventional radiographs[15], slightly lower than a study[16] using printed bitewing and digital images viewed on a monitor but higher than another study[17] which also used radiographs obtained from a digital system. The comparison of the kappa values and devices used to display the images are shown in Table 3.

Table 3 *Kappa values from previous studies, according to inter-observer agreements in evaluations of proximal caries*

Study	System	Kappa value
This study	Digital (smartphone display)	0.47 - 0.82
Abuzenada[17]	Digital (monitor)	0.44 - 0.47
Adibi *et al.*[16]	Digital (printed film)	0.778
	Digital (monitor)	0.847
Countryman *et al.*[7]	Digital (1st medical-grade display)	0.331 - 0.797
	Digital (2nd medical-grade display)	0.333 - 0.811
	Digital (1st tablet display)	0.239 - 0.785
	Digital (2nd tablet display)	0.300 - 0.858
	Digital (common display)	0.383 - 0.780
Kamburoglu *et al.*[15]	Conventional	0.717 - 0.780

However, agreement among observers in proximal caries can be affected by numerous factors. Dental caries penetrated into dentine can be more detectable than caries that are confined only in enamel. One study[7] that found a considerably wide range of inter-observer agreement (0.239 - 0.858) consisted of sampled extracted teeth with artificial incipient caries and recurrent caries-like lesions. While other studies[15-17] that showed higher kappa values included samples with various depths of caries.

The number and specialty of observers may also contribute to radiographic interpretation. Fewer observers from the same department tend to have substantial agreement.[15,16] Meanwhile, dentists from different fields of expertise can show more discrepancy in that regard.[17] Participating observers should be skilled in radiographic caries detection. As there were studies that included oral and maxillofacial radiologists, oral and maxillofacial radiology residents[6,7,12], operative dentists[6] as well as general practitioners with considerable amount of working experience[11,12]. Seven observers specialized in those three different fields of dentistry were selected in this study and the agreement level ranged from "moderate" to "almost perfect".

Regarding the effect of visual acuity on radiographic interpretation, there were still limited studies addressing this issue.[20] A questionnaire-based survey performed in a dental school in New Zealand showed that 92 % of the teachers considered their eyesight satisfactory and sufficient for their dental practice.[18] As for the seven observers participating in our study, they have either normal eyesight or apply corrective lens that help restore their vision to normal range.

When compared between male and female dentists, no gender-specific differences in proximal caries detection were discovered. Whereas age, which can be related to the amount of experience, plays a more important role. The same study found that examiners with experience had almost four times greater chance of a correct assessment than examiners with less experience.[19]

Considering the growing usage of a digital radiographic system, choosing the proper displays for image evaluation is imperative to ensure accurate diagnosis which will lead to the appropriate management for each detected lesion. Countryman *et al.*[7] compared the performance of five different displays (one common monitor, two medical-grade monitors and two tablet displays) in

the detection of artificial incipient and recurrent caries-like lesions. The result showed no significant differences among the three types of display monitors. However, the auto-calibrating medical-grade monitors performed better when incipient and recurrent lesions were compared. In addition, Araki *et al.*[8] investigated the effect of display monitor devices on digital radiographic caries diagnosis by comparing one common monitor, one medical-grade monitor and one tablet display. The result showed the tablet display had lower diagnostic accuracy than the common monitor and the medical-grade monitor especially for superficial caries, but there was no significant differences between the common monitor and the medical-grade monitor on diagnostic accuracy of superficial caries.

According to Landis and Koch's guideline[14], a "substantial" agreement is quite a high-level degree. The calculated weighted kappa values from this study were also comparable to previous literatures[7,15,16,17,] which evaluated both conventional and digital bitewing radiographs via various methods. These results may encourage using a smartphone display as an optional but still acceptable method in detection of proximal caries. However, further studies with *in vitro* setting to reach gold standard in confirmation of carious lesions and other statistics (e.g. sensitivity, specificity, receiver operating characteristic curve (ROC curve)) are required to confirm the accuracy of this method.

In addition, since this study was performed on only one type of display, more monitor types and possibly related factors should also be included to facilitate comparison and determine the significance of each factor in respect of digital radiograph evaluation and diagnosis.

Conclusion

Images of digital bitewing radiographs viewed on a smartphone provided an acceptable result in terms of consistency between dentists and may be considered one of the methods used for proximal caries detection.

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References

1. Hirschorn DS, Krupinski EA, Flynn MJ. PACS Displays: How to Select the Right Display Technology. ***J Am Coll Radiol*** 2014;11(12, Part B):1270-6.

2. National Electrical Manufacturers Association. Setting standards for excellence. Digital imaging and communication in medicine (DICOM) Part 14: Grayscale standard display function. Rosslyn, VI: NEMA.

3. Handelman G, Rogers A, Babiker Z, Lee M, McMonagle M. Media messaging in diagnosis of acute CXR pathology: an interobserver study among residents. ***Intern Emerg Med*** 2018;13(8):1257-63.

4. Gordan V, Garvan C, Heft M, Fellows J, Qvist V, Rindal D, *et al.* Restorative treatment thresholds for interproximal primary caries based on radiographic images Findings from the Dental Practice-Based Research Network. ***Gen Dent*** 2009;57(6):654-63.

5. Wenzel A. Dental Caries. In: White SC, Pharoah MJ, editors. Oral radiology: principles and interpretation. 7th ed. St. Louis: Elsevier; 2014. p. 285-298.

6. Onem E, Baksi G, Sen BH, Söğüt Ö, Mert A. Diagnostic accuracy of proximal enamel subsurface demineralization and its relationship with calcium loss and lesion depth. ***Dentomaxillofac Radiol*** 2011; 41(4):285-93.

7. Countryman S, Sousa Melo S, Belém M, Haiter-Neto F, Vargas M, Allareddy V. Performance of five different displays in the detection of artificial incipient and recurrent caries-like lesions. ***Oral Surg Oral Med Oral Pathol Oral Radiol*** 2017;125.

8. Araki K, Fujikura M, Sano T. Effect of display monitor devices on intra-oral radiographic caries diagnosis. ***Clin Oral Invest*** 2015; 19(8):1875-9.

9. Tadinada A, Mahdian M, Sheth S, Chandhoke TK, Gopalakrishna A, Potluri A, *et al.* The reliability of tablet computers in depicting maxillofacial radiographic landmarks. ***Imaging Sci Dent*** 2015; 45(3):175-80.

10. Vasconcelos TV, Santaella GM, Nascimento HAR, Rovaris K, Ambrosano GMB, Freitas DQ. Digital radiographs displayed on different devices: effect on the detection of vertical root fractures. ***Int Endod J*** 2016;49(4):386-92.

11. Hellén-Halme K, Lith A. Carious lesions: diagnostic accuracy using pre-calibrated monitor in various ambient light levels: an *in vitro* study. ***Dentomaxillofac Radiol*** 2013;42(8):20130071.

.12. Hellén-Halme K, Nilsson M, Petersson A. Effect of monitors on approximal caries detection in digital radiographs—standard versus precalibrated DICOM part 14 displays: an in vitro study. ***Oral Surg Oral Med Oral Pathol Oral Radiol Endod*** 2009;107(5):716-20.
13. Isidor S, Faaborg-Andersen M, Hintze H, Kirkevang LL, Frydenberg M, Haiter-Neto F, *et al.* Effect of monitor display on detection of approximal caries lesions in digital radiographs. ***Dentomaxillofac Radiol*** 2009;38(8):537-41.
14. Landis J, Koch G. The Measurement Of Observer Agreement For Categorical Data. ***Biometrics*** 1977;33(1):159-74.
15. Kamburoglu K, Kolsuz M, Murat S, Yüksel S, Ozen T. Proximal caries detection accuracy using intraoral bitewing radiography, extraoral bitewing radiography and panoramic radiography. ***Dentomaxillofac Radiol*** 2012;41(6):450-9.
16. Adibi S, Amrollahi A, Dehghani Nazhvani A, Movahhedian N. Assessing the Accuracy of Caries Diagnosis in Bitewing Radiographs Using Different Reproduction Media. ***J Dent (Shiraz)*** 2018;19(3):174-80.
17. Abuzenada B. Detection of proximal caries with digital intraoral bitewing radiography: An interobserver analysis. ***Saudi J Health Sci*** 2019;8(1):38-41.
18. Chandler NP, Gray AR, Murray CMJBo. Eyesight: a study of the staff of a dental school. ***BDJ open*** 2017;3(1):1-4.
19. Geibel M-A, Carstens S, Braisch U, Rahman A, Herz M, Jablonski-Momeni A. Radiographic diagnosis of proximal caries—influence of experience and gender of the dental staff. ***Clin Oral Invest*** 2017;21(9):2761-70.
20. Halpenny D, O'Driscoll D, Torreggiani WC. Ocular health among radiologists in the age of PACS: is it time for our profession to open its eyes to this issue in light of existing European legislation? ***Br J Radiol*** 2012;85(1020):e1309-e11.