ACTA ODONTOLOGICA SCANDINAVICA
2018, VOL. 76, NO. 5, 346–350
https://doi.org/10.1080/00016357.2018.1460490

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

Low reproducibility between oral radiologists and general dentists with regards to radiographic diagnosis of caries

Elmira Pakbaznejad Esmaeili[a], Tuomas Pakkala[b], Jari Haukka[c] and Päivi Siukosaari[a,d]

[a]Department of Oral and Maxillofacial Diseases, Clinicum, University of Helsinki, Helsinki, Finland; [b]Department of Social Services and Health Care, City of Helsinki, Helsinki, Finland; [c]Department of Public Health, Clinicum, University of Helsinki, Helsinki, Finland; [d]Helsinki University Hospital, Helsinki, Finland

ABSTRACT

Aim: Early clinical and radiological diagnosis of dental caries is one of the fundamental objectives of clinical dentistry because of the high frequency of the disease and severe complications if caries remains untreated, especially among the elderly and patients with immunodeficiency. Dental panoramic tomography (DPT) is a common radiographic method for evaluating dentition when indicated, especially in an adult population. The aim of this study was to assess the reproducibility of diagnosis between specialists in oral radiology and general dentists with regards to caries lesions based on DPTs of adults.

Material and methods: One-hundred DPTs taken from adult patients (average age 35) and then analyzed and reported on by 42 general dentists were then analyzed independently by two specialists in oral radiology with respect to caries lesions in the premolar and molar areas using radiographic criteria established for caries diagnosis. The general dentists versus oral radiologists were not calibrated before. Level of agreement between specialists and general dentists was measured using Cohen's kappa.

Results: Comparison between observations of general dentists and specialists in oral radiology showed that 61% of the caries lesions on proximal surfaces of premolars and molars observed by specialists went unobserved by general dentists. Cohen's kappa value for specialists was 0.85 ($p < .001$) and for each specialist and general dentists 0.48 ($p < .001$) and 0.44 ($p < .001$).

Conclusions: The reproducibility between specialists in oral radiology and general dentists for detecting caries in DPTs was low.

ARTICLE HISTORY
Received 5 June 2017
Revised 20 March 2018
Accepted 20 March 2018

KEYWORDS
Caries detection; diagnosis; general dentists; image analysis; panoramic tomography

Introduction

Untreated dental caries requiring restorative treatment is a common odontological disease with a prevalence of 31% in dentate Finnish adults [1]. Undiagnosed and untreated dental caries may ultimately cause bacterial pulp infection, dental abscess and sometimes even life-threatening systematic conditions [2]. The impact of impaired oral health on general health, especially among older populations is a well-known issue [3–6]. According to the report released by the FDI World Dental Federation, '*As part of the recent international collaborative Global Burden of Disease Study (1990-2010), untreated tooth decay was identified as the most common condition among 291 diseases studied*' [4, p. 5].

The primary basic method for caries diagnosis is clinical examination, whereas radiographic examination a supplemental diagnostic tool [7]. Detection of caries lesions developed on proximal or occlusal surfaces may sometimes fail if it involves clinical examination only [8]. Among dental radiographic techniques, intraoral bitewings (BWs) are more informative than DPTs in revealing caries lesions located on proximal surfaces of premolars and molars [9,10], while for revealing caries located on occlusal surfaces, BWs and DPTs turned out to be of equal diagnostic value [11]. A DPT gives a wide view of the teeth, their supportive hard tissues and some adjacent structures, with acceptable diagnostic resolution [12]. When radiographic assessment of the whole dentition is clinically indicated, panoramic tomography is often preferred as an initial imaging method owing to its lower patient dose compared to a full-mouth periapical survey, and when required, DPTs are supplemented by intraoral projections [12]. Radiologically detected caries lesions must also be included in any DPT report that must be provided by a qualified, competent and skilled dentist [13,14].

Use of public dental services (PDS) has increased during recent decades in Finland, especially since 2002 as a result of oral health care reform [1,15]. As a result of this reform, the whole population at any age can benefit from PDS [15]. Thus, in Finland the public sector plays a very important role in providing diagnostic procedures, preventive care and restorative care [1].

In the Department of Social Services and Health Care of the City of Helsinki, dentists who order DPTs (either general dentists or other dental specialists), must ensure that these are reported either by themselves or by oral radiologists.

CONTACT Elmira Pakbaznejad Esmaeili elmira.pakbaznejad@helsinki.fi University of Helsinki, PL 41 (Mannerheimintie 172) 00014, Helsinki, Finland
Supplemental data for this article can be accessed here.

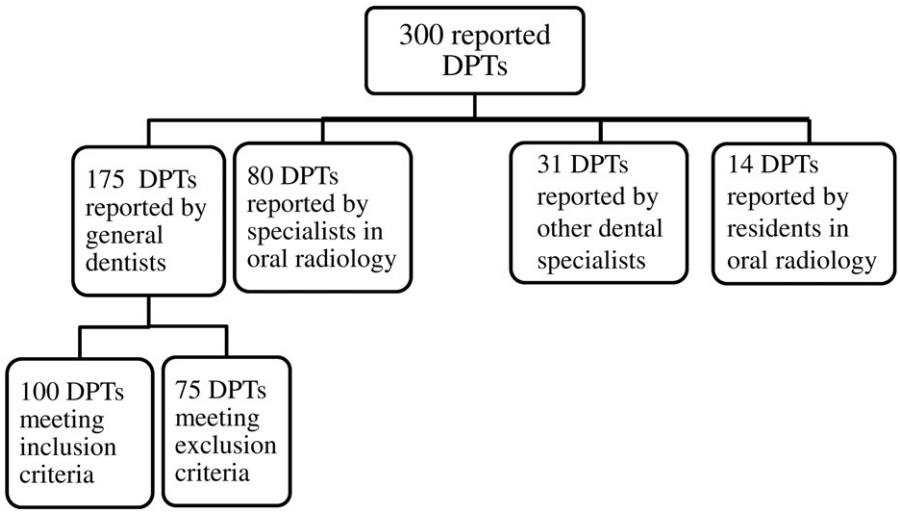

Figure 1. Chart demonstrating process of final data collection from 300 dental panoramic tomographs: 100 dental panoramic tomographs reported by general dentists.

Presumably, DPTs are not always complemented with BWs. Thus, in some situations, despite the relatively low reliability of DPT with respect to caries lesions of proximal surfaces, it remains the only radiographic examination during a patient's whole dental treatment period.

The purpose of this study was to assess the reproducibility between specialists in oral radiology and general dentists with regards to diagnosis of caries lesions based on DPTs of adults.

Materials and methods

Study permission

Study permission was issued by the Department of Social Services and Health Care of the City of Helsinki (HEL 2014-014932 T 130201).

Study sample

The study sample was randomly selected by automatic computer randomization fulfilling the following criteria: (1) year of birth before 1994 to insure inclusion of only adult patients in the study, (2) patient's files with a code for ordering a DPT (EB1HA) and for a DPT report (WZA90d) used by general dentists on the same day between January 2012 and December 2013 or (3) patient's files with a code for ordering a DPT and a DPT report used by specialists (WZA90h) on the same day between January 2012 and December 2013.

Data collection

Files of the 300 randomly selected patients reported were retrieved from the patient data management system of the Department of Social and Health care in Helsinki (Effica®; Tieto, Helsinki, Finland), and the educational background of each of the dentists who provided the DPT report was registered.

Of the 300 DPTs, 175 (58%) that were reported by general dentists were included in this study as the primary sample, from which those DPTs meeting the following exclusion criteria were excluded: (1) more than four missing/extracted teeth in the premolar and molar areas, (2) largely restored dentition (more than two surfaces of at least three teeth restored) and (3) patient positioning error leading to low image quality. Based on these criteria, 75 DPTs were excluded from the study. This resulted in having 100 reported DPTs that were considered as the main sample of the study (Figure 1).

Those 100 DPT reports were viewed from Effica® and observations of general dentists with regards to primary and secondary caries lesions of the proximal and occlusal surfaces of the premolars and molars (anterior teeth excluded) were recorded. Patients' DPTs were opened with Digora® for Windows 2.9 software (Soredex Dental, Tuusula, Finland) and viewed using Eizo MX210-FlexScan® monitors (Eizo Nanao Co, Japan) by two specialists in oral radiology independently. Afterwards, both oral radiologists interpreted and reported the same DPTs independently and recorded their observations with regards to primary and secondary caries lesions of the same teeth and same surfaces. Observations of oral radiologists were compared and then to the observations of the general dentists.

Radiographic caries recording criteria

The following definitions for radiographic appearance of caries were used as described by Wenzel [7] and Whaites [16]:

Proximal enamel caries: a triangular-shaped radiolucent shadow in the enamel area or extending to the dentinoenamel conjunction (DEJ), with its broad base located at the level of contact points (Figure 2(a)) [7,16].

Proximal dentinal caries: irregularly shaped radiolucent shadow spreading along the DEJ or extending into dentine at the level of contact points (Figure 2(b)) [7,16].

Occlusal dentinal caries: a wide-based irregular radiolucent shadow spreading into the dentine underneath a fissure (Figure 2(c)) [7,16].

Recurrent caries: irregularly shaped radiolucency below a restoration or next to it (Figure 2(d)) [7,16].

In their reports, the general dentists distinguished correspondingly between initial caries lesions restricted to the enamel, dentinal caries lesions extending to the dentine and recurrent caries occurring next to a restoration.

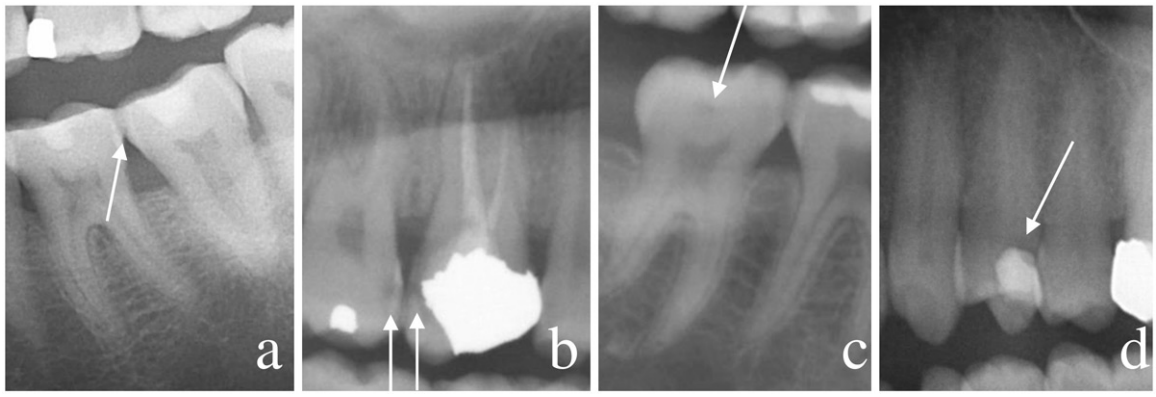

Figure 2. Cropped dental panoramic tomographs displaying proximal enamel caries (a), proximal dentinal caries (b), occlusal dentinal caries (c) and proximal recurrent caries (d).

Table 1. Inter-rater agreement between two oral radiologists on all 4653 surfaces of premolars and molars in 100 dental panoramic tomographs.

Observers		Oral radiologist 2 Caries	Oral radiologist 2 No caries	Total	Cohen's kappa value
Oral radiologist 1	Caries	179	21	200	
Oral radiologist 1	No caries	36	4417	4453	
		215	4438	4653	0.85 ($p < .001$)

Statistical analysis

Cohen's Kappa was calculated using an R language package irr [17] to evaluate the level of agreement (1) between two oral radiologists for the total surface, (2) between each oral radiologist versus 42 general dentists clustered in one group as one observer for the total surfaces, (3) between two oral radiologists for each surface of each tooth and (4) between each oral radiologist versus 42 general dentists clustered in one group as one observer for each surface of each tooth.

Table 2. Inter-rater agreement between each oral radiologist versus 42 general dentists clustered in one group on all 4653 surfaces of premolars and molars in 100 dental panoramic tomographs.

Observers		General dentists Caries	General dentists No caries	Cohen's kappa value
Oral radiologist 1	Caries	76	124	
Oral radiologist 1	No caries	30	4423	
				0.48 ($p < .001$)
Oral radiologist 2	Caries	74	141	
Oral radiologist 2	No caries	32	4406	
				0.44 ($p < .001$)

Results

The age of the patients ranged between 18 and 74 years (average age of 35). In total, 42 general dentists provided the 100 DPT reports included in this study. Of the 4653 total surfaces of the premolars and molars, 179 surfaces (3.8%) showed the radiological presence of caries based on the opinion and complete agreement of both oral radiologists. The two oral radiologists had a very good level of agreement regarding the total surfaces (Table 1). The strength of agreement for the total surfaces between each oral radiologist versus general dentists was moderate (Table 2). The strength of agreement between oral radiologists, and between each oral radiologist versus general dentists for each surface of each tooth and index of inter-rate agreement [18,19] is in Supplementary Appendix 1. There strongest level of agreement (good and very good) between the oral radiologists, and at the same time the lowest level of agreement (moderate and fair) between each oral radiologist versus general dentists was found for those teeth and surfaces shown in Figure 3. Of those teeth and surfaces, the distal surfaces of the maxillary right first molar and first premolar, maxillary left first premolar, mandibular left second premolar and the mesial surface of the mandibular right first molar had the highest level of agreement between two oral radiologists and the highest level of disagreement between each oral radiologist versus general dentists.

Of the surfaces showing a radiographic presence of caries according to the observations of both oral radiologists, 61% (109 of 179) were not observed by general dentists. Table 3 shows more details on those unobserved 109 lesions. About 89% of them were located on proximal surfaces of molars and premolars. Of these, 60% were dentinal caries and the rest enamel caries.

Discussion

When we evaluated the reproducibility of radiographic diagnosis of caries in the premolar and molar regions in DPTs between specialists in oral radiology and general dentists, we found only a small difference in the total amount of the surfaces analyzed, including the intact ones. However, when we compared only those surfaces showing radiographic presence of caries based on the observations of specialists, more than half were not observed by general dentists.

Our finding indicates that caries lesions on proximal surfaces of premolars and molars were those that remained mainly unobserved by general dentists. Considering that most of the DPTs taken from adults in the Department of

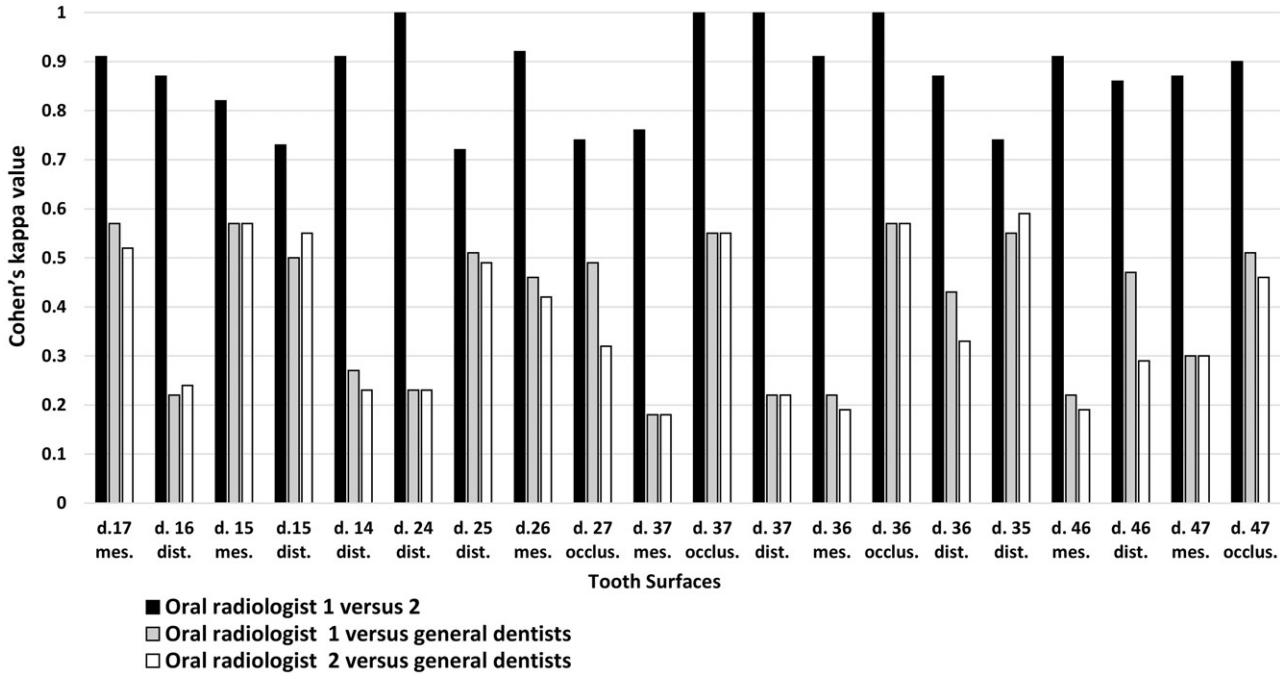

Figure 3. Chart demonstrating inter-rater agreement between oral radiologists and each oral radiologist versus the 42 general dentists clustered in one group over 13 teeth in 100 dental panoramic tomographs.

Table 3. Extent and location of unobserved and unreported caries lesions by general dentists but observed by both oral radiologists on 109 surfaces of premolars and molars in 100 dental panoramic tomographs.

	Proximal surfaces		Occlusal surfaces
Teeth	Enamel caries $n = 39$	Dentinal caries $n = 58$	Dentinal caries $n = 12$
Upper premolars	2	20	0
Upper molars	15	14	5
Lower premolars	0	3	1
Lower molars	22	21	6

Social Services and Health Care of the City of Helsinki are analyzed and reported by general dentists, they should probably be well advised to pay specific attention to the proximal surfaces of teeth in clinical examination.

The lesions that were missed by general dentists but observed by radiologists may belong to false-positive or false-negative diagnosis. False-positive findings are reported to be common and problematic phenomena during radiological assessment of occlusal dentinal lesions among dentists [20]. Moreover, these lesions may be inactive and may not need any intervention, or some of them may be non-cavitated requiring only preventive care or follow-up.

There are variations in both clinical and radiological caries diagnostic decisions among dental practitioners. They often disagree on stage and even presence of caries regardless of method used for diagnosis [21]. There is a high range of sensitivity for all types of caries diagnostic methods, including radiological ones [21].

There are studies showing different levels of variations and diagnostic threshold between dentists in radiological detection of caries, expressing the necessity of further training, calibration and adjustment of diagnostic criteria [20,22]. These studies show higher variations over occlusal caries lesions among observers, while our study indicates lower reproducibility over proximal surfaces. This may result from overlapping proximal surfaces of premolars in DPTs which is one of the disadvantages of this method in caries diagnosis [12]. Specialists in oral radiology, however, are expected to use more standardized criteria for this purpose.

There are, however, no studies comparing diagnostic skills of general dentists to oral radiologists. Considering high level of variations between dentists for caries diagnosis and high level of disagreement with oral radiologists in this study, standardizing their diagnostic skills is very important. Thus, using universally approved criteria for caries detection may contribute to proper diagnosis.

The ambient light conditions and the exact make and model of the used by the general dentists interpreting the images initially were unknown. However, the levels of lighting in a dental surgery tend to be generally high for normal clinical work, and the lighting is only occasionally dimmed for the duration of radiological diagnostics. The monitors used by general dentists in the Department of Social and Health Care in Helsinki are off-the-shelf models not specifically designed for diagnostics nor gray-scale calibrated.

The ambient light conditions for the radiologists in the study conformed to the Guidelines of the American Association of Physicists in Medicine (AAPM) [23] and the Institute of Physics and Engineering in Medicine (IPEM) [24]. They used DICOM-calibrated color liquid-crystal display (LCD) clinical viewing stations (Eizo Flexscan MX210, Eizo Corp., Ishikawa, Japan).

Earlier research [25] suggests that, in caries diagnostics, type of monitor has little bearing on the overall diagnostic accuracy in caries diagnostics, but ambient light may have more effect. The effect of monitors and ambient light are, however, not considered separately in this study, but rather as part of the overall difference in diagnostic accuracy between dentists and specialists in oral radiology.

Too much reliance should not be placed upon DPTs as the primary radiographic tool in cardiology [9,10], and a negative result in a DPT should not count as truly negative. The Finnish Current Care Guidelines [26] on caries management recommend BWs for caries diagnostics in cases where clinical examination has revealed a carious lesion extending into the dentine, or multiple extending initial lesions or known clinical risk factors in the patients' history.

A limitation of this study is the lack of corroborating clinical findings because of incomplete patients' files or interrupted treatment period of some patients. In addition, only clinical examination may not reveal all caries lesions without a proper radiographic examination [8]. We have no knowledge of whether these unobserved caries lesions were clinically diagnosed and treated. In the future, studies that assess both the clinical and radiological diagnosis of caries simultaneously under optimal conditions should be recommended, in order to overcome possible barriers to caries diagnosis.

Our conclusion is that compared to the expert opinion of the oral radiologists assessing the images under ideal circumstances, most of the caries lesions radiographically observable on proximal surfaces of the premolars and molars remained unobserved by general dentists based on their DPT report. In dental practice, diagnosis of caries should not rely only on DPT findings, especially when images are analyzed under sub-optimal light conditions. Rather, general dentists are encouraged to double-check for caries clinically and to supplement the DPT examination with BWs when necessary. Indeed, what could be most beneficial to general dentists would be in-service training with respect to image-interpretation skill. DPT should not be the sole examination used for caries detection.

Acknowledgements

We are grateful to Tuomo Maisala D.D.S. at the Department of Social Services and Health Care of the City of Helsinki for automatic computer randomization of the data.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Elmira Pakbaznejad Esmaeili http://orcid.org/0000-0003-2830-1270

References

[1] Suominen-Taipale L, Nordblad A, et al., editors. Oral health in the Finnish adult population. Health 2000 survey. KTL-National Public Health Institute. Department of health and functional capacity. Helsinki: Hakapaino OY; 2008. Available from: https://www.julkari.fi/bitstream/handle/10024/103030/2008b25.pdf?sequence=1

[2] Shay K. Infectious complications of dental and periodontal diseases in the elderly population. Clin Infect Dis. 2002;34:1215–1223.

[3] Hollister MC, Weintraub JA. The association of oral status with systemic health, quality of life, and economic productivity. J Dent Educ. 1993;57:901–912.

[4] FDI World Dental Federation. Oral Health. 2006. Available from: https://www.omd.pt/noticias/2014/03/fdioralhealthworldwide.pdf

[5] Gil-Montoya JA, de Mello AL, Barrios R, et al. Oral health in the elderly patient and its impact on general well-being: a nonsystematic review. Clin Interv Aging 2015;10:461–467.

[6] Joseph BK, Kullman L, Sharma PN. The oral-systemic disease connection: a retrospective study. Clin Oral Invest. 2016;20:2267–2273.

[7] Wenzel A. Dental caries. In: White SC, Pharoah MJ, editors. Oral radiology. Principles and Interpretation. St. Louis: Elsevier Mosby; 2014. p. 285–298.

[8] Hopcraft MS, Morgan MV. Comparison of radiographic and clinical diagnosis of approximal and occlusal dental caries in a young adult population. Commun Dent Oral Epidemiol. 2005;33:212–218.

[9] Akkaya N, Kansu O, Kansu H, et al. Comparing the accuracy of panoramic and intraoral radiography in the diagnosis of proximal caries. Dentomaxillofac Radiol. 2006;35:170–174.

[10] Kamburoglu K, Kolsuz E, Murat S, et al. Proximal caries detection accuracy using intraoral bitewing radiography, extraoral bitewing radiography and panoramic radiography. Dentomaxillofac Radiol. 2012;41:450–459.

[11] Thomas MF, Ricketts DN, Wilson RF. Occlusal caries diagnosis in molar teeth from bitewing and panoramic radiographs. Prim Dent Care. 2001;8:63–69.

[12] Lurie AG. Panoramic imaging. In: White SC, Pharoah MJ, editors. Oral Radiology. Principles and Interpretation. St. Louis: Elsevier Mosby; 2014. p. 166–184.

[13] Board of the Faculty of Clinical Radiology. Standards for the reporting and interpretation of imaging investigations. London: The royal College of Radiologists. 2006. Available from: https://www.rcr.ac.uk/sites/default/files/bfcr061_standardsforreporting.pdf

[14] Whaites E. Introduction to radiological interpretation. In: Whaites E, Drage N, editors. Essentials of dental radiography and radiology. China: Churchill Livingstone Elsevier; 2013. p. 249–254.

[15] Niiranen T, Widström E, Niskanen T. Oral health care reform in Finland - aiming to reduce inequity in care provision. BMC Oral Health. 2008;8:3.

[16] Whaites E. Dental caries and the assessment of restorations. In: Whaites E, Drage N, editors. Essentials of dental radiography and radiology. China: Churchill Livingstone Elsevier; 2013. p. 255–268.

[17] Gamer M, Lemon J. Various coefficients of interrater reliability and agreement. 2012. Available from: https://CRAN.R-project.org/package=irr

[18] Fleiss JL. Measuring nominal scale agreement among many raters. Psychol Bull. 1971;76:378–382.

[19] Falotico R, Quatto P. On avoiding paradoxes in assessing inter-rater agreement. Ital J Appl Stat. 2010;22:151–160.

[20] Espelid I, Tveit AB, Fjelltveit A. Variations among dentists in radiographic detection of occlusal caries. Caries Res. 1994;28:169–175.

[21] Bader JD, Shugras DA. Variation in clinical decision making related to caries. In: Fejerskov O, Kidd E, Nyvad B, et al. editors. Dental caries. The disease and its clinical management. London: Blackwell Munksgaard; 2008. p. 555–571.

[22] Espelid I, Tveit AB. A comparison of radiographic occlusal and approximal caries diagnoses made by 240 dentists. Acta Odontol Scand. 2001;59:285–289.

[23] Samei E, Badano A, Chakraborty D, et al. Assessment of display performance for medical imaging systems: executive summary of AAPM TG18 report. Med Phys. 2005;32:1205–1225.

[24] Scally A. Recommended standards for the routine performance testing of diagnostic X-ray imaging systems. York: University of Bradford; 2005.

[25] Pakkala T, Kuusela L, Ekholm M, et al. Effect of varying displays and room illuminance on caries diagnostic accuracy in digital dental radiographs. Caries Res. 2012;46:568–574.

[26] The Finnish Medical Society Duodecim and Finnish Dental Society Apollonia. Caries management (Finnish) (online). Current Care Guidelines. Working group set up by the Finnish Medical Society Duodecim and the Finnish Dental Society Apollonia. Helsinki, 2014. (referred September 22, 2014). Available from: www.kaypahoito.fi