The Efficiency of Computer-Aided Diagnosis of Non-Carious Tooth in Digital Bitewing and Panoramic Radiographs

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Abstract

The novel computer-aided diagnosis (CAD) is an approach that is expected to improve the subjectivity of traditional image analysis. This study aims to assess the threshold and determine the accuracy of computer-aided software for diagnosing proximal surfaces of non-carious posterior teeth.

A simple random sampling of 400 non-carious tooth surfaces from Bitewing radiographs was performed by two experienced observers. The descriptive analysis of threshold value from CAD (Denti.AI) was performed in both digital bite-wing and the available panoramic radiographs of the same tooth surfaces. The reliability of caries diagnostic performance from both radiographic images was calculated by using Cohen's Kappa Statistics. The inferential statistic was also used for non-normality data and determined by p-value at 0.05.

CAD showed that 287 (71.8%) tooth surfaces were an absence of proximal carious lesion through bitewing radiographs, while the presence of carious lesions was interpreted in 113 (28.2%) tooth surfaces. On the other hand, CAD showed an almost equal number of negative surfaces (50 or 43.5%) and positive surfaces (65 or 56.5%) through panoramic radiographs. The threshold value (Mean ± SD) of false-positive results of Bitewing and panoramic radiographs were 15.3 ± 12.2 and 34.9 ± 28.0, respectively. The interclass reliability between two types of radiographs, bitewing and panoramic, was -0.055 ($p < 0.001$), which indicates that there was no agreement in negative result detection in panoramic and bitewing radiographs through computer-aided caries detection software.

The study showed that computer-aided caries detection software presented a reliable result in ruling out proximal non-carious lesions through bitewing radiographs, which allows the users to considered using the software in proximal caries screening. However, further study should be conducted to determine the comprehension of diagnostic accuracy interpreted by the software in both carious and non-carious lesions.

Keywords: *Computer-aided diagnosis, Caries detection, Bitewing, Panoramic, Radiographs*

1. Introduction

Dental caries is a bacterially based disease that progresses when acid produced by bacterial action on dietary fermentable carbohydrates diffuses into the tooth and dissolves the mineral, so-called demineralization process (Featherstone, 1999). It becomes a problem that people of all ages since it has the potential to affect the quality of life. Fifty-one million school hours are lost annually due to acute pain caused by dental caries that are playing a part as a major contributor. Dental caries can evoke aesthetics and functional complaint and even complicate other dental treatments. Moreover, according to WHO, it is stated that dental caries are one of the most common chronic diseases and affect people throughout their lifetime, causing pain, discomfort, disfigurement, and even death (WHO, 2008). These problems also take place in Thailand. From the information from the Thai Ministry of Public Health, the prevalence of dental caries evaluated in different age groups is as followed; pre-school age (three-year-old and five-year-old), school-age (twelve-year-old), adolescence (fifteen-year-old), adult (thirty-five to forty-four-year-old), and elderly (sixty to seventy-four-year-old). The prevalence for each age group is shown as 52.9%, 75.6%, 52.0%, 62.7%, 91.8%, and 98.5%, respectively (Division, 2017). It is clearly shown that dental caries are affecting every person, regardless of age.

As above, an increase in the prevalence of dental caries has brought to the consideration of a concept of prevention rather than treatment. Then, reliable diagnostic methods to review the stage of the caries process and assist in the early detection of dental caries are very important. Two main methods in caries detection are clinical examination and radiographic examination. Clinical examination has always been the traditional method of caries detection using direct vision or vision assisted with standard operating light (Price, 2013). However, due to the improved technology in the dental field, more alternative methods are added to visualize and assist in early caries detection such as transillumination and fluorescence (Abogazalah & Ando, 2017). Apart from visual-tactile screening for dental caries, dental radiograph has been widely used as a diagnostic tool in general practice. From its frequent usage, the accuracy of radiographic caries detection plays an important role in management decisions. According to a systematic review, sensitivity was found to be limited in detecting different sites of lesions (24% sensitivity for proximal area and 35% sensitivity for occlusal surface). On the other hand, specificity was generally high on the proximal surface and moderate on the occlusal surface in any kind of lesions (97% specificity for proximal area and 78% specificity for occlusal surface) (Schwendicke, Tzschoppe, & Paris, 2015).

The sensitivity of a radiograph refers to its ability to correctly identify an existing carious lesion. High sensitivity allows early detection of incipient caries, thus allow early treatment and preventing any further tooth loss. Moreover, the specificity of a radiograph refers to its ability to correctly detect when the tooth is sound, and no carious lesion is present. High specificity in the detection of proximal caries means a decrease in false-positive results which prevent unnecessary cavity preparation and tooth loss. Therefore, an effective tool for caries detection should provide high sensitivity to provide early detection while the high specificity should be expected to prevent over-treatment of the lesion (Kamburoglu, Kolsuz, Murat, Yuksel, & Ozen, 2012). Intraoral bitewing is the primary diagnostic tool used for proximal caries detection. The examination has been accomplished using one or two radiograph(s) per side to access all the contact surfaces from the distal of the canine to the most distal molar interproximal contact (Terry, Noujeim, Langlais, Moore, & Prihoda, 2016). However, there are still shortcomings that limit its usage, therefore extraoral bitewing or, in other words, panoramic bitewing is introduced to overcome the limitation of intraoral bitewing (Abu El-Ela, Farid, & Mostafa, 2016).

As far as we have now, technology has brought computer-aided diagnosis (CAD) into caries detection. For instance, Dentistry.AI, Denti.AI, and Logicon (Carestream Dental LLC, Atlanta, GA). This software functions through different kinds of radiographs. Despite being an innovative technology, it allows better dental caries detection. Then, this study aimed to assess the threshold and determine the accuracy of computer-aided software for diagnosing proximal surfaces of non-carious posterior teeth.

2. Objectives

1) To identify the threshold of computer-aided software for diagnosing proximal surfaces of non-carious posterior teeth in digital bitewing and panoramic radiographs

2) To determine the accuracy of computer-aided caries detection software for evaluation of proximal surfaces in non-carious posterior teeth in digital bitewing and panoramic radiographs

3) To compare diagnostic reliability of computer-aided caries detection software between digital bitewing and panoramic radiographs

3. Materials and Methods

The samples were calculated by using Taro Yamane (Yamane, 1973) formula with a 95% confidence level. Co-decision of two oral and maxillofacial radiologists who had more than 20 years of experience randomly chose 400 non-carious surfaces from 1979 surfaces of digital bite-wing radiographs from Oral Radiology Clinic at College of Dental Medicine, Rangsit University. All include images had acceptable image quality with visible contact or acceptable overlap less than half of the enamel. The cases with orthodontic appliances and prosthesis contact were excluded.

All selected original images were adjusted by density and contrast enhancement tools, saved as JPEG file with 300 dpi, and uploaded onto CAD (Denti.AI) application (https://www.denti.ai) for the detection of the carious lesion as in the following steps (Figure 1-8).

1.) 'Add Collection' then insert case number (as all the cases were recorded anonymously) to name the folder created.

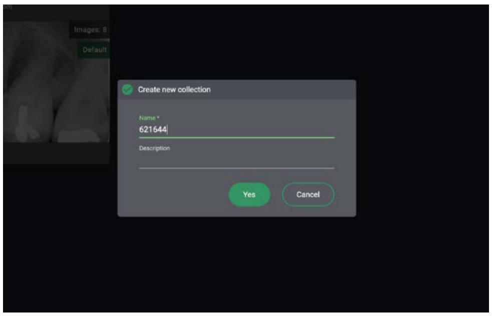

Figure 1 Denti.AI interface and add collection menu.

2.) Upload image (supported file formats: jpeg, jpg, tiff, png, BMP)

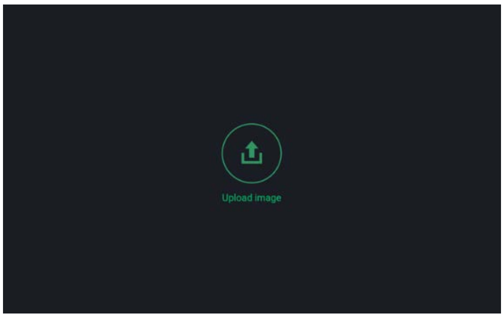

Figure 2 Denti.AI interface and add collection me

3.) Select the image

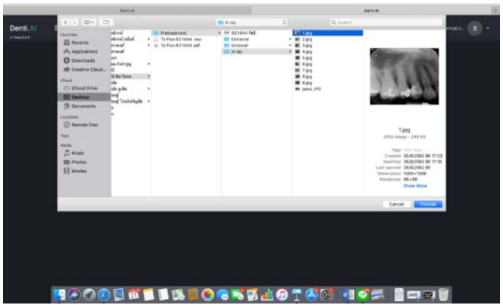

Figure 3 Radiographic image selection

4.) Insert Image type and identify the patient's ID, gender, image, and date

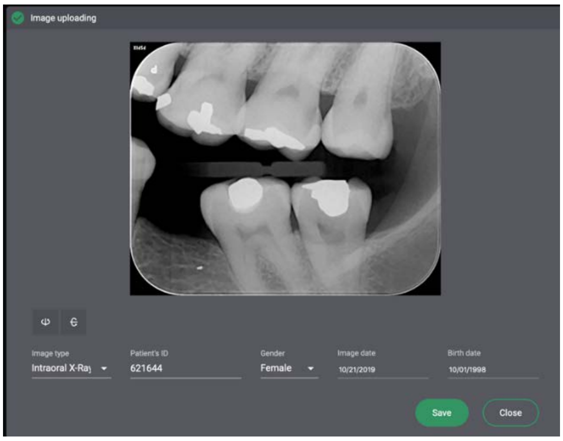

Figure 4 Image data record form

5.) Click 'Analyze' to run the software for diagnostic data

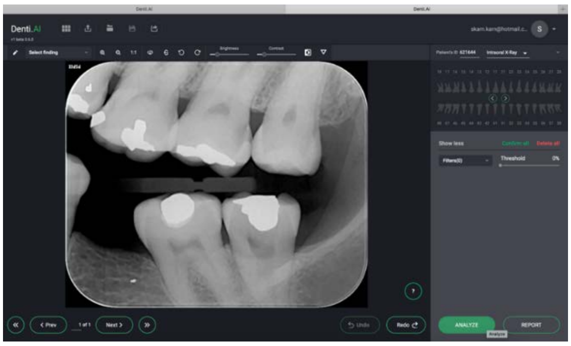

Figure 5 Analyzing tool

6.) The results are shown as a dotted box on the radiograph with a description on the lower right panel.

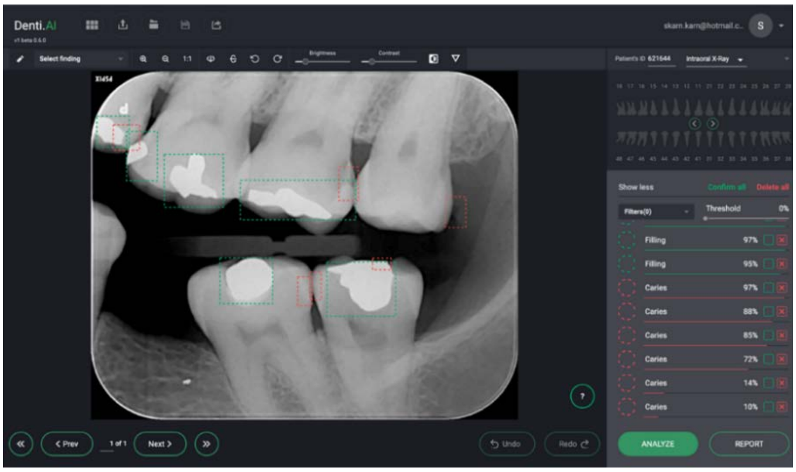

Figure 6 Diagnostic results shown on the radiograph

Furthermore, the presented diagnostic results could be adjusted to focus on the desired lesion using the 'Select Finding' option on the upper left on the tool panel. The radiograph can be zoomed in and out and flipped vertically, horizontally, or rotate as desire. Moreover, brightness and contrast can be adjusted to improve the visualization of the radiograph.

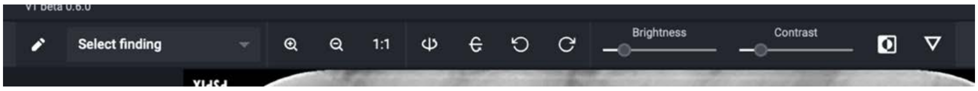

Figure 7 Toolbar for adjusting the image

A panoramic radiograph was also uploaded and analyzed as the result was shown on the lower right panel, stating the percentage (probability) of having the written lesion. Moreover, the upper right panel indicated the sound teeth with or without filling present in green and the teeth with the carious lesion in red, and, lastly, the missing teeth in gray. The analysis of the lesion was shown as a dotted box as same as in Bitewing radiograph.

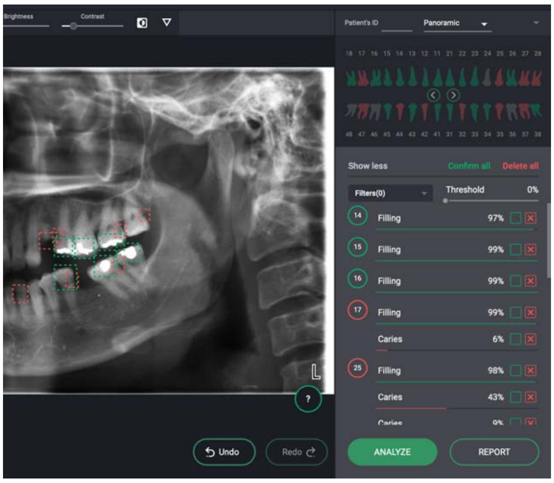

Figure 8 Panoramic radiograph analysis

The descriptive analysis of threshold values *(%)* from CAD *(*Denti.AI*)* was recorded after uploading the chosen panoramic and bitewing radiographs to the software. in both digital bitewing and the available panoramic radiographs of the same tooth surfaces.

The reliability of caries diagnostic performance from both radiographic images was calculated by using Cohen's Kappa Statistics Due to the non-normality of CAD threshold value, the Wilcoxon sign rank test was conducted to compare the statistically significant difference between bitewing and panoramic radiograph. The p-value was determined at 0.05.

4. Results and Discussion

4.1 Results

From four hundred non-carious tooth surfaces in bitewing radiographs, 287 tooth surfaces were absent of proximal carious lesion which coincides with the result interpreted by a gold standard. On the other hand, 113 tooth surfaces (28.2%) were shown as presented with the proximal carious lesion, which was considered as false-positive data from the interpretation of the software. The total surfaces interpreted with panoramic radiographs were 115 surfaces. Others were excluded due to overlapping contact surfaces. The results from the program showed that 50 surfaces (43.5%) were an absence of the proximal carious lesion. On the other hand, 65 surfaces (56.5%) were interpreted to be present with the proximal carious lesion (Table 1).

Data are presented as (% surfaces)

Table 1 The comparison of caries diagnosis from gold standard and CAD threshold response

Diagnosis	Interpretation	Radiographs	
		Bitewing	Panoramic
No caries	Caries Absent	287(71.8)	50(43.5)
	Caries Present	113(28.2)	65(56.5)
Total surfaces		400(100)	115(100)

The false-positive result was presented in the program in terms of the percentage of having the proximal carious lesion (Figure9). The significant CAD threshold value between bitewing radiograph (Mean (SD)=15.3 (12.2) and 34.9 (28.0)) for panoramic radiograph (p<0.05).

The interclass reliability between two types of radiographs, bitewing and panoramic, was calculated using Cohen's Kappa Coefficient (K). The result was -0.055, p < 0.001, indicating that there was no agreement in negative result detection in panoramic and bitewing radiographs through computer-aided caries detection software.

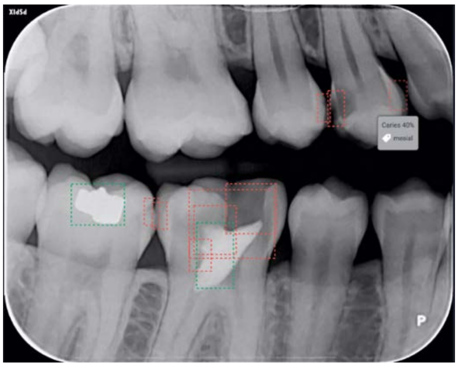

Figure 9 Example of the false-positive result shown on the distal surface of tooth 14 through CAD software.

4.2 Discussion

The early detection of dental caries diagnosis was important to provide appropriate management including prevention to patients. Therefore, artificial intelligence was introduced to assist the detection of proximal caries lesion in the hope to simplified and shorten the time of diagnosis. Then, the purpose of this research was to determine and assess the function of newly introduced CAD software designed for the evaluation of proximal caries in posterior teeth. Since the software presented results of proximal caries detection in terms of probability percentage of having carious lesion on that surface, it still relies on the user's judgment to decide the diagnosis of the particular surface (Gakenheimer, 2002). Lots of information can be gathered and computed to create a quick computer-aided diagnosis and treatment planning. The software does have superiority over humans in terms of the number of working hours they can put in without fatigue, whereas human intellect and mind need a break before they perform competitive tasks (Deshmukh, 2018).

In this study, the ability of CAD to analyze non-carious lesions from bitewing radiographs was under-evaluated. There was only 71.8% of non-carious surfaces correctly diagnose when compared with an experienced observer. Therefore, the low threshold ranges from 3.1-27.5 % could still represent the false positive of caries detection. On the other hand, the wider range of computer aid caries detection threshold was significantly observed from a panoramic radiograph. The panoramic threshold ranges were higher and wider than the bitewing radiograph (6.9-62.9 %), which can be inferred that if the program showed the percentage within the range of Mean (SD), the result is most likely to be a faulty diagnosis.

However, the program showed 113 tooth surfaces (28.2%) of caries present in contrast to the result of the gold standard performed using bitewing radiograph. It implied that not just the program showed an acceptable outcome in caries detection, it could also produce a false positive caries detection.

In an aspect of caries detection of the software by the panoramic radiograph, almost three-quarters of surfaces had been excluded out (285 surfaces or 71.2%) as a reason for overlapping contacts in the panoramic radiograph. Then, bitewing mode panoramic might be the better choice for a screening test (Abdinian, Razavi, Faghihian, Samety, & Faghihian, 2015). It also showed an almost equal number of correct (43.5%) and incorrect (56.5%) diagnostic cases. This evidenced supported that conventional panoramic radiograph produces a still unreliable result to use as a tool of proximal caries detection.

Both panoramic and bitewing radiographs showed false-positive values. However, the location of false-positive results was not related due to the low Cohen's Kappa value (k = -0.055, $p < 0.001$), which indicates that there was no agreement in negative result detection in panoramic and bitewing radiograph through computer-aided caries detection software with the significantly different threshold percentage between them ($P<0.05$).

After analyzing the results from the program comparing to the gold standard, the negative results of the gold standard showed the contrastive result presented as true negative and false positive in which a true negative value was higher, which implied that the carious detection of the program was in a way of an accurately correct diagnosis rather than being misdiagnosis. The program yielded high sensitivity but, despite the above-mentioned data, the faulty diagnosis was still present because of limited specificity (Wenzel, Hintze, Kold, & Kold, 2002), which might be affected by the poor quality of the image and inequalities of the contrast of the images. Higher sensitivity is preferred over specificity for minimal intervention dentistry, as false-negative may have significantly higher repercussions than false-positive. Undiagnosed and untreated decay could grow and lead to loss of healthy tooth structure, possible need for endodontic therapy, or tooth loss, while a false-positive would lead to conservative minimal intervention treatment, including topical fluoride application and closer monitoring of lesions. Our study showed that the computer-aided program through bitewing radiographs offered a significant advantage over panoramic radiographs in the diagnoses of interproximal carious lesions (Sato, Da Silva, Lee, Yonemoto, & Kuwajima, 2021).

With these, the computer-aided program shows a justifiable result to be used in screening examination but dentists should not rely on the automatic detection of proximal caries through software in generating diagnosis and treatment plan for the carious lesion as its accuracy is still limited (Lee, Kim, Jeong, & Choi, 2018). Further studies should be done to determine the comprehension of false-positive data shown by the program.

5. Conclusion

The present study showed that computer-aided caries detection software presented a reliable result in ruling out proximal carious lesions through bitewing radiographs. Moreover, the program showed a highly sensitive result in detecting carious lesions, which allows users to effectively use the software in proximal caries screening. On the other hand, panoramic radiographs showed poor results in ruling out the proximal carious lesions. However, further studies should be conducted to determine the comprehension of diagnostic accuracy interpreted by the software in both carious and non-carious lesions.

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