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Introducing a Dental Caries Marking Software and Evaluate Radiologists' Disagreement in Caries Detection Using this Software

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Abstract

Statement of Problem: Bitewing radiograph is the main reference for diagnosis of proximal and recurrent caries. There is no software for gathering and analyzing radiologists' opinion in the field of caries detection on digital bitewing radiograph (DBR).

Objectives: The main aim of this study is to introduce the first windows application that could be used for marking caries on DBR. This software is called Dental Caries Marking Software (DCMS). The second aim is to create the first DBR caries dataset to be used for future software development projects in the field of automatic caries detection; also gathering and documenting the disagreements and critiques regarding DCMS.

Materials and Methods: DCMS has been designed and implemented by the researchers of this study. This software is divided into two parts. The first part is DCMS writer that is used for gathering the user's opinion and The second part is DCMS analyzer that is used for reading and analyzing the user's opinion file. Eight radiologists with different experiences used DCMS for marking dental caries on 200 DBR, 50 of which were repeated twice for assessing the accuracy of each radiologist.

Results: A total of 3833 points were marked by 8 users on 150 non repetitive DBR. Only 35 points were marked similarly by 8 users; in other words, 8 users totally agreed with 4% of the caries points. According to 50 repetitive DBR, the maximum accuracy of users was 69% and the minimum was 50%.

Conclusions: There is significant debate over the diagnosis of caries on DBR; therefore, for unifying the radiologist's opinions, the need for intelligent caries detection software is apparent. DCMS is useful software for gathering caries data. Moreover, the use of conventional display monitor has negative impacts on accurate diagnosis of caries on DBR.

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Introduction

Dental caries are among the most common problems in dentistry, which has a very high incidence in the population especially in developing countries [1]. The appropriate type of restoration and treatment planning needs early and accurate diagnosis of caries [2]. Therapeutic decision-making related to caries diagnosis

and therapeutic decision-making has shown substantial variations between dentists and radiologists [3–6]. This variation is usually accepted as reflections of education level and work experience of dentists and radiologists [6].

Sole clinical assessment of proximal contacts leads to unacceptable false negative results, especially in cases of tight proximal contacts where precise examining is not possible [7]. Interproximal carious lesions develop between the contacting proximal surfaces of two adjacent teeth. They first appear clinically as opaque regions caused by loss of the enamel transparency at the outermost enamel layer between the contact point and the top of the free gingival margin [8-10]. As the carious lesion progresses through the enamel, it takes on a triangular configuration, with the top of the triangle located at the enamel–dentine border. When it reaches the enamel–dentine border, it expands laterally and towards the inner dentine, forming another triangle in the dentine, with the base of the triangle located in the enamel-dentine border and the top of the triangle pointing towards the pulpal space [10]. According to previous studies, 25% to 42% of the carious lesions remain undetected by clinical examination alone [11-13]. Among the other types of caries detection methods, intraoral films and digital sensors are the most common ones. Bitewing radiograph is the most common and the main reference technique for diagnosis of proximal and recurrent caries [14]. Nowadays, conventional intraoral film, solid state detectors and photostimulable phosphor (PSP) plates were used to take bitewing radiograph [15]. Solid state detectors consist of either a charge-coupled device (CCD) that uses a thin wafer of silicon as the basis for image recording or a light-sensitive complementary metal oxide semiconductor (CMOS) chip and a scintillator layer that converts X-rays to light [15-17]. A PSP plate consists of a polyester base coated with crystalline halide composed of europium-activated barium fluorohalide compounds [18-20].

Apart from the detector types, radiographic diagnosis of caries is related to the amount of demineralization and a 30% to 40% mineral loss is needed for radiographic visibility of carious lesion [1, 15].

Today, digital radiographic technique has a worldwide acceptance and a large number of dentists use digital bitewing radiograph (DBR) for caries detection. Digital systems have many advantages, such as reduced exposure, elimination of film processing and the possibility to improve the quality of the images by using the software [21-24]. These systems, however, are more expensive and have not yielded contrasting results regarding the diagnostic ability [25-26]. Also, there is no persistent agreement between previous studies regarding the effect of different imaging software [27-28]. In addition, there have been several studies on the comparison of conventional film various digital system in detection of proximal caries in some studies, but no significant difference was reported between these methods [27, 29] while some other studies have proved otherwise [30]. There is no software for gathering and evaluating the radiologists' opinion on the field of caries detection on DBR.

In this study, three purposes were followed. The main purpose of this study was to introduce the first windows application that could be used for marking caries on DBR. This custom-made software is called Dental Caries Marking Software (DCMS). We also aimed to create first DBR caries dataset that will be used for future software project in field of automatic caries detection. This dataset could be used as train phase for neural network. Our third purpose was to determine the amount of disagreement among oral radiologists with different experiences in the field of caries detection by using DCMS. The factor that effects the radiologists' disagreement was checked. We also made an attempt to find out the amount of radiologists' disagreement in the caries detection on repetitive radiograph.

Materials and Methods

For gathering and analyzing opinions of radiologists and dentists in the field of dental caries detection on DBR, a custom- made windows software (DCMS) has been designed and implemented (by Hasan Baseri). This software is divided into two parts. The first part is DCMS writer that is used for gathering the user's opinion. The interface of DCMS writer is shown in Figure 1. The second part is DCMS analyzer that is used for reading and analyzing the user's opinion file. The interface of DCMS analyzer is shown in Figure 2. In DCMS writer, six caries detection options were considered; the user can use these six options for marking the depth of teeth caries on bitewing radiographs. If the depth of the teeth caries is just observed in the enamel, then the user of DCMS must select the Enamel option to mark the teeth caries. If the teeth caries reaches the DEJ (Dentin Enamel Junction), then the user must select DEJ option to mark it. If the depth of caries reaches the dentin, then the user of DCMS must select the Dentin option to mark it. If the depth of caries reaches the pulp, then the user of DCMS must select the Pulp option to mark it. If the user observes recurrent caries, then he/she can select Recurrent options to mark this teeth caries and if user suspects about the teeth caries, then Questionable option is selected. So in DCMS writer for marking teeth caries, the following six options have been considered:

- Enamel (is shown in green)
- DEJ (is shown in yellow)
- Dentin (is shown in orange)
- Pulp (is shown in red)
- Recurrent (is shown in purple)
- Questionable(is shown in blue)

Each caries point marked with each user contained two facts:

- Coordinates of caries point
- Depth of caries point

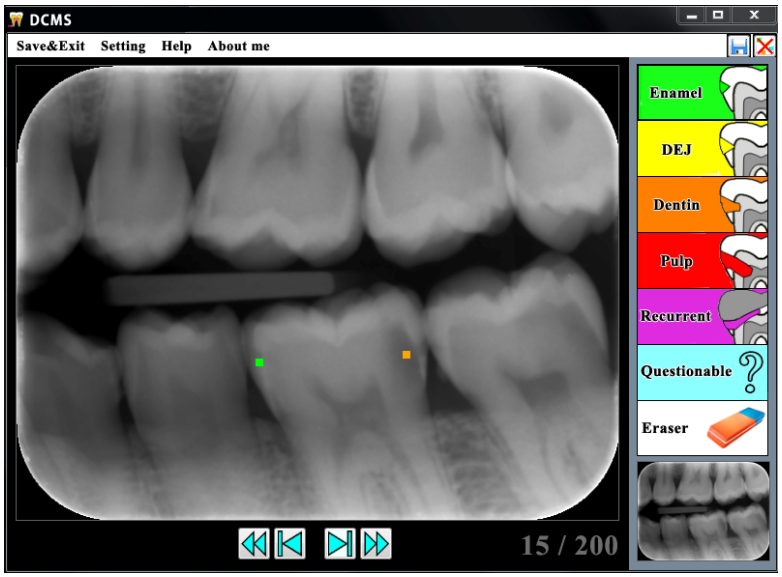

Figure 1: Interface of DCMS writer

Two users might agree on the coordinates of caries but disagree on its depth. For example, User_1 in a point detected the enamel caries and User_2 detected the DEJ caries on the same point, so these users agreed on the coordinates of caries point but disagreed on depth of caries.

When the user marks all the caries on bitewing radiograph, then the DCMS writer receives the user's characteristics, such as name, education level, work experience (in year), and teaching experience (in year). Finally, DCMS writer creates a file that contains the user's opinion and characteristics which specifies the person and the experience related to that opinion.

In this study,we used Bitewing radiographstwhich were taken with size 2 PSP imaging plates (Sordex,Finland) and MINRAY Intraoral X-ray unit (Sorodex, Finland ,70 KvP , mA)

For selecting radiographs, all situations that may occur within a bitewing radiograph were considered and eventually 150 standard bitewing radiographs were selected. 50 out of 150 bitewing radiographs were repeated twice. These repetitive radiographs which specify the accuracy of each user were numbered from 151 to 200. These 200 radiographs imported to the DCMS writer. None of the users knew that the 50 radiographs were repeated twice.

DCMS writer was given to 8 radiologists. These radiologist have different teaching and work experience. The academic rank of user_1 is associate professor and the academic rank of user_2 to user_6 are assistant professor and user_7 with user_8 is PhD student. Each radiologist marked caries on 200 bitewing radiograph and completed the user's characteristic and then sent her/his DCMS's file to researchers of this study.

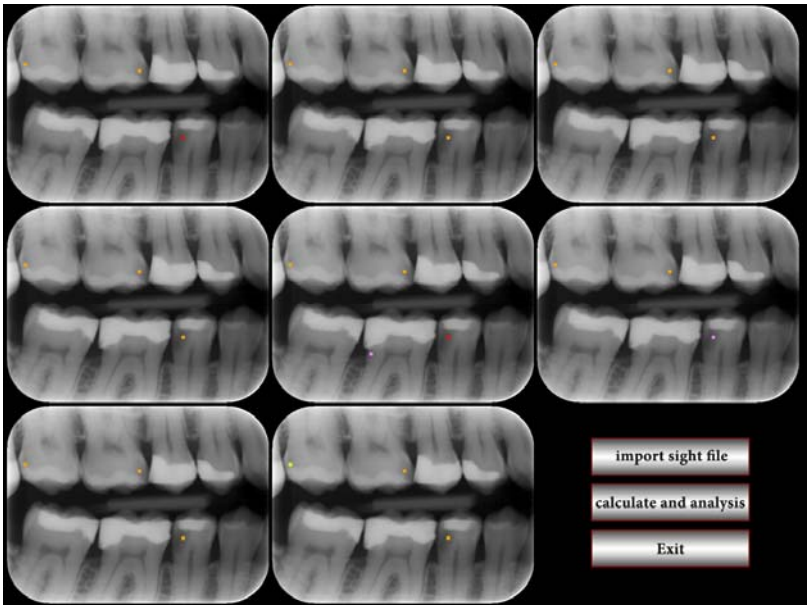

Figure 2: Interface of DCMS analyzer

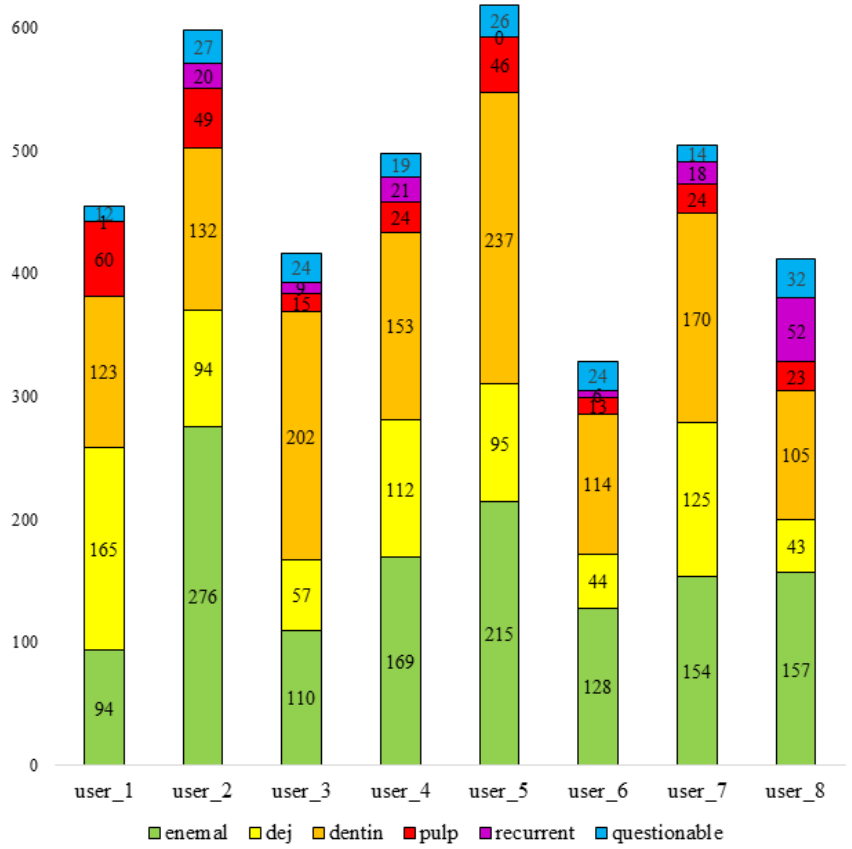

Figure 3: Number of dental caries each user marked on 150 bitewing radiograph

Results

All users' opinion file was analyzed with DCMS analyzer. A total of 3833 points were marked by 8 users on 150 non repetitive bitewing radiographs. These 3833 points were limited to 863 same coordinates and different depth points. User_1 marked 455 caries point on 150 bitewing radiograph. This user detected 94 Enamel caries, 165 DEJ caries, 123 Dentin caries, 60 Pulp caries, 12 Recurrent caries and one Questionable caries on 150 bitewing radiograph. The number of caries point marked by each user on 150 bitewing radiograph is shown Figure 3. As you can see, the users had different opinions on the same radiograph.

All users' opinions were limited to 863 same coordinate and different depth points. Only 172 out of 863 points were marked with 8 users. In other words, all users completely agreed about 20% of caries points in terms of coordinates of point not the depth of caries point. The number of users who marked the same coordinate points on 150 bitewing radiographs is shown in Table1.

Only 35 out of 863 points were marked completely the same by 8 users. In other words, all users completely agreed about 4% of caries point in terms of coordinates of point and depth of caries point. These 35 caries points consisted of 9 Enamel caries, 0 DEJ caries, 21 Dentin caries, 4 Pulp caries, 1 Recurrent caries and 0 Questionable caries. The number of users who marked the same points in terms of the same depth and same coordinate on 150 bitewing radiographs is shown in Table 2. All users are completely agreed only in 6 out of 150 radiographs. All users marked no caries point on these 6 radiographs, Figure 4 (a, b, c, d, e, f).All users marked one caries point on 3 radiographs, Figure 4 (g, h, i) with the same coordinate and different depths.

In this study, 50 radiographs were repeated twice to indicate the accuracy of each user. The number of

Table 1: Number of users who marked the same coordinate points on 150 bitewing radiographs

	Eight users	Seven users	Six users	Five users	Four users	Three users	Two users	One user	Total coordinate points
Number of marked same coordinate points	172	100	76	82	64	83	100	186	863
Percent	20%	11%	9%	9%	7%	10%	12%	22%	100%

Percent= (number of marked same coordinate points / 863) * 100

Table 2: Number of users marking the same points in terms of the same depth and coordinate on 150 bitewing radiographs

Depth of caries	Eight users	Seven users	Six users	Five users	Four users	Three users	Two users	One user
Enamel	9	15	19	38	48	80	95	200
DEJ	0	0	3	15	42	56	80	146
Dentin	21	28	26	41	36	43	63	112
Pulp	4	3	6	7	14	9	14	19
Recurrent	1	3	8	3	3	5	13	33
Questionable	0	0	0	0	0	2	4	113
Total	35	49	62	104	143	195	269	623

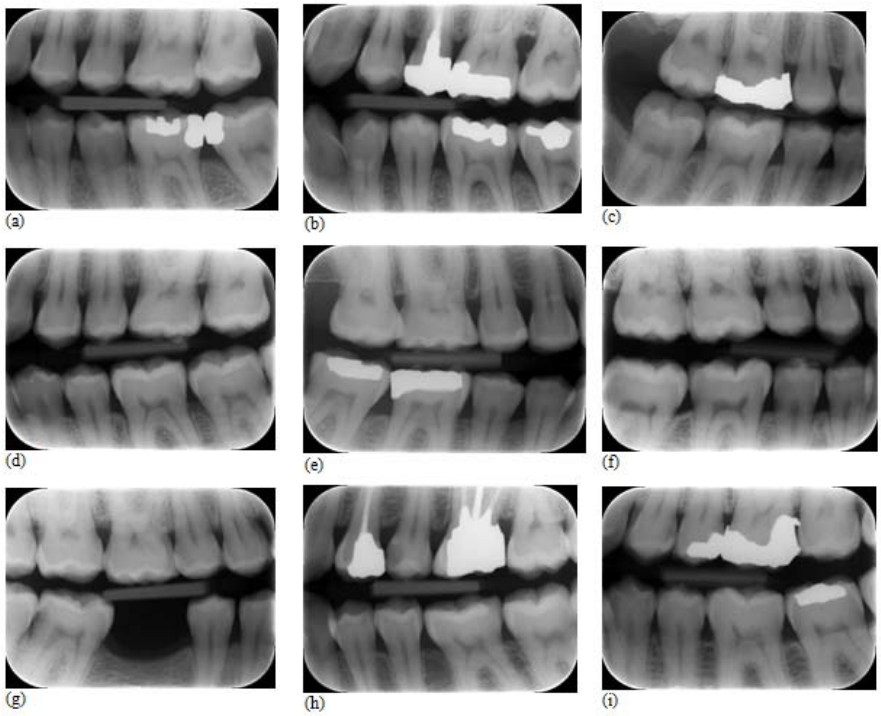

Figure 4: Six radiographs with complete agreement between 8 users (a, b, c, d, e, f). Three radiographs with complete agreement just in coordinates (g, h, i)

bitewing radiograph that each user marked similarly on 50 repetitive bitewing radiographs is shown in Table 3. For example, User_1 marked 13 out of 50 radiographs completely the same in terms of similar coordinate and depth and this user marked 15 out of 50 radiographs just the same as coordinate. Each user marked different numbers of caries point in 50 repetitive radiographs. For example, User_1 detected 163 caries point on the first 50 radiographs and 167 caries point on the second radiographs. The number of caries points that each user marked on 50 repetitive bitewing radiographs regarding the depth of caries is shown in Table 4.

The amount of accuracy of each user was obtained from the number of the same caries point each user marked on 50 repetitive radiographs. For example, User_1 marked 131 similar coordinate caries points on 50 repetitive radiographs. In other words, the accuracy of this user for detecting similar coordinate caries point is 79%. This user marked 111 completely similar caries points on 50 repetitive radiographs. In other words, the accuracy of this user for detecting caries point in terms of similar coordinate and depth is 67%. The number of same caries points each user marked on 50 repetitive bitewing radiographs regarding the same coordinates is shown in Table 5.

Discussion

There is a lot of debate and disagreement among radi-

Table 3: Number of bitewing radiographs each user marked similarly on 50 repetitive bitewing radiographs

	user_1	user_2	user_3	user_4	user_5	user_6	user_7	user_8
Same coordinate and same depth	13	9	16	11	13	19	12	10
Same coordinate and different depth	15	15	21	17	15	24	19	15

Table 4: Number of caries points each user marked on 50 repetitive bitewing radiographs regarding the depth of caries

	Enamel		DEJ		Dentin		Pulp		Recurrent		Questionable		Total	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b
User_1	33	36	50	59	53	44	24	26	2	2	1	0	163	167
User_2	101	102	34	27	41	51	22	16	7	5	6	4	211	205
User_3	39	38	17	20	80	70	5	6	6	6	8	1	155	141
User_4	65	38	42	45	50	51	10	5	2	3	10	3	179	145
User_5	81	75	34	20	89	98	17	20	5	6	0	0	226	219
User_6	45	38	11	11	46	52	4	5	6	1	2	0	114	107
User_7	44	60	47	46	59	32	11	13	4	1	8	3	174	155
User_8	60	36	8	6	36	34	9	1	14	9	18	11	145	97

a means the first 50 bitewing radiographs
b means the second 50 repeated bitewing radiographs

ologists regarding caries detection on DBR. These factors can be categorized into two different categories, factors regarding the computer interface and environmental factors.

All participants installed this software on their PCs, and as it turns out the hardware differences have had a significant role in the process. The difference between the quality of the display monitors, which was divided into three categories: Cathode Ray Tube, Liquied-Crystal Display and Light-emitting Diode. In addition to that factor regarding the graphics' hardware and setting of the display like resolution and screen brightness.

Light-emitting Diode backlight display monitors had a greater impact than other conventional display monitors on the diagnosis of dental caries on DBR. Actually, when users observed their opinion file on Led backlight display monitors, they believed teeth caries were displayed better in this monitor. Another question to be answered here is why the users had disagreement on 50 repetitive radiographs whereas they observed these radiograph on their own computer? To answer this and other questions in the field of radiologists' disagreement, we must take the technical and environmental factors into account. These factors include optical illusions in gray scale images [15] ,radiologist carise detection experience[31],the lighting in in the surrounding environment and fatigue of radiologist [32],

All the factors that affect the radiologists' disagreement not meaning for intelligent caries detection software. The unique software for automatic dental caries detection is LCD (Logicon Caries Detector) which was introduced in 1998. According to raiders of LCD design company; this software increases the accuracy of human observer in detection of dental caries by 20%. Numerous studies on comparison of human opinion with LCD software are available in the field of dental caries detection. Some studies have reported no significant difference between human and LCD [33] while some others have proved LCD is useful for caries detection [34]. Also, some studies have proved that LCD is weak for caries detection [35]. For example, in the year 2002, a total of 190 extracted teeth radiographs for caries detection were given to four human observers and then examined with LCD. The authors of that study concluded that for caries detection on radiographs, the new software was required that to be more powerful than LCD [35].

Conclusions

Many factors affect the accurate diagnosis of caries on DBR which caused lots of disagreement among human observers. Digital bitewing radiograph requires intelligent caries detection software which is stronger than previous ones to detect caries automatically and help the dentist and radiologist to detect dental caries more accurately. Conventional display monitor has negative impacts on accurate diagnosis of caries on DBR; therefore, using medical diagnostic display monitor for caries detection is recommended.

The method that present in this study for gathering and analyzing radiologist' opinion in the field of caries detection on DBR is a new and useful method that cloud be used in other filed of dentistry for achieving doctors' disagreement. If doctors have much disagreement then useful tips must be presented for unifying doctors' opinion.

The dataset (DBR and Radiologist' opinion) which collected in this study is a first digital teeth caries dataset that cloud be used for future software designing

Table 5: Number of same caries points each user marked on 50 repetitive bitewing radiograph

	User_1	User_2	User_3	User_4	User_5	User_6	User_7	User_8
Number of marked same coordinate points	131	177	121	123	190	93	137	88
Percent of coordinate points similarity	79%	85%	82%	76%	85%	84%	83%	72%
Number of marked same depth and coordinate points	111	131	93	89	153	74	89	60
Percent of depth and coordinate points similarity	67%	63%	63%	55%	69%	67%	54%	50%

in field of automatic teeth caries detection.

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Conflict of Interest

The authors of this manuscript certify that they have no financial or other competing interest concerning this article.

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