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A New Method to Secondary Caries Detection in Restored Teeth

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Abstract— Dental caries appear in both primary and secondary caries. Secondary caries are created below the restored teeth and is not visible by naked eye. Therefore to diagnose this type of caries, the dental radiography images are used. In dental radiography images, the secondary caries of restored teeth are appeared as radiolucent areas. In this study a new method to secondary caries diagnoses in restored teeth is proposed. In this paper after image quality enhancement by Gamma correction, by threshold selection on cumulative frequency diagram, the teeth with secondary caries are diagnosed. Due to technical limitations in radiographic instruments the nonlinear changes on pixels is caried and this changes are revised with Gamma correction process. This method carried on 100 dental radiography images and the results demonstrate that the maximum accuracy rate for secondary caries diagnosis is 82% and minimum error rate is 18%.

Index Terms— Secondary caries, Dental radiography, Radiolucent area, Preprocessing, Gamma correction, Cumulative frequency diagram, Mach band

1 Introduction

IN Dentistry science, to diagnose secondary caries in restored teeth which are not visible by eye, dental radiography images are used [1]. In these images secondary caries are seen as radiolucent areas. For example in fig.1 areas of A, B and C have caries and seen as radiolucent. In dental radiography images, besides caries there are other areas seen as radiolucent which are not caries but related to the optical illusion that called Mach band effect [2]. So the dentist may have mistake in diagnosing such caries and after opening the area sees that there is no caries and it has been mistaken by Mach band effect which in this case there would be some damage to the teeth of patient [3].

Technical limitations in instrument used for image production, print or display cause them to impose nonlinear changes on image pixels which lead to reduce quality of image. That is, there is exponentiation of each gray level of pixels to a number like γ. Moreover, since radiography instruments are not able to display the exact color, depth and tissue of objects in images, so the gamma applied on each pixel is not same in all points of image. Therefore, adaptive gamma correction which has been in recent papers [4], [5], by improving image quality, can help dentist in interpreting the dental radiography images. In [6] besides reviewing different methods of gamma correction in digital images, there is a new method to improve image quality based on local content of image (the context of different areas). By performing this method on dental radiography images, radiolucent areas of teeth becomes more apparent and it will be easier to diagnose secondary caries.

In this paper, after improving clarity of radiolucent areas in radiography image, the context of radiolucent area is analyzed to diagnose secondary caries in restored teeth to understand that this radiolucent area is due to secondary caries or due to optical illusion. If radiolucent area gray levels exist on image, it means that there is caries otherwise is due to Mach band effect. If radiolucent area is due to caries, its effect will be reflected on histogram of image.

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2 Preprocessing

As mentioned previously, in this paper gamma correction is used to enhance image quality and to diagnose secondary caries easier on dental radiography images. Based on power law, the luminance of a pixel with gray level of r in the image produced by an instrument would be change as following [7] which is due to the limitations of instrument:

$$S = cr^{\gamma} \quad (1)$$

In (1), c and r are assumed as constant which depend on imaging device and image display. Investigations indicate that the position of objects to the imaging device (such as distance and angle of each part of object) effects on the value of γ. In adaptive gamma correction methods, γ calculated for each area locally. So adaptive gamma correction methods such as [4],[5],[6] enhance image quality significantly.

In fig.2 there are two images which the first one is related to the original image and the second one shows the same image after enhancing by adaptive gamma correction method in [6]. As seen in fig. 2b, after applying this method on dental radiography images, radiolucent areas related to caries area (A,B,C) are more apparent, while radiolucent area related to teeth with Mach band effect (D) reduced. So using adaptive gamma correction has two characteristic:

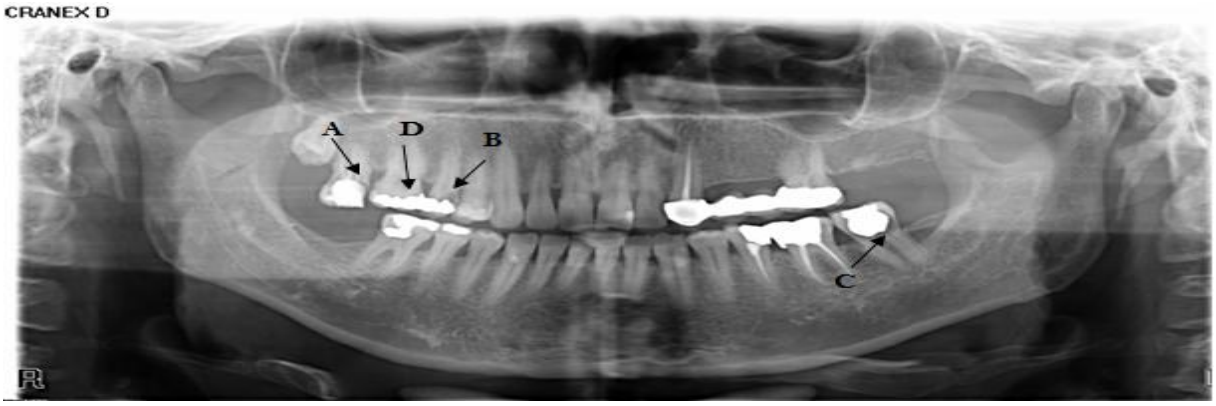


Fig.1. Radiography image with caries in the A, B and C in the radiolucent area

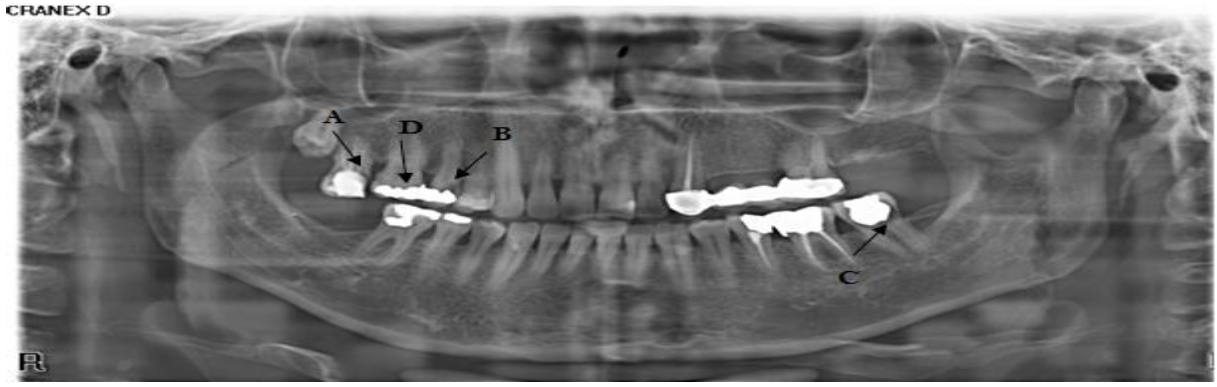


Fig.2.Effect of adaptive gamma correction on fig.1

- Make the radiolucent area related to caries more apparent
- Reducing Mach band effect

3 PROPOSED METHOD

The caries on restored teeth are appeared as radiolucent areas around restored area. Because caries change the color of tooth, while there is no such a radiolucent area in teeth without caries. So radiolucent area in the restored teeth is used to caries diagnosis. Since caries on enamel causes chemical changes on it, these changes are also reflected physically on radiography image (as radiolucent area). Our investigations indicate that these changes will be seen on the image histogram.

In the histogram of restored teeth without caries, there is just one area on histogram whose peak related to the gray level of restored area. While histogram of restored teeth with caries has two areas which the area with little gray level is related to caries and the area with higher gray levels is related to restored area which is seen on histograms in fig.3. These histograms are normalized form of the original histogram in which the gray levels of background and whiteness of restored area are omitted, because they are same in all images and have no useful information. In fig.4 histogram of restored teeth of fig.3 after gamma correction is shown. As seen in fig.4 after gamma correction, the histogram of teeth with secondary caries is stretched but the histogram of teeth without caries is also remained. In the stretched histogram it is easy to select threshold to secondary caries diagnosis.

Looking carefully in histogram of fig.4, it can be said that the histogram of gray levels is an appropriate feature to caries diagnosis on teeth, because based on distribution of gray levels on histogram we can diagnose the carious teeth. But to automatic diagnosis and easier selection of threshold the histogram transformed to cumulative diagram. By selecting a gray level as threshold and calculating the area under cumulative diagram before this threshold, it is possible to differentiate healthy teeth from caries one. In fig.5 cumulative diagram of histograms of fig.4 are shown. From fig.5 gray level 70 is selected as threshold, because the area under cumulative diagram before this threshold in carious teeth is smaller than teeth without caries.

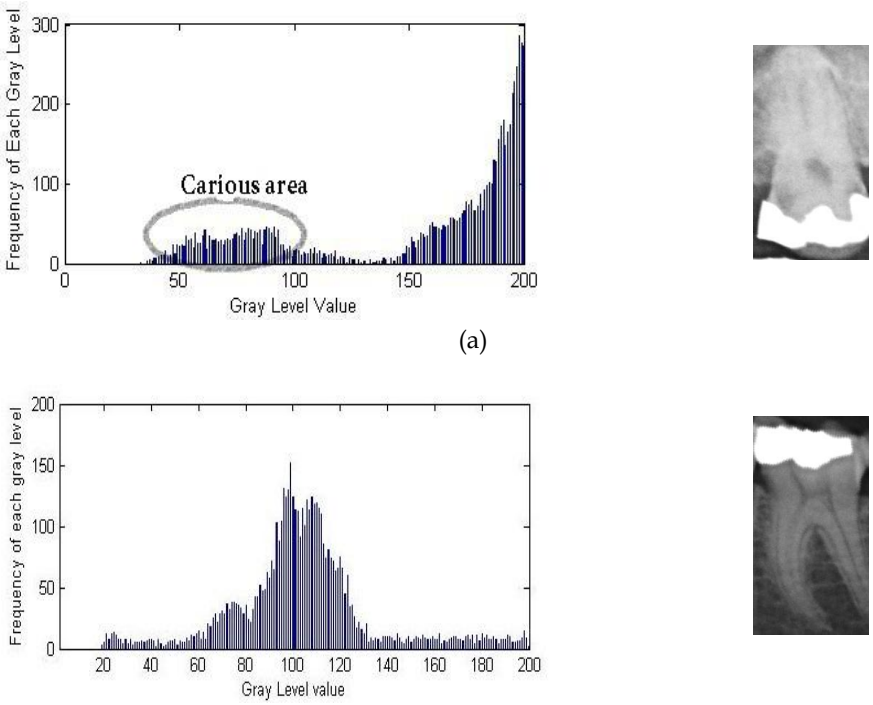


Fig.3. (a) Carious restored tooth and its histogram (b) Healthy restored teeth and its histogram

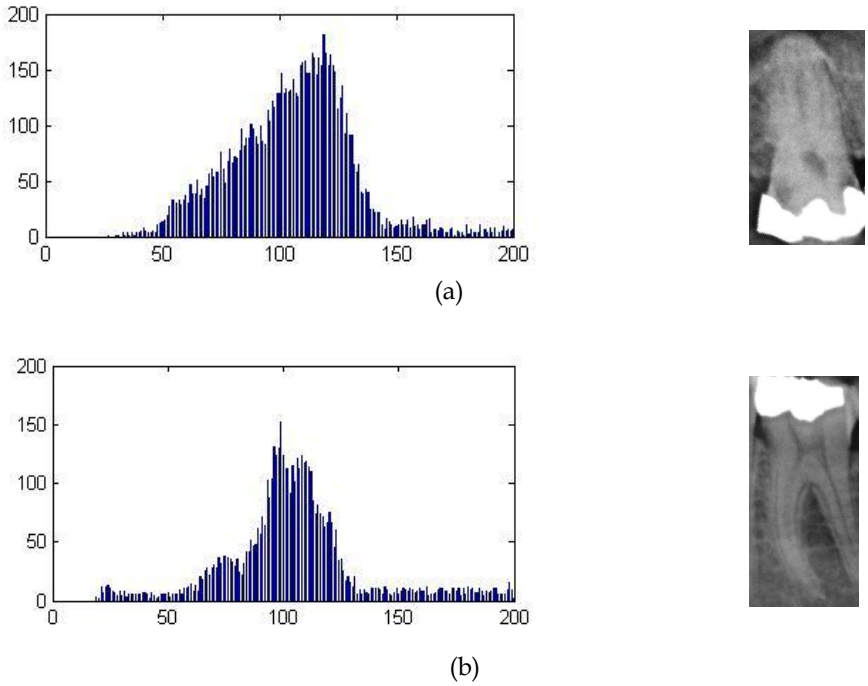
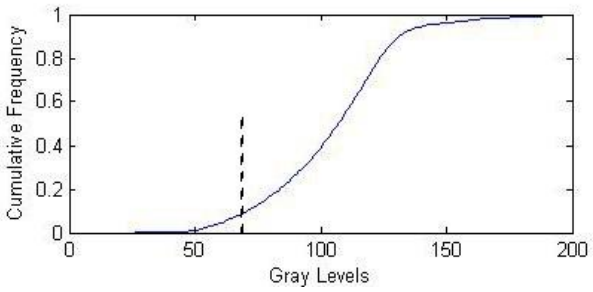
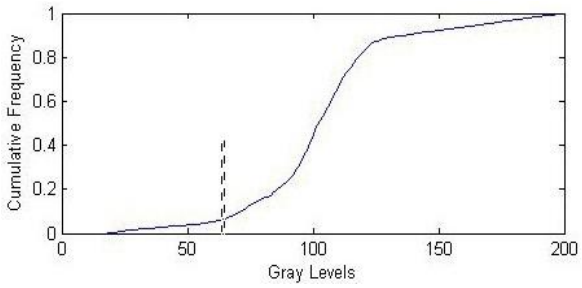


Fig.4. (a), (b) Histogram of fig.3a, fig.3b after gamma correction



(a)



(b)

Fig.5. Cumulative diagrams of fig.4a, fig.4b

4 Conclusion

In this paper a new method to secondary caries diagnosis in dental radiography images is proposed. In this method, at first the clarity of radiolucent area in radiography image is increased and then teeth with secondary caries are diagnosed using cumulative histogram. Therefore the procedure of secondary caries diagnosis is as following:

1. Preprocessing with gamma correction
2. Calculation of histogram
3. Normalization of the calculated histogram
4. Cumulative histogram calculation
5. Calculating area under cumulative diagram and applying selected threshold

To deliberate accuracy rate of proposed method in secondary caries diagnosis in restored teeth, two criteria are used which called GDR (Good Detection Rate) and FDR (False Detection Rate). The GDR shows proposed method accuracy rate in secondary caries diagnosis and FDR shows error rate. The equations used are as following:

$$FDR = \frac{FN}{FN+TN} \quad (2)$$

$$GDR = \frac{TP+TN}{FN+FP+TP+TN} \quad (3)$$

Parameters used in (2) and (3) are introduced in the following:

- TP (True Positive): The number of carious teeth diagnosed correctly
- FN (False Negative): The number of healthy teeth diagnosed with caries
- FP (False Positive): The number of carious teeth diagnosed healthy
- TN (True Negative): The number of healthy teeth diagnosed correctly

The proposed method has been applied on 100 restored teeth images and the results without preprocessing are shown in Table 1 and results by applying gamma correction are shown in Table 2. By selecting gray level of 50 as threshold and 1% as area threshold, the proposed method has 82% accuracy rate in secondary caries diagnosis. By comparing Table1 and Table 2 seen that in the case of preprocessing the accuracy rate of diagnose is increased relative to the case without preprocess. Gamma correction process not only makes the radiolucent area of teeth with caries apparent, but also reduces Mach band effect which can be seen by comparing area D in fig.2a, fig.2b.

TABLE 1
GDR AND FDR IN CARIES DIAGNOSIS FOR DIFFERENT THRESHOLD WITHOUT PREPROCESSING

Gray level threshold	Area under diagram	TP (out of 26)	FP (out of 26)	TN (out of 74)	Accuracy rate (%)	Error rate (%)
60	4	10	16	50	60	32
75	6	16	10	40	56	45
80	9	10	16	60	70	18
85	11	10	16	62	72	16
90	12	12	14	50	62	32
95	14	10	16	56	66	34

TABLE 2
GDR AND FDR IN CARIES DIAGNOSIS FOR DIFFERENT THRESHOLD WITH GAMMA CORRECTION

Gray level threshold	Area under diagram	TP (out of 26)	FP (out of 26)	TN (out of 74)	Accuracy rate (%)	Error rate (%)
50	1	22	4	60	82	18
55	2	22	4	50	72	32
80	14	18	8	50	68	32
85	15	16	10	54	70	37

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