A Pilot Study of Grayscale Value to Differentiate Cavitated Carious Lesion from Non-cavitated Lesion

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Abstract

Grayscale value is an adjunct for the caries detection in some dental radiographs, due to its distinguishability of the cavitated carious lesion from the non-carious one. This study aims to confirm an effect of the grayscale intensity in the dental radiographs of demineralized enamel on the distinction of a carious lesion. Seventy-one freshly extracted premolar teeth (43 non-cavitated and 28 cavitated carious lesions) were clinically reviewed by visual and tactile examinations. Post-radiography of all teeth with a bitewing technique, the mean grayscale values were calculated. Using a hard tissue macrotome, ground sections, 400 mm thick, were serially and mesio-distally cut in a parallel direction to each anatomical crown's long axis and observed with a stereomicroscope. Intra-and inter-observer agreements were assessed with a Pearson correlation. Statistical scores and histological gold standard indicated the diagnostic ability. It was revealed that mean grayscale value of the non-cavitated lesion was significantly different from that of the cavitated one ($p < 0.05$). Unlikely, mean grayscale of the non-cavitated lesion was not significantly different from that of the sound enamel ($p > 0.05$).

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Introduction

Dental caries is an infectious disease causing a demineralization and a destruction of tooth structures. It is commenced with a white opaque area at the outermost of enamel. Some diagnoses of the dental caries are necessary for a treatment plan to prevent an extension of the decay. A visual assessment is simple to detect an initial dental caries. Only three-fifths of the decalcified teeth are correctly identified by some dentists, with one-fifth of the sound teeth misdiagnosed decay.[1] At an interproximal area, which is a limited visual field, a detection of the caries is dependent on both a dentist's experiences and an assistance of some dental radiography.[2]

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A number of practical methods are valuable for the detection of an early carious lesion at a proximal surface. They include a combination among some visual and clinical examinations with a bitewing radiography and an application of some advance diagnostic instrument (e.g. a fiber-optic transillumination and a laser fluorescence). Although the visual field for some cavitated one can be improved by such instrument, an examination of an initial non-cavitated parts cannot be effectively enhanced. Taken together, a digital radiograph is a challenge option for an improvement of the detection of an initial caries.

In a digital radiography system, an image is consisted of a set of cells ordered in rows and columns. Each cell is defined by an x-coordinate, a y-coordinate, and a grayscale value. With an individual cell called pixel contributing to an image file in a computer, the grayscale value is correspondent to an X-ray intensity at that location during an exposure of a digital sensor. Despite its superiority on a diagnostic ability at the detection of proximal caries over a visual inspection, the digital dental radiograph is relied on an amount of the dental tissue demineralization at a 40% mineral loss.[3] Hence, an initial carious detection is suggested by using some digital image processing methods.[4,5] Most of some existing techniques either by amending the grayscale value range of all image pixels (such as contrast, density, and brightness), or by filtrating an image to emphasize some certain features and to a removal of other features (such as smoothing, sharpening, and an edge enhancement). However, none are satisfactory results for an initial caries detection, due to their indistinguishability of the grayscale value of non-cavitated carious lesion from the normal enamel.[6]

By using only some grayscale differentiations, it is possible to improve the efficacy of an initial caries detection. Hence, this study aims at a confirmation whether a grayscale intensity of a digital radiograph is affected by the demineralization of enamel at a clinical feasibility in the distinction of a carious lesion, when compared to the gold standard of some microscopic features.

Materials and methods

Seventy-one human premolars containing no restorative material and extracted for an orthodontic purpose were used in this study. One of their proximal sides with a carious lesion confining to enamel or extending to dentin served as experimental teeth, while the other one without such lesion as controls. All teeth were stored in a 0.1% thymol solution. Up to the cemento-enamel junction (CEJ) level at mid-buccal and -lingual points, their anatomical roots were embedded in some blocks fabricated from plaster of Paris. The roots' remaining parts were covered with some pink baseplate waxes. The teeth were randomly divided into groups and sorted with their contact areas tightly connecting to each other to mimic the clinical carious lesions. According to a guideline of the American Dental Association Caries Classification guideline,[7] clinical color, size, surface texture, and surface hardness of each group were classified by two observers. Under a standard bitewing condition, some digital radiographs were taken from each block. An X-ray device (XCP-DS, DentSply Sirona, York, PA, USA) was horizontally positioned with a 35-cm focus-receptor distance. Photostimulable phosphor (PSP) plates exposing at 70 kV, 15 mA and 0.3 seconds were used to image each set of teeth. The radiographs were exported in an 8-bit grayscale image with a *.tiff file format.

Images of each tooth were isolated and mean grayscale of pixels were measured from the carious sides and their controls by an investigator. With a 30-minute period per viewing session in a quiet room, the images were evaluated by two observers on an LCD medical monitor (MDNG-2121; Barco, Kortrijk, Belgium) set at a screen resolution of $2*10^6$ pixels and an 8-bit grayscale image using a standard software (ImageJ; National Institute of Health, Bethesda, MD, USA).[8] One week later, the images were re-evaluated in a randomized order. Presence of proximal caries without overlapping between the adjacent teeth was examined in all images. Prior to an observation, an arbitrary adjustment of the brightness and contrast was performed by each investigator to accommodate their own viewing processes. A region of interest (ROI) was selected to cover an extension of the lesion. A duplicated ROI was applied to control side of one particular tooth. ROI selections in carious and non-carious lesions were demonstrated in Figure 1. A mean grayscale was computed from the grayscale values containing in each ROI area with the software. A correlation of the mean grayscale values and the histological result were analyzed afterwards.

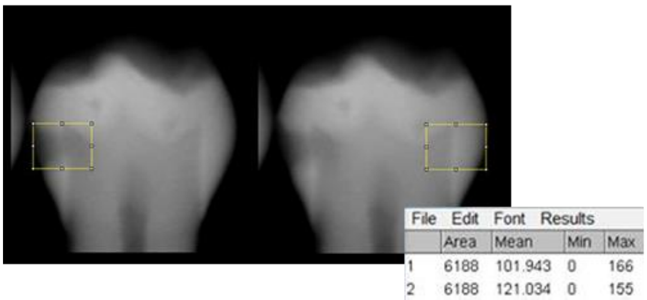

Figure 1. A demonstration of the selections of some regions of interest in a tooth and mean grayscale calculations using an ImageJ® software.

For the histological validations of the caries states, ground sections, 400 mm thick, were serially and mesio-distally cut in a parallel direction to each anatomical crown's long axis using a hard tissue macrotome (Isomet 5000; Buehler, Lake Bluff, IL, USA). Using a high resolution stereomicroscope (Olympus SZX16, Tokyo, Japan) at a 1.25 magnification, each tooth's section with the deepest carious lesion was assessed by the following scales:

0 – No caries lesion in the proximal surface;
1 – Proximal caries in enamel;
2 – Proximal caries at the dentino-enamel junction (DEJ) or in the dentin's outer half;
3 – Proximal caries in the dentin's inner half.

Intra-and inter-observer agreements were assessed with a weighted kappa coefficient. The criteria were no agreement (0.10), poor agreement (0.10–0.40), significant agreement (0.41–0.60), strong agreement (0.61–0.80), and excellent agreement (0.81–1.00). A difference between mean grayscale values of non-carious and those of carious lesions was evaluated with an independent t-test. Correspondences between grayscale scores and histological observations were calculated using a Chi-square test with a 0.05 significant level. Description statistics was applied to demonstrate the range of mean grayscale values obtained from each level of caries classification.

Results

Thirty carious lesions and 41 incipient caries were clinically recognized. From histological analyses of the proximal tooth surfaces by caries level, 41 surfaces (57.75%) showed enamel caries, 5 surfaces (7.04%) dentin caries confined to DEJ, and 25 surfaces (35.21%) deep caries extending to the inner half of dentin.

Intra- and inter-observer kappa coefficient scores calculated for each observer in the radiographic caries detections were 0.95 and 0.83, respectively. Mean grayscale values of carious and non-carious lesions in 8-bit digital radiograph images are shown in Table 1. A majority of the teeth with enamel caries were seen with a 65-128 grayscale range. Approximately one-fourth (24.39%) of the teeth with incipient caries had as same grayscale range as those without caries. An independent t-test indicated an insignificant difference between the mean grayscale values of incipient carious lesions and those of sound enamel.

Mean grayscale range	Caries involvement (number of tooth side)			
	Enamel	DEJ	Dentin	Control
0-64	1	1	4 (32%)	9
65-128	30	3	20 (56%)	48
129-255	10	1	1 (12%)	14

Table 2. A comparison of mean grayscale value of carious and non-carious lesion in 8-bit digital radiograph image.

Discussion

Some visual restrictions limit a dentist's ability of caries detection, particularly in the proximal areas. Digital radiography is the most recommended adjunct method in caries diagnoses, due to its linear grayscale response of the acquired images and potential for the reduction of the dose to the patient.[9,10] Although a grayscale manipulation in the digital radiographs enhances an accurate caries diagnosis,[11] there is a low sensitivity for some enamel lesion detection, regardless of the type of imaging receptors.[12] Consequently, this study was designed to investigate the difference of mean grayscale value for initial carious lesion in digital dental radiography.

Despite some high inter- and intra-observer agreements in this study, mean grayscale values of cavitated and non-cavitated carious lesions were not significantly different. Even from a dental radiograph with a good quality, an initial carious lesion undetectable by an experienced dental radiologist has been scarce.[13]

The present results correspond well with a previous report showing the digital radiographs' low detections of a white spot lesion at the enamel's outermost area.[14] A subsurface area of the white spot lesion in enamel has contained a low mineral content (10-70% volume), but shown an excess of 40% mineral loss in a radiographic detection.[15-18] Hence, an overlook of a grayscale difference possibly occurs in an early demineralization.

The quality of an image is affected by some selected exposure parameters, some appropriate patient-positioning procedures, and a technician's skills.[19] In spite of an employment of some PSP plates with a 70 kVp and a 0.3s exposure time recommended for the enamel lesions,[20] some variations in research methodology have caused the inappropriate contrast images in this study. Due to an improper primary exposure, post-image processing procedures have been unable to correct the image errors.[21] When the contrast is too low, the detection of a small carious lesion at the interproximal enamel is problematic.[20]

The selections of ROI also influence a computation of the mean grayscale. An accurate grayscale value has been dependent on the area of ROI selection, noise, and inconsistency in brightness and contrast.[22] A small proportion of the grayscale values containing in each rectangular ROI may not affect the calculation of their mean value. Either the ROI selection or the usage of an average grayscale possibly shows some significant change in the calculation.

Conclusions

Mean grayscale value of the non-cavitated lesion was significantly different from that of the cavitated one, with an insignificant difference from that of the sound enamel ($p > 0.05$). Some modifications of the research methodology are necessary to define a standard mean grayscale value for the detection of an initial caries.

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Declaration of interest

The authors report no conflict of interest.

References

1. White SC, Hollender L, Gratt BM. Comparison of Xeroradiographs and Film for Detection of Proximal Surface Caries. J Am Dent Assoc. 1984;108(5):755-9.
2. Baelum V, Heidmann J, Nyvad B. Dental Caries Paradigms in Diagnosis and Diagnostic Research. Eur J Oral Sci. 2006;114(4):263-77.
3. Pereira AC, Verdonschot EH, Huysmans MC. Caries Detection Methods: Can They Aid Decision Making for Invasive Sealant Treatment? Caries Res. 2001;35(2):83-9.
4. van der Stelt PF. Better Imaging: The Advantages of Digital Radiography. J Am Dent Assoc. 2008;139 Suppl:7S-13S.
5. Wenzel A. Digital Radiography and Caries Diagnosis. Dentomaxillofac Radiol. 1998;27(1):3-11.
6. Valizadeh S, Goodini M, Ehsani S, Mohseni H, Azimi F, Bakhshandeh H. Designing of A Computer Software for Detection of Approximal Caries in Posterior Teeth. Iran J Radiol. 2015;12(4):e16242.
7. Young DA, Nový BB, Zeller GG, Hale R, Hart TC, Truelove EL. The American Dental Association Caries Classification System for clinical practice: a report of the American Dental Association Council on Scientific Affairs. J Am Dent Assoc. 2015;146(2):79-86.
8. Schneider CA, Rasband WS, Eliceiri KW. NIH Image to Image J: 25 years of image Analysis. Nat Methods. 2012;9(7):671-5.
9. Wenzel A. Radiographic Display of Carious Lesions and Cavitation in Approximal Surfaces: Advantages and Drawbacks of Conventional and Advanced Modalities. Acta Odontol Scand. 2014;72(4):251-64.
10. Bader JD, Shugars DA, Bonito AJ. Systematic Reviews of Selected Dental Caries Diagnostic and Management Methods. J Dent Educ. 2001;65(10):960-8.
11. Bansal GJ. Digital radiography. A Comparison with Modern Conventional Imaging. Postgrad Med J. 2006;82(969):425-8.
12. Bottenberg P, Jacquet W, Stachniss V, Wellnitz J, Schulte AG. Detection of Cavitated or Non-Cavitated Approximal Enamel Caries Lesions using CMOS and CCD Digital X-Ray Sensors and Conventional D and F-Speed Films at Different Exposure Conditions. Am J Dent. 2011;24(2):74-8.
13. Mejàre I, Gröndahl H, Carlstedt K, Grever A, Ottosson E. Accuracy at Radiography and Probing for The Diagnosis of Proximal Caries. Scand J Dent Res. 1985;93(2):178-184.
14. Neto JM, Santos RL, Sampaio MC, Sampaio FC, Passos IA. Radiographic Diagnosis of Incipient Proximal Caries: An Ex-Vivo Study. Braz Dent J. 2008;19(2):97-102.
15. Olga KI, Mira J, Aneta M, Zabokova-Bilbilova E, Pavlevska M, Todorovska G. The Ultrastructural Changes of the Initial Lesion at Early Childhood Caries. J. Int. Dent. Med. Res. 2017;10(1):36-41.
16. Ferreira RI, Haiter-Neto F, Tabchoury CP, de Paiva GA, Bóscolo FN. Assessment of Enamel Demineralization using Conventional, Digital, and Digitized Radiography. Braz Oral Res. 2006;20(2):114-9.
17. Hintze H, Wenzel A, Jones C. In Vitro Comparison of D- and E-Speed Film Radiography, RVG, and Visualix Digital Radiography for the Detection of Enamel Approximal and Dentinal Occlusal Caries Lesions. Caries Res. 1994;28(5):363-7.
18. Roopa KB, Pathak S, Poornima P, Neena IE. White Spot Lesions: A Literature Review. J Pediatr Dent. 2015;3(1):1-7.
19. Nishikawa K, Shibuya H, Wakoh M, Kuroyanagi K. Dependency of Dose Response of Charge-Coupled Device-Based Digital Intra-Oral Radiographic Systems on Tube Voltage. Dentomaxillofac Radiol. 1999;28(6):364-7.
20. Dehghani M, Barzegari R, Tabatabai H, Ghanea S. Diagnostic Value of Conventional and Digital Radiography for Detection of Cavitated and Non-Cavitated Proximal Caries. J Dent (Tehran). 2017;14(1):21-30.
21. Pongnapang N. Practical Guidelines for Radiographers to Improve Computed Radiography Image Quality. Biomed Imaging Interv J. 2005;1(2):e12.
22. Eberhard J, Hartman B, Lenhard M, Mayer T, Kocher T, Eickholz P. Digital Subtraction Radiography for Monitoring Dental Demineralization. An in vitro study. Caries Res. 2000;34(3):219-24.