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Effect of Zooming, Colorization, and Contrast Conversion on Proximal Caries Detection

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Abstract

Background: Different enhancements have been used to improve the diagnostic accuracy of radiographic images in digital systems. However, the diagnostic accuracy of the effects of these enhancement options on dental caries has not been determined.
Objectives: This study evaluated the effects of software enhancements of zooming, colorization, and contrast conversion on the accuracy of proximal caries detection.
Materials and Methods: In this diagnostic in vitro trial study, 42 non-cavitated and restoration-free extracted permanent molars and premolars were selected and mounted onto 14 blocks in contact with each other. Radiographic images were obtained from the teeth in similar standardized condition using the paralleling technique. The images were shown without any enhancement or with using the options of zooming, colorization, and contrast conversion. Depth of proximal caries was determined by a radiologist using four-scaled criteria. The diagnostic accuracy of digital images that had undergone different enhancements was calculated by the chi-square test.
Results: The diagnostic odds of the original digital images were lower than 20 (5.7). By using the enhancement options of zooming, colorization, and contrast conversion, the diagnostic odds of the enamel proximal caries had a score of less than 20. The score was higher than 20 for proximal caries located in the outer and inner half of the dentin.
Conclusions: The enhancement options of zooming, colorization, and contrast conversion did not significantly influence the diagnostic accuracy of digital images in enamel caries, but they enhanced caries diagnosis/progression in the outer and inner half of the dentin.

Keywords: Colorization, Contrast Conversion, Enhancement, Proximal Caries, Zooming

1. Background

Dental caries is the most common chronic infectious disease around the world. However, proximal dental caries detection has some limitations even with new advances. Dental caries have gradual progression and does not appear in radiographs until they reach more than half the depth of the enamel. This kind of caries is the most common, and therefore the correct detection at the right time is indispensable (1). A number of methods such as probing, visual inspection, intraoral conventional, and digital radiographs are suggested for caries detection. Visual inspection is not possible if caries has caused less than 25% - 42% tissue demineralization (1, 2). Moreover, it can extend through the dentin without visible macroscopic impression on the enamel. Therefore, visual inspection is not always sufficient, and radiography is the most important appliance aside from clinical examination for caries detection (3). An ideal radiographic technique should be able to recognize the presence or absence of caries, define its quantitative size and depth, and display its activity rate. Early detection of oral and dental lesions has been introduced outreached recently using clinical and paraclinical diagnostic methods; consequently, dental tissue destruction has decreased and a satisfying treatment service may be reached (4).

A large body of evidence shows that digital radiographic systems are an effective means for dental caries detection because they have many advantages, such as eliminating films and chemical processing. More importantly, they have less exposure time (up to 90%) than conventional intra oral dental films, have rapid image retrieval time, have lower exposure radiation dose (up to 60%), have high sensitivity, lack silver halide crystals, and implement computerized image processing. Moreover, these systems obtain more data, conduct fast and simple image saving and transferring possibility, and have reduced noise. These advantages lead to the conventional technique being substituted by digital systems (5, 6). Digital enhancement techniques, such as adjustment of brightness, contrast, or edge enhancement, help to increasing diagnostic accuracy (7,

8). Some studies have confirmed this ability in proximal caries detection (9). By contrast, some studies have reported no significant difference in the diagnostic accuracy between the original images and the digitally enhanced ones in RVG® and Vistascan® systems (10, 11). Manufacturers claim their superiority, but the proficiency of the enhancement options is not always approved. If they actually have this diagnostic capability, then superior proximal caries detection will be advantageous for dentists. Few studies have been performed to clarify the benefits of enhancements.

2. Objectives

Therefore, this study aims to determine the effect of colorization, contrast conversion, and zooming on proximal caries detection.

3. Materials and Methods

In this diagnostic in vitro study, 42 non-cavitated, restoration-free permanent molar and premolar teeth were mounted in contact with each other on 14 silicone blocks. Each block was imaged using the parallel technique by a digital radiograph system (MINRAY, Soredex, Tusula, Finland) with photo-stimulable storage phosphor (PSP) receptors (Digora- fmx with blue plates, Soredex, Tusula, Finland) under similar exposure settings (70 kVp, 7 mA, 0.16 s, SOD 32cm, and OID 2 cm).

Subsequently, the images were evaluated as original images first without any digital enhancement and then by applying 100% zooming, contrast conversion, and colorization on a 16 in monitor (Flatron, W1752s LG,) with 900 x 1600 resolution using SCANORA 4.3.1 software (Figure 1).

An experienced oral and maxillofacial radiologist observed all the images and scaled the situation of proximal caries using a 0 - 3 point scale (0: no caries, 1: enamel caries, 2: caries in the outer half of dentin, and 3: caries in the inner half of dentin). All specimens underwent histological evaluation (which is the gold standard). For this purpose, the teeth were separately mounted on transparent acrylic blocks and sectioned mesiodistally by a BUEHLER® IsoMet® Low Speed Saw (Lake Bluff, Illinois, USA). The thickness of each section was 0.1 mm. Slides were prepared from the specimens and observed under a light microscope (Olympus, Taiwan) by a maxillofacial pathologist. The presence or absence of caries was reported for each specimen based on the 0 - 3 point scale. Radiographic and histopathologic results were compared. Results of diagnostic accuracy at different depths of caries were compared with the gold standard results using the chi-square test. SPSS 18.0 was used for statistical analysis ($P < 0.05$).

4. Results

In this study, the diagnostic accuracy of the four image observation methods with no digital enhancement and the application of contrast conversion and colorization were compared with the histological evaluation as the gold standard.

Based on histopathological observations, 30 and 54 samples were correspondingly carious and intact, respectively. Among the total number of 84 surfaces, 34 and 50 samples were diagnosed as carious and intact, respectively, in the no enhancement group. Overall, 28 and 56 teeth were diagnosed as carious and intact for the zooming group, 25 and 59 for colorization, and 27 and 57 for contrast conversion, respectively. The statistical analysis estimated the diagnostic accuracy indices, including sensitivity, specificity, diagnostic accuracy and diagnostic odds, positive predictive value, negative predictive value, positive likelihood ratio, and negative likelihood ratio values in all methods (no enhancement, zooming, colorization, and contrast conversion). These indices are all reported in Table 1.

The chi-square test found significant differences in terms of location and extension of carious lesions between the observation of the original image without digital enhancement and the gold standard results ($P < 0.001$). Sensitivity, specificity, positive predictive value, negative predictive value, diagnostic accuracy, positive likelihood ratio, negative likelihood ratio, diagnostic odds ratio, and the Kappa value of the proximal caries restricted in the enamel, outer half of the dentin, and inner half of the dentin are shown in Tables 2 - 5.

In enamel caries, the diagnostic odds ratio was less than 20 in all methods (with and without enhancement), and it was more than 20 in the dentin extended caries when enhancements were applied.

5. Discussion

In this in vitro study, the sensitivity and specificity of the digital enhancement options decreased and increased, respectively. Moreover, in all steps, the diagnostic odds ratio was less than 20, and the insufficient validity and reliability of these tasks were implied. Nonetheless, the use of zooming, colorization, and contrast conversion led to a greater-than-20 value of the diagnostic odds ratio for proximal caries extending to the dentin. Accordingly, when proximal caries penetrated into the outer and inner depths of the dentin, the accuracy of the results approached the gold standard, i.e., higher diagnostic accuracy was achieved. However, note that with the progression of caries into the dentin, the results of the observa-

Figure 1. (A) Zooming Of Digital Images, (B) Contrast Conversion of Digital Images, and (C) Colorization of Digital Images of the Teeth Set in a Row as in Normal Occlusion

The fourth tooth in every block is an anterior tooth for simulating a normal contact only.

Table 1. Indices of the Diagnostic Accuracy of Observation of the Digital Images With and Without Enhancement

Method Index	Sensitivity[a]	Specificity[a]	Diagnostic Accuracya	Positive Predictive Value[a]	Negative Predictive Value[a]	Positive Likelihood Ratio	Negative Likelihood Ratio	Diagnostic Odds
No enhancement	66.7	74.1	74.1	58.82	80	2.5	0.45	5.7
Zooming	63.33	83.33	76.2,	67.86	80.36	3.8	0.44	8.6
Colorization	53.33	83.33	72.62	64	76.27	3.2	0.56	5.7
Contrast conversion	60	83.33	75	66.67	78.95	3.6	0.48	7.5

[a]Values are expressed as No. (%).

Table 2. Indices of the Diagnostic Accuracy of Observation of the Original Digital Images Without Digital Enhancement for Various Locations of the Carious Lesions

Location/Index	Sensitivity[a]	Specificity[a]	Positive Predictive Value[a]	Negative Predictive Value[a]	Diagnostic Accuracy[a]	Positive Likelihood Ratio	Negative Likelihood Ratio	Diagnostic Odds Ratio	Kappa Value
Enamel	57.14	85.11	36.36	93.02	81.48	3.84	0.5	7.62	0.34
Outer half of the dentin	71.43	86.96	62.5	90.91	83.33	5.48	0.33	16.67	0.56
Inner half of the dentin	25	97.56	50	93.02	91.11	10.25	0.77	13.33	0.29

[a]Values are expressed as No. (%).

Table 3. Indices of the Diagnostic Accuracy of Observation of the Digital Images Enhanced With Zooming For Various Locations of the Carious Lesions

Location/Index	Sensitivity[a]	Specificity[a]	Positive Predictive Value[a]	Negative Predictive Value[a]	Diagnostic Accuracy[a]	Positive Likelihood Ratio	Negative Likelihood Ratio	Diagnostic Odds Ratio	Kappa Value
Limited in enamel	50	91.84	50	91.84	85.96	6.13	0.54	11.25	0.42
Outer half of the dentin	60	95.74	81.82	88.24	87.1	14.1	0.42	33.75	0.61
Inner half of the dentin	66.67	93.75	40	97.83	92.16	10.67	0.36	30	0.46

[a]Values are expressed as No. (%).

tion of the original images would be more reliable. The important point is to be able to detect enamel proximal caries when the carious lesion has minimal extension, so that the dental practitioner can initialize preventive treatments such as fluoride therapy.

In general, this study showed that digital radiography without processing was not suitable for caries detection compared with the gold standard as it had a diagnostic odds ratio of less than 20.

Several studies have shown no difference in diagnostic accuracy between enhanced and unenhanced images in digital radiography (12, 13). However, dentists benefit from

Table 4. Indices of the Diagnostic Accuracy of Observation of the Digital Images Enhanced With Colorization Filter for Various Locations of the Carious Lesions

Location/Index	Sensitivity[a]	Specificity[a]	Positive Predictive Value[a]	Negative Predictive Value[a]	Diagnostic Accuracy[a]	Positive Likelihood Ratio	Negative Likelihood Ratio	Diagnostic Odds Ratio	Kappa Value
Limited in enamel	33.33	91.84	42.86	88.24	82.76	4.08	0.73	5.63	0.28
Outer half of the dentin	60	95.74	81.82	88.24	87.1	14.1	0.42	33.75	0.61
Inner half of the dentin	50	93.75	40	95.74	90.38	8	0.53	25	0.39

[a] Values are expressed as No. (%).

Table 5. Indices of the Diagnostic Accuracy of Observation of the Digital Images Enhanced With Contrast Conversion Filter for Various Locations of the Carious Lesions

Location/Index	Sensitivity[a]	Specificity[a]	Positive Predictive Value[a]	Negative Predictive Value[a]	Diagnostic Accuracy[a]	Positive Likelihood Ratio	Negative Likelihood Ratio	Diagnostic Odds Ratio	Kappa Value
Limited in enamel	66.67	90	54.55	93.75	86.44	6.67	0.37	18	0.52
Outer half of the dentin	53.33	95.74	80	86.54	85.48	12.53	0.49	25.71	0.55
Inner half of the dentin	50	95.74	50	95.74	92.16	11.75	0.52	22.5	0.46

[a] Values are expressed as No. (%).

changing the brightness or contrast clinically. An inaccurate application of the enhancement facilities can lead to misdiagnosis (14). However, can the effective and meticulous use of enhancement options lead to increased diagnostic accuracy? Despite the increasing popularity of digital radiography, only a few patients have benefitted from its perks because of the fact that many capabilities of these systems are ignored and not routinely used (15-18). Some studies mentioned this ability and emphasized more on the agreement among observers (8-10); concurrently, some denied this objective and reported no difference in detecting subsurface proximal demineralization with various modalities (19, 20). Haiter-Neto et al. (2009) (11) reported no difference in detection potential between raw images of PSP and those processed with task-specific filters, but they recommended the application of fine enhancement for initial slight caries detection even if there is no considerable effect on diagnostic accuracy. Kositbowornchai et al. (2004) (21) found no superiority in applying pseudocolor, zooming, or increasing brightness in the diagnostic accuracy of occlusal caries. They suggested that visual system habitude for observing and interpreting the images could evade the exact detection in manipulated images. However, this supposition requires more investigation. Belem et al. (2013) (20) evaluated the impaction of enhanced digital radiography in proximal caries detection and reported increased sensitivity and accuracy with sharpening; however, they found that negative filtering led to a decrease in accuracy. Mehr-Alizadeh et al. (2012) (22) also reported increased sensitivity, positive predictive value, negative predictive value, and diagnostic accuracy of the zoomed images rather than the basics in their study on the diagnostic accuracy of dentinal occlusal caries detection. Their specificity had no significant difference. However, the results of our study showed increased values except for sensitivity.

The main purpose of introducing digital enhancement options is to modify the image characteristics for better visualization and interpretation (19). Filters are set as gadgets derived from mathematical algorithms that assist in image processing (9). Enhancement can compensate for the image quality deficiencies caused by insufficient exposure or noise by changing and improving the basic images (11).

Incipient enamel caries is not detectable in radiography because extending beyond the half depth of the enamel tissue will not be observed until demineralization reaches 30% - 40% (23). However, dentinal caries are more easily detectable than enamel carries. This study confirmed that the diagnostic odds ratio in image evaluation can be increased through digital software enhancement.

Confounding variables were controlled as much as possible in this study. In a standard situation, a parallel technique and a consistent object-to-receptor distance were set for all imaging stages (24). In the clinic, the size, shape, and caries location are variable. Therefore, studies should determine the factors affecting the results of radiographic interpretation. In applying digital systems, the images should be observed on a high resolution monitor with reduced ambient light in the viewing room to help improve the diagnostic accuracy, as what was done in our studies (23, 24).

Most previous studies were conducted for the qualitative evaluation of caries existence. Therefore, the recent quantitative caries assessment is a breakthrough in

research methods. Consequently, we examined the various digital enhancement filters for determining the lesion depth and the presence or absence of caries in this study.

5.1. Conclusion

This study on the digital enhancement diagnosis of proximal caries showed that digital enhancement did not have a significant effect on improving the diagnostic accuracy in incipient enamel lesions. However, with caries progression and penetration into the outer and inner depths of the dentin, the caries is better diagnosed with the enhancement options.

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