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Accuracy of Digital Subtraction Radiography in Combination with a Contrast Media in Assessment of Proximal Caries Depth

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Abstract

Background and aims. Radiography is used to diagnose the demineralization process and carious lesions; however, conventional radiography and direct digital images do not show these lesions when the amount of demineralization is less than 40%. Digital subtraction radiography has recently been used to improve the diagnostic quality of these lesions. The purpose of this study was to compare the caries depth estimated by digital subtraction radiography in combination with barium sulfate in diagnosing proximal dental caries with histopathologic evaluation.

Materials and methods. In this study 30 molars and premolars (24 demineralized lesions with cavity, 8 without cavity) were studied. Direct digital images were taken (kVp: 68, mA: 8; t: 0.12 for premolars and t: 0.16 for molars) whereas the position of X-ray tube and CCD receptor and teeth was fixed. To prepare the second images 135 gr/L barium sulfate was used. The images obtained with the same exposure and geometry and then subtracted. The depth of the lesions in direct digital and subtracted images were assessed and compared with the depth measured in histopathologic assessments.

Results. The mean depths (± SD) of the lesions were 1.80 ± 0.77 mm in direct digital radiography, 2.32 ± 0.76 mm in subtracted images after barium sulfate treatment, and 2.51 ± 0.43 mm in histopathologic sections. The statistical difference between direct digital radiography and the other methods was significant ($P < 0.05$). However, the differences were not statistically significant between subtracted images and histopathologic sections. The average intra-class correlation coefficient was 0.7241 (CI: 95%).

Conclusion. The present study has demonstrated that digital subtraction radiography images have the potential to measure the depth of proximal caries with no significant difference with histopathologic evaluation.

Key words: **Barium sulfate, dental caries, digital subtraction radiography.**

Introduction

Radiographic underestimation of caries extent is a chief concern when considering a treatment plan.[1] This shortcoming may be the result of the broad proximal surfaces of posterior teeth and the fact that radiography cannot reveal caries until approximately 30–40% demineralization has occurred.[2,3]

Digital imaging techniques have been found helpful in diagnosing carious lesions[1,4] and are improving continuously by employing additional techniques. One of these techniques is digital subtraction radiography (DSR), which increases diagnostic performance by removing unchanged areas (during a period of time) and highlighting changed region.[5,6] But, most of previous investigations on DSR have studied early lesion diagnosis, whereas caries extent detection has not been fully studied.

It has been demonstrated that a contrast medium, such as stannous fluoride leads to increased radiographic density in demineralized areas, resulting in more accurate caries detection in DSR.[7] Regarding several disadvantages of this material,[8,9] we applied barium sulfate (BS), routinely used as a medical contrast medium with high atomic number to achieve the mentioned radiographic contrast. Barium sulfate is water soluble and even in the case of swallowing, has no known adverse effects or allergic reactions.[10]

The purpose of this study was to compare the caries depth estimated by digital subtraction radiography in combination with barium sulfate in diagnosing proximal dental caries with histopathologic evaluation.

Materials and Methods

Thirty extracted permanent molars and premolars were selected. Twenty two of these had proximal caries with cavitation and varying depth. Eight teeth had white spots in proximal with intact enamel surface. The teeth that were extracted for different reasons disinfected for 48 hours in 10% formalin.

Then, they were individually mounted in acrylic blocks. A fixed position was considered for these blocks between the X-ray beam indicator and image receptor to get reproducible projection geometry. The focus-detector distance was 24 cm.

An 18-mm plexiglass slab was placed between the x-ray tube and teeth to stimulate the soft tissue and the location of X-ray beam indicator was circled (because of round collimator shape) on these slabs.

The image receptor was charge coupled device (CCD, Planmeca , Dixi 2V3) and the images were taken by an intra-oral digital system (Planmeca, Helsinki, Finland) with 68 kVp, 8 mA, t: 0.12 s for premolars and t: 0.16 s for molars.

These images were considered as the first images before barium sulfate treatment.

On the next step, barium sulfate (BS) solution was prepared with regular concentration (135 gr/L water) and was put on carious lesions by a spatula. According to the literature,[7] the time of application was 20 min, and repeated every 5 min to avoid deposition; after this time the teeth were washed by high pressure water for 1 min to be cleaned. After this time in both cavitated and non-cavitated teeth there was no evidence of the solution.

In this step, the second images were taken the same as the first images.

The first (before treatment) and the second (after treatment) images were saved by Dimaxis 2.4.1 software (Planmeca, Helsinki, Finland) in an 8-bit TIFF format and subtracted by Photoshop CS2 9.02 software (Adobe Systems Inc. San Jose, CA, USA) (Figure 1).

After subtractions, the samples with no change were excluded. These samples consisted of 8 teeth without cavitation (with white spot) and a still unknown histopathological state of decay. Measurements were performed on the remaining samples with cavitation.

The first step of the computer-assisted subtraction procedure was gamma correction. A digital algorithm applied to these pair of radiographs to standardize the density and contrast. Although the previously described device led to acquisition of standard first and second digital images, there could still be pair of radiographs with geometric discrepancy; so reconstruction of images was necessary. Computer algorithms can perform the

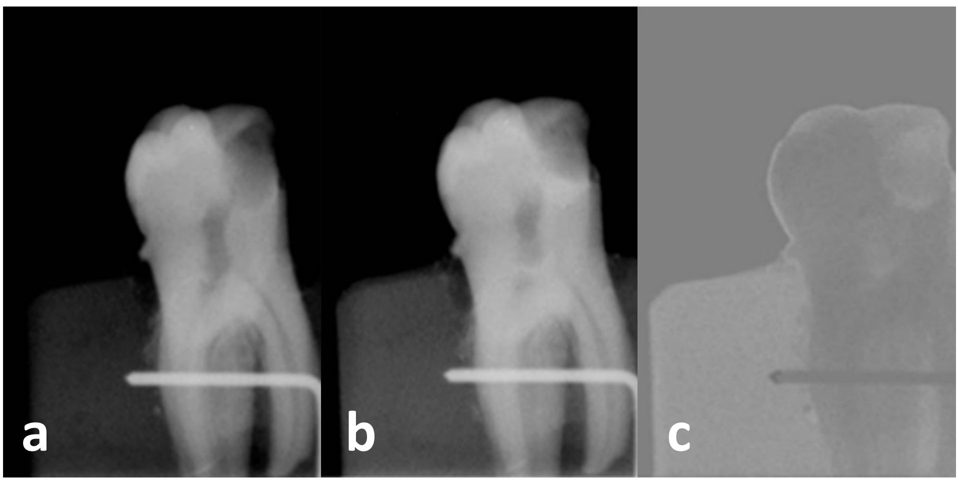

Figure 1. The first (a), the second (b) and the subtracted images (c).

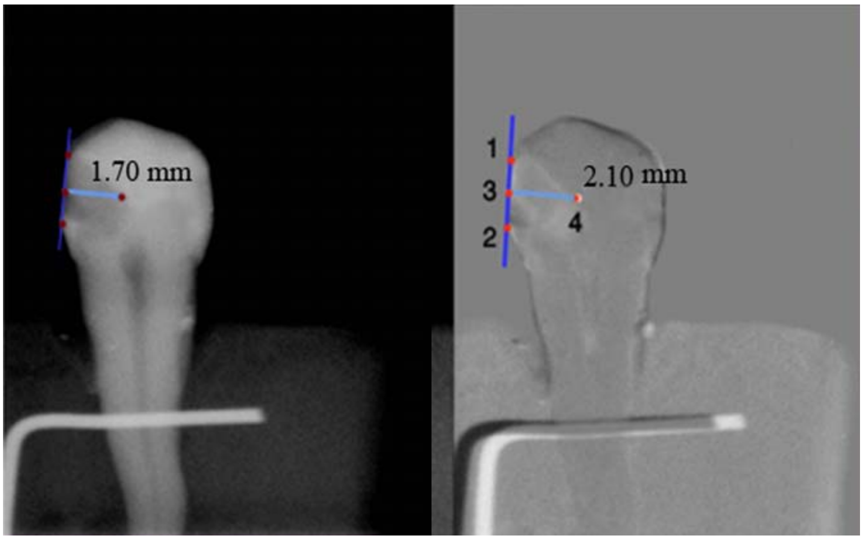

Figure 2. Caries depth measurements on the image before barium sulfate treatment (left) and on the subtracted image after barium sulfate treatment (right).

calibration of the gray scale and correct the distortions due to misalignment during image capture up to 5 degree.

Caries depth measurements were done on two series of images: (1) first images before BS treatment; and (2) subtracted images after BS treatment.

Photoshop software was used to perform the measurements. Four points were plotted in the image: (1) the most coronal outer border of the lesion; (2) the most apical, outer border of the lesion, then a line was drown between these two points; (3) the middle point of this line considered as point 3;[11] and (4) a line from point 3 was drown in a right angle to the line connecting the points 1 and 2, continuing to reach the inner border of the lesion and this point considered as point 4. The distance between points 3 and 4 was considered as caries depth. These points and lines were drawn on original, subtracted and digital images of histopathologic section (Figure 2).

Because of digital image magnification that is unavoidable and to subtract the images with minimal errors, L-shaped metal bars were attached on acrylic blocks of teeth. The lengths of horizontal and vertical portions of bars were both 10 mm. Magnification was calculated by dividing the measured length of the bars on each image to the real length.

After determining caries depths in both series of images in similar ways, the teeth were prepared for histopathologic examination. Teeth were embedded in epoxiresin blocks to have the least injuries to enamel and dentin during sectioning. The sectioning was performed by diamond disks while the thickness of sections was 1000–1500 micron. Three sections of the deepest portion of caries were selected and stuck on slides by Canada balsam. After fixation, digital images of the sections were taken and depth assessing was performed similar to the digital radiographic images (4 points & 2 lines) with Photoshop software (Figure 3).

All statistics were carried out in SPSS 9 for

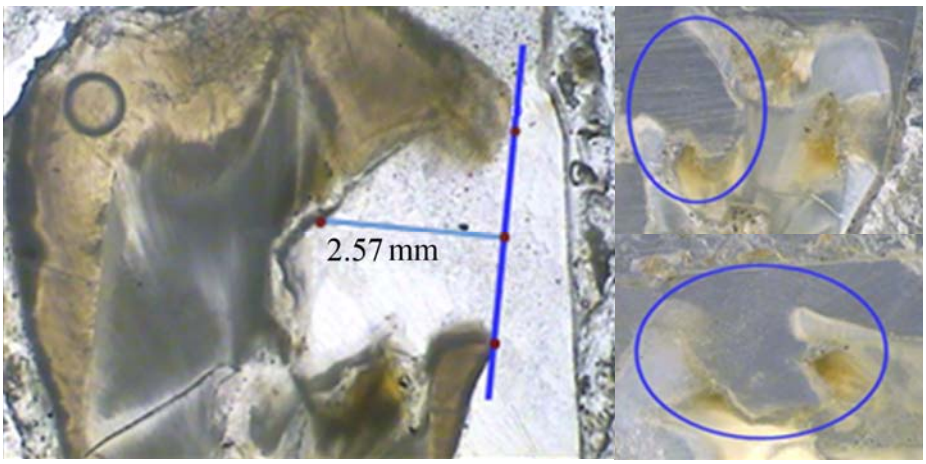

Figure 3. Digital images of the histopathologic sections. Measurement were made on screen using computer software.

Windows (SPSS Inc, Chicago, Ill, USA). The data obtained from the three groups were assessed by paired t-test and analysis of variance (ANOVA), regarding their normal distribution. Pearson correlation coefficients were also calculated between the three measures. Single measure intraclass correlation coefficient (ICC) was determined and linear regression model was applied to assess the final model. Measurement reliability was assessed by single measure ICC and average measure ICC. Type I error (α) was set at 0.05 and P value less than α was considered statistically significant.

Results

Of 30 studied samples, 8 had no cavity, and 2 of them showed two separate caries. Therefore, a total of 24 samples were finally evaluated.

The mean caries depth in direct digital radiographs was 1.8 ± 0.77 (with median of 1.8 and range of variation of 0.40–3.30). The mean was 2.32 ± 0.76 (median of 2.35 and range of variation of 0.90–3.70) in subtracted images and 2.51 ± 0.43 (median of 2.59 and range of variation of 1.43–3.48) in histopathologic assessments. Analysis of variance (ANOVA) revealed a significant difference for these measurements ($F = 41.377$, $P < 0.001$). The difference was significant between direct digital radiography and the other two methods; subtracted images and histopathologic sections had no significant difference (Table 1).

The data resulted from three groups showed a positive and significant correlation (Table 1). Regression analysis indicated that it is possible to predict approximate values of histopathologic depth by measuring subtraction images ($r = 0.845$, $r^2 = 0.699$, $F = 54.76$).

The non-standardized amount of β for caries depths in subtracted images to predict this value in histopathologic studies was estimated to be 0.478 (with standard error of 0.065). The standardized β was calculated 0.836 ($t = 7.400$, $P < 0.001$), and the fixed coefficient was 1.404 (with standard error of 0.158) ($t = 9.632$; $P < 0.001$).

The calculated formula was as follows: Caries depth in histopathologic method = (Caries depth in subtraction method × 0.478) + 1.404.

ICC estimated the reliability of subtraction technique as 0.7. Level of confidence ranged from 0.46 to 0.87. The absolute mean value of differences between subtracted images and histopathologic studies was 0.42 ± 0.26 mm. These differences ranged from −0.8 to 1.13 mm, by having 16 positive data and 8 negative data.

The ICC confidence, for estimating researchers stability in 30 replication of 10 random samples of histopathologic sections by single measure was 0 .174 ($P < 0.001$ ranged from 0.7969 to 0.9813, for 95 % level of confidence).

Histopathological examination of the 8 excluded samples—the cases with no change after subtraction—revealed decay in 6 cases in enamel or dentin.

Discussion

Radiographic evaluation of caries depth can be a challenging clinical problem. The advent of digital techniques makes it possible to improve caries depth measurements.[12]

Because of the difficulties in radiographic diagnosis of proximal caries and depth estimation for the reasons of variations in radiographs due to exposure and geometric variations, tooth shape, and human eye tendency to smooth out the shades of gray, the National Institutes of Health has published a consensus statement on diagnosis and management of dental caries emphasizing the necessitate for advances in radiographic diagnostic methods of caries.[13] But before a new diagnostic method that is able to estimate caries depth is released for clinical application, laboratory studies should be performed on extracted human teeth.

The present results showed that the caries depth estimated by DSR with BS does not have a significant difference with histopathologic evaluations, while direct digital radiography could not perform this task as accurately, and underestimates the depth. This can be explained with the penetrative characteristics of barium with high atomic number in demireralized den-

Table 1. Differences between groups, tested by paired *t*-test

Compared groups	Average	SD	t	P	r
Direct digital and subtraction	0.5167	0.1579	16.032	< 0.001	0.979
Direct digital and histopathology	−0.7097	0.4706	7.310	< 0.001	0.8314
Subtraction and histopathology	−0.1930	0.4607	2.053	0.052	0.845

SD: Standard deviation
In all cases: P < 0.001
r: Correlation coefficient

tin which demonstrates less demineralized areas (less than 30–40%) that could not be imaged radiographically either conventionally or digitally. On the other hand, in cases with clinically intact enamel neither subtracted nor direct digital images could not reveal demineralization in enamel or dentin under the intact surface. These results are in contrast with a previous study which reported the stannous fluoride to be helpful in white spot detection.[7]

Histopathologic evaluation of ground sections of the teeth was considered as the gold standard for in vitro studies, by which the demineralized area can be assessed reproducibly.[14] It seems that regarding the expensive tools and the practical difficulties of tooth sectioning in histopathologic evaluations, DSR accompanying with barium sulfate might be considered as an alternative standard for in vitro studies. In addition, this method may increase the accuracy of in vivo studies, besides its safe clinical application, as barium sulfate has no known side effect.

It should be mentioned that previous studies have reported stannous fluoride as a contrast medium to detect the early lesion and caries depth.[7,15] Barium sulfate is applied for this purpose for the first time to avoid the known adverse effects of stannous fluoride; such as tooth staining, bad taste, gingival damages, and systemic hazards in the case of swallowing,[9] where as barium sulfate has no known adverse effects.[10,16]

Conclusion

The present study has demonstrated that DSR images in combination with barium sulfate have the potential to measure the depth of proximal caries with no significant difference with histopathologic evaluation. However, because of geometric limitations, in vivo application of digital subtraction radiography requires more developments, and clinical application of this technique accompanying with any contrast media needs further studies.

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