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Diagnostic Accuracy of Image Enhancement in Intra-Oral Direct Digital Radiography in the Assessment of Interproximal Caries

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Abstract

Background: The first commercial system for digital radiography was introduced in 1987, and it has evolved a great deal since then. Currently, it is possible to enhance images in digital radiography.
Objectives: The aim of this study is to evaluate the diagnostic accuracy of image enhancement in direct digital radiography as it relates to interproximal carries assessment.
Materials and Methods: Following extraction, 50 human teeth were kept in acidic gel (methyl cellulose + acetate buffer PH = 4.8) for 42 days at 37°C to cause caries before mounting. Direct digital radiography was then taken. Two filters were used: sharpen and emboss. Three radiologists evaluated the images with two weeks interval. The histologic assessments were gold standard. Additionally, SPSS 20 was used to draw an ROC curve and calculate AUC. Cohen's kappa and interclass correlation coefficient (ICC) were used to measure intra- and inter-observer reliability.
Results: For the emboss filter, sensitivity was 95%, specificity was 100%, and accuracy was 96%. For the sharpen filter, sensitivity was 88%, specificity was 100%, and accuracy was 90%. Also, the AUC for the emboss filter was 0.97, and it was 0.94 for the sharpen filter. Cohen's simple kappa was in the range of excellent.
Conclusions: Using these filters in intra-oral direct digital radiography (especially the emboss filter) can help some clinicians to increase diagnostic accuracy in the assessment of inter proximal caries of posterior teeth.

Keywords: Dental Caries, Digital Dental Radiography, Image Enhancement, Sensitivity, Specificity

1. Background

The first commercial system for digital radiography was introduced in 1987, and it has evolved a great deal since then. Film-based radiography is slowly being replaced by digital radiography, and many causes have led to the switch in systems. One of them is that, it is possible to enhance images in digital radiography (1). Several studies have demonstrated the benefits of this enhancement, although others have produced contradictory results or a non-effect (2-5).

Although the diagnosis of minimal mineral material loss in initial defects is often difficult in radiography because proximal areas of posterior teeth are frequently extended, this ability to augment images may represent an opportunity for improvement (6).

2. Objectives

The aim of this study is the evaluation of diagnostic accuracy of image enhancement in direct digital radiography as it relates to interproximal carries assessment.

3. Materials and Methods

In this in vitro study, a sample size of 50 teeth was considered. Selection criteria for teeth included:

1. Human posterior permanent
2. Intact interproximal surfaces

The teeth were kept in 5% hypochlorite for 24 hours after cleansing of their residual soft and hard tissues. The teeth were then covered with wax to prevent any damage to their surfaces, other than proximal. They were kept in acidic gel (methyl cellulose+acetate buffer PH = 4.8) for 42 days at 37°C to cause caries (7). Afterward, each three teeth were mounted together in acrylic. Our goal was to mount teeth together according their natural positions in the mouth.

Following this, direct digital radiography was taken. We considered a 0.5 cm distance between object and film when reconstructing intra-oral conditions. Intra-oral system was exposed with 60 kvp and 8 mA to exposer; 1cm plastic of Plexiglas was used as soft tissue. Digital images were exposed by 0.08 seconds. The images were taken by

a Kodak 5100 (France, Rochester). The images were saved and underwent filtering by Kodak dental imaging software 6.12.15.0, then were saved to JPG format for data export.

Next, these images were shown by specific program on a 15 inch monitor. The light and contrast levels of the monitor were standardized before evaluation of the images. In this single-blind trial, three oral and maxillofacial radiologists evaluated images with two weeks interval. We did not let them make any changes in contrast, magnification, or other factors. The distance between radiologist and monitor was set at 60 cm during the evaluation. All images were shown randomly to radiologists.

Two filters were used to enhance images in this study: sharpen and emboss. Figure 1 shows the right mandibular region of mounted teeth without any filters. Figures 2 and 3 depict images enhanced by emboss and sharpen filters, respectively.

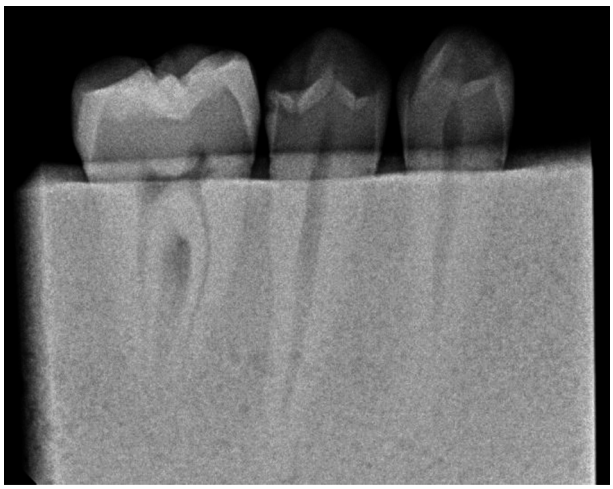

Figure 1. Basic Image from Mounted Teeth

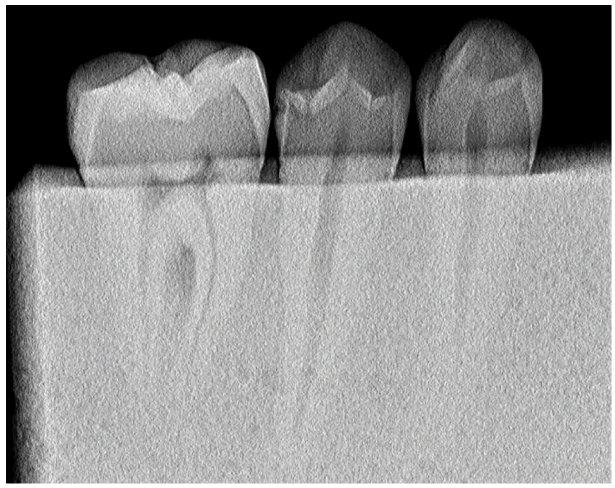

Figure 2. Image Enhanced by Emboss Filter

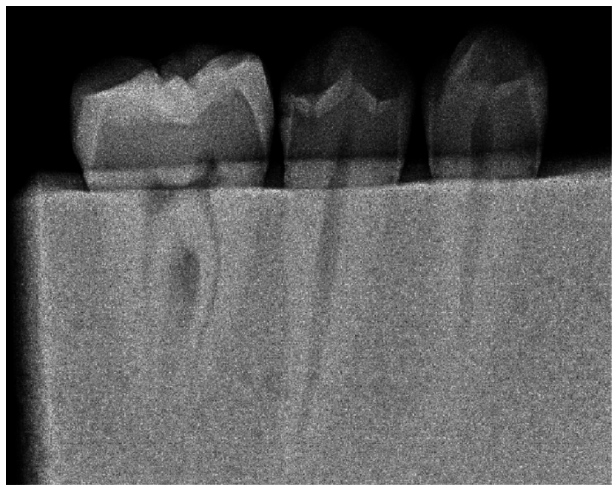

Figure 3. Image Enhanced by Sharpen Filter

The histologic assessments performed in this study were gold standard. Teeth were sectioned by Sakura Accucut SRM 200-Japan and then evaluated under a light microscope (Olympus BX41, Japan), and vertical (mesio-distal) sectioning on proximal surfaces was considered.

Following observation, the presence or absence of dental caries in proximal surfaces was recorded on a scale as follows:

0 = Absence of caries
1 = Half of external enamel
2 = Half of internal enamel
3 = DEJ
4 = Half of external dentin
5 = Half of internal dentin

A receiver operating characteristic (ROC) curve was used to compare the diagnostic accuracy of these two filters. The areas under the ROC curves and 95% confidence intervals were calculated by ROC curve analysis. Furthermore, we measured the area under curve (AUC) to compare ROC curves, and Cohen's kappa was used to evaluate the level of agreement between radiologists. Finally, the interclass correlation coefficient (ICC) allowed us to assess interobserver reliability with two weeks interval. We used SPSS 20 for Windows (SPSS Inc., Chicago, IL, USA) for all analyses.

4. Results

For the emboss filter, sensitivity was 95% (CI = 0.85 - 0.98), specificity was 100% (CI = 0.43 - 1), and accuracy was

96%. For the sharpen filter, sensitivity was 88% (CI = 0.76 - 0.95), specificity was 100% (CI = 0.56-1), and accuracy was 90%. Specificity was the same at 100% in both enhanced image groups because none of these filters showed any false positive results. However, the fact that sensitivity was higher in the emboss filter group means that the emboss filter causes fewer false negative results.

Based on the ROC curve (Figure 4) the mean AUC was 0.97 for emboss filter (CI = 0.94-1), and 0.94 (CI = 0.88 - 1) for the sharpen filter.

We can say, therefore, that accuracy is higher with the emboss filter than with the sharpen filter, but the difference is not statistically significant. The overall conclusion is that these filters increase diagnostic accuracy, but not to the extent we expected.

Table 1. Results of the Study Analysis

Diagnostic methods	Sharpen filter	Emboss filter
Sensitivity	88%	95%
Specificity	100%	100%
Accuracy	90%	96%
PPV[a]	1	1
NPV[b]	0.5	0.6

[a] PPV (positive predictive value).
[b] NPV (negative predictive value).

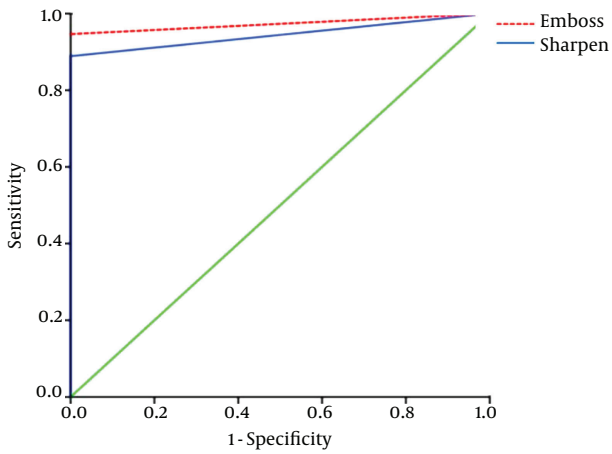

Figure 4. ROC Curves of Emboss and Sharpen Filters

Cohen's kappa is related to the number of agreements among different diagnoses. It can range from 0 (weak) to 1 (excellent). Intra- and inter- observer agreement coefficients were assessed in this study. According to recommendations by Fleiss, kappa coefficients (8) over 0.75 were regarded as excellent, 0.40 to 0.75 as fair to good, and below 0.40 as poor.

In our study, intra- and inter- observer agreement coefficients were in the range of significant increase. Additionally, ICC was used for inter-observer reliability, which showed appropriate agreement between two weeks interval for both of the reviewers.

5. Discussion

Dental radiography is an important diagnostic tool in the standard evaluation of pathologies. Today, dental radiography is a standard part of many dentists' practices because it provides diagnostic data that is not available by clinical examination. It has been said that digital radiography systems in particular have considerable diagnostic value, and increase patient comfort while decreasing patient x-ray dose, cost, and time. Based on evidence, we can say that the main advantage of digital radiography is for the patient, because it decreases the required x-ray dose without decreasing from an image's diagnostic value (9).

While decreased exposure is generally seen as a benefit of digital radiography, under some conditions the number of films taken by digital radiography results in exposure equal to that of film-based radiography. In a study, 28% of CCD films and 6% of conventional films were unacceptable and required repetition. Sommers found more technical errors in CCD. In fact, the average number of repeated images required was 10 for CCD and 3 for conventional film. Common faults in pre-apical CCD included inappropriate vertical angle and cone cut, and inappropriate horizontal angle and film positioning in conventional films. No differences were reported in type and fault numbers of these two groups, or in bite wing. It was suggested that the frequent need for repetition may cause an increase in the number of exposures, and our experience in this study affirms Sommers' conclusions (10).

Although other studies did not result in any differences between conventional film and digital radiography in caries diagnoses, our study's outcomes do not affirm these findings (2-5). These studies generally compared images without using any image enhancement filters. However, some studies were interested in the application of enhancements, such as the one performed by Moystad and Gotfredsen, who enhanced images by contrast and brightness filters, and achieved more diagnostic accuracy (11, 12). On the contrary, Tyndall and Ohki stated that contrast and brightness filters may decrease diagnostic accuracy of digital images (13).

Similarly, Wicht and Haak used the grayscale reversal filter. However, it was not helpful in increasing diagnos-

tic accuracy of inter proximal caries, despite improvement in the placement of fine endodontic files and bone healing (14).

With these findings in mind, we selected the emboss and sharpen filters, as there were so few studies focused on them.

In an in vitro study by Wenzel and Gotfredsen, false positive reports were fewer by men, and persons unfamiliar with digital radiography reported six times more false positives. The important takeaway from this study was that digitally enhanced images have no effect on false positive reports (15).

Abesi et al. reported in 2012 that the diagnostic accuracy of digital images is similar to that of conventional film radiography in the detection of non-cavitated proximal caries (16). Therefore, any digital enhancement filter that improves proximal caries detection can be beneficial for increasing diagnostic accuracy.

Similarly, in an in vitro study by Furtado Belem et al., filters were used to enhance images of proximal caries. Negative, sharpen and both were applied to enhance images. The authors reported that the sharpen filter demonstrated the highest performance indices, and so it may be considered a useful adjunct for detecting subtle proximal caries lesions (17). Given this, we used the sharpen filter to compare with emboss; the other studies are about other filter enhancements.

In another study, Takeshita et al. used filtered images (Perio, Negative, Colors 1, and Colors 2) to evaluate diagnostic accuracy. The negative filter showed weak outcomes (18). We concluded from this that using many filters that enhance digital images may be confusing. It should also be noted that using improper filters can cause diagnostic problems. We used two modalities of the filters included in our study. Digital radiographic enhancement is a new field and requires more studies in order to evaluate the usefulness of different filters as they relate to various disease conditions.

In conclusion, using these filters in intra-oral direct digital radiography (especially the emboss filter) can help some clinicians to increase diagnostic accuracy in the assessment of inter proximal caries of posterior teeth.

Acknowledgments

Tabriz dental faculty.

Footnotes

Authors' Contribution: Farzad Esmaeili: conductor; Teymour Abbasi: data sorting; Nazli Rabienejad: manuscript writing, performing study; Shabnam Seyedzadeh Sabounchi: analysis.

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References

1. Parks ET. Digital radiographic imaging: is the dental practice ready?. *J Am Dent Assoc.* 2008;**139**(4):477–81. [PubMed: 18385032].
2. Wenzel A. Digital radiography and caries diagnosis. *Dentomaxillofac Radiol.* 1998;**27**(1):3–11. doi: 10.1038/sj.dmfr.4600321. [PubMed: 9482015].
3. Lobo M, Pecharki GD, Gushi LL. Occlusal caries diagnosis and treatment. *Brazil J Oral Science.* 2003;**2**:239–44.
4. Wenzel A. Current trends in radiographic caries imaging. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 1995;**80**(5):527–39. [PubMed: 8556463].
5. Tyndall DA, Ludlow JB, Platin E, Nair M. A comparison of Kodak Ektaspeed Plus film and the Siemens Sidexis digital imaging system for caries detection using receiver operating characteristic analysis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 1998;**85**(1):113–8. [PubMed: 9474625].
6. White SC, Pharoah M. J. . Oral radiology: Principles and interpretation. 6 ed. Elsevier; 2009.
7. 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. [PubMed: 10867420].
8. Fleiss JL. Statistical methods for rates and proportions. 2 ed. New York: John Wiley; 1981.
9. Syriopoulos K, Sanderink GC, Velders XL, van der Stelt PF. Radiographic detection of approximal caries: a comparison of dental films and digital imaging systems. *Dentomaxillofac Radiol.* 2000;**29**(5):312–8. doi: 10.1038/sj/dmfr/4600553. [PubMed: 10980568].
10. Sommers TM, Mauriello SM, Ludlow JB, Platin E, Tyndall DA. Preclinical performance comparing intraoral film and CCD-based systems. *J Dent Hyg.* 2002;**76**(1):26–33. [PubMed: 11935928].
11. Moystad A, Svanaes DB, Risnes S, Larheim TA, Grondahl HG. Detection of approximal caries with a storage phosphor system. A comparison of enhanced digital images with dental X-ray film. *Dentomaxillofac Radiol.* 1996;**25**(4):202–6. doi: 10.1259/dmfr.25.4.9084274. [PubMed: 9084274].
12. Gotfredsen E, Wenzel A, Grondahl HG. Observers' use of image enhancement in assessing caries in radiographs taken by four intraoral digital systems. *Dentomaxillofac Radiol.* 1996;**25**(1):34–8. doi: 10.1259/dmfr.25.1.9084283. [PubMed: 9084283].
13. Ohki M, Okano T, Nakamura T. Factors determining the diagnostic accuracy of digitized conventional intraoral radiographs. *Dentomaxillofac Radiol.* 1994;**23**(2):77–82. doi: 10.1259/dmfr.23.2.7835507. [PubMed: 7835507].
14. Haak R, Wicht MJ. Grey-scale reversed radiographic display in the detection of approximal caries. *J Dent.* 2005;**33**(1):65–71. doi: 10.1016/j.jdent.2004.08.003. [PubMed: 15652170].
15. Wenzel A, Haiter-Neto F, Gotfredsen E. Risk factors for a false positive test outcome in diagnosis of caries in approximal surfaces: impact of radiographic modality and observer characteristics. *Caries Res.* 2007;**41**(3):170–6. doi: 10.1159/000099314. [PubMed: 17426395].
16. Abesi F, Mirshekar A, Moudi E, Seyedmajidi M, Haghanifar S, Haghighat N, et al. Diagnostic accuracy of digital and conventional radiography in the detection of non-cavitated approximal dental caries. *Iran J Radiol.* 2012;**9**(1):17–21. doi: 10.5812/iranjradiol.6747. [PubMed: 23329955].
17. Belem MD, Ambrosano GM, Tabchoury CP, Ferreira-Santos RI, Haiter-Neto F. Performance of digital radiography with enhancement filters for the diagnosis of proximal caries. *Braz Oral Res.* 2013;**27**(3):245–51. doi: 10.1590/S1806-83242013000300004. [PubMed: 23739784].

18. Takeshita WM, Vessoni Iwaki LC, Da Silva MC, Filho LI, Queiroz Ade F, Geron LB. Comparison of the diagnostic accuracy of direct digital radiography system, filtered images, and subtraction radiography. *Contemp Clin Dent.* 2013;**4**(3):338–42. doi: 10.4103/0976-237X.118391. [PubMed: 24124300].