Diagnostic accuracy of proximal caries by digital radiographs: an in vivo and in vitro comparative study

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Objectives. The aim of this study was to evaluate if the diagnostic accuracy of proximal dental caries in digital radiographs was similar when obtained in in vivo and in vitro conditions.
Study design. Thirty-nine noncavitated teeth were collected from 11 subjects who had part of upper or lower jaws excised owing to cyst or neoplasm. Before operation, radiographs of the teeth involved were taken with the digital imaging system Digora Optime (Soredex, Helsinki, Finland), and after operation, the same extracted teeth were mounted in plaster blocks and exposed with the same digital imaging system. The teeth were subsequently sectioned for histologic validation of the lesions. Six observers evaluated all of the radiographs according to a 5-category scale. Receiver operating characteristic analysis was performed. Repeated-measure analysis of variance was used for the statistical analysis.
Results. There were no significant differences between digital radiographs taken in in vivo and in vitro conditions for diagnosis of proximal dental caries ($P = .286$).
Conclusion. Detection accuracy of proximal dental caries obtained from an in vitro study can be considered to be representative of diagnostic accuracy of proximal dental caries obtained in the real clinical situation. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;109:463-467)**

Intraoral radiography is one of the most commonly used methods for dental caries diagnosis, especially for proximal dental caries that is hard to visually inspect. With digital intraoral radiography introduced to dentistry, many studies have been performed to validate the reliability and reproducibility of digital intraoral radiographs for caries diagnosis.[1-11] To get a golden reference standard, all of the studies were based on extracted human teeth with only a few exceptions, in which artificial lesions or artificial teeth were used.[12,13]

Evidence-based diagnosis and evidence-based treatment planning decisions require a diagnostic method as accurate as possible to reveal a lesion status. In vitro studies demonstrate that the digital intraoral radiograph has the same diagnostic value as the film intraoral radiograph for proximal caries diagnosis.[1-6] Whether the results obtained from an in vitro condition are a real representation of those obtained in vivo has not been evaluated.

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The aims of the present study were: 1) to evaluate the diagnostic accuracy of in vivo proximal dental caries in digital radiographs; and 2) to compare the diagnostic accuracy of proximal dental caries in digital radiographs obtained in in vitro and in vivo conditions.

MATERIAL AND METHODS

The study conducted at the Peking University Hospital of Stomatology involved 11 subjects who had tumors or cysts of the jaws needing resection. The average age of the subjects was 39.7 years. The subjects comprised 5 men and 6 women. The study plan was approved by the ethical committee of Peking University Health Science Center, document no. ICRB 00001052-08051. Patients gave their written consents to participate in the study.

Teeth

Thirty-nine human permanent teeth (4 canines, 16 premolars, and 19 molars) were collected during the operations. None of the teeth were cavitated. The teeth from each subject were mounted in plaster blocks according to their anatomic position. The most prominent parts of the proximal surfaces were put at the same vertical level to simulate their normal anatomical contacts. Thus, a total of 11 plaster blocks of teeth were constructed.

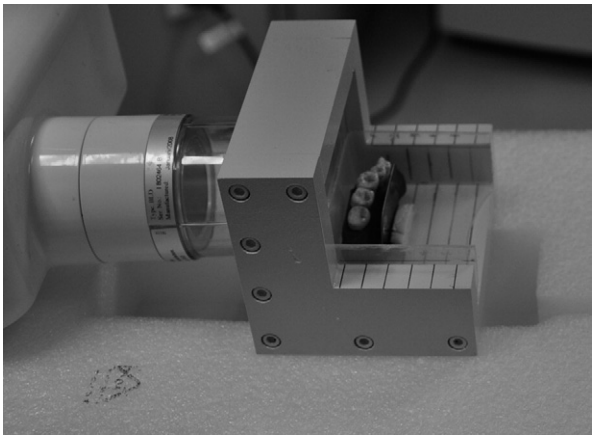

Fig. 1. Photo of a specially designed holder that enables standard projection geometry.

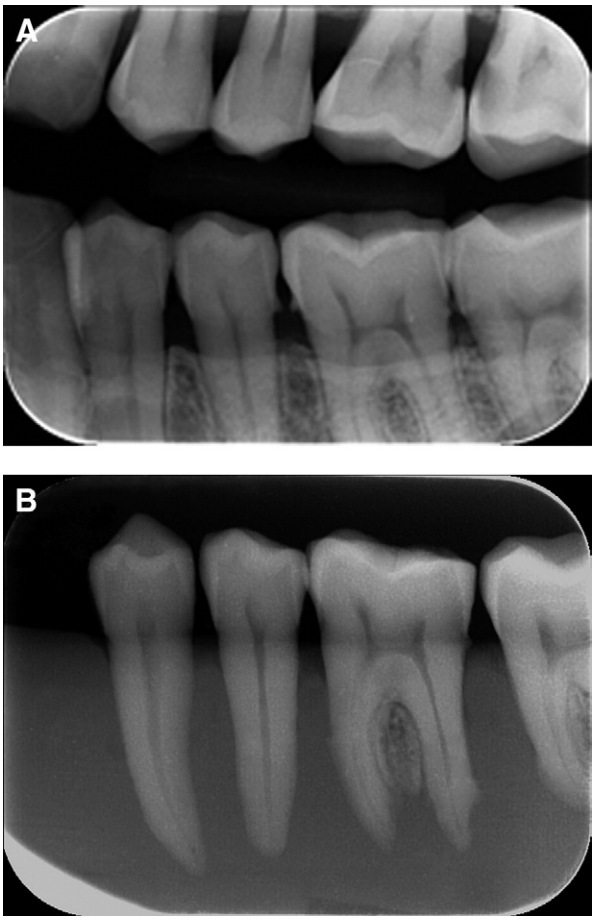

Fig. 2. **A,** Sample preoperation image of a patient. **B,** Sample postoperation image of the same patient. Teeth were mounted in a plaster block.

Test radiographs

Test radiographs were made in the Department of Oral and Maxillofacial Radiology, Peking University School and Hospital of Stomatology. The X-ray unit used was MinRay (Soredex, Tuusula, Finland) with a spot size of 0.7 mm, 2 mm Al filtration, and constant nominal tube potential selectable at either 60 kVcp or 70 kVcp. Before surgical removal of the teeth, the in vivo test radiographs were made with the digital intraoral radiographic system Digora Optime (Soredex) at exposure settings of 60 kVcp, 7 mA, and 0.25 s for premolars and 0.32 s for molars. Proprietary storage phosphor plates (SPP) were used to record the image.

To mimic the real exposure conditions, the test radiographs of tooth bolcks were taken with the same digital intraoral radiograpic system Digora Optime and the proprietary SPP at the same exposure settings, i.e., 60 kVcp, 7 mA, and 0.25 s for premolars and 0.32 s for molars. A 2.0-cm-thick acrylic phantom was put in front of the tooth blocks to simulate soft tissues. For reproducibility, the blocks were placed in a specially designed holder that enabled standard projection geometry (Fig. 1).

The SPPs were immediately scanned after exposure with the proprietary software DfW v. 2.5. The selected scanning resolution was 400 dpi, which was called "high" resolution in the software. The raw data images were subsequently processed with the proprietary default processing algorithm and saved as 8-bit images.

Viewing

Six observers who had experience of caries diagnosis were employed in the present study. Each observer evaluated both series of radiographs independently with respect to proximal carious lesions. The radiographs were displayed on a flat-panel TFT color PC monitor. The screen resolution was 1,280 $\times$ 960 and display ratio 1:1. Before viewing, brightness and contrast of the monitor was calibrated by one of the investigators using the SMPTE test pattern that is included in the DentalEye software (DentalEye, Stockholm, Sweden). Additional adjustment of brightness and contrast of the displayed image by the observer was not allowed. To display the radiographs serially, the ACDSee v. 3.0 (ACD Systems International, British Columbia, Canada) software package was used. The order in which the radiographs were presented was individually randomized for each observer. Examples of the radiographs taken from the patient and the tooth block are shown in Fig. 2.

Viewing took place in a room with dimmed light. The observers had no prior information about the number of carious lesions. For intraobserver variance analysis, 1 observer reassessed 1 series of radiographs 2 weeks later.

Table I. Histologic analysis of tooth surfaces

	n	%
Sound	37	47%
Caries in outer enamel	24	31%
Caries in inner enamel	7	9%
Dentin caries	10	13%
Total	78	100%

Using the following scale, the observers were instructed to rate their level of confidence about the presence or absence of carious lesions on the proximal surfaces of the teeth:

1 = definitely no caries.

2 = probably no caries.

3 = questionable.

4 = probably caries.

5 = definitely caries.

Histologic validation

When all radiographs had been made, the teeth were cut into 700-μm-thick slices and examined with an ×10 magnifying stereomicroscope by 2 investigators. The lesions were defined by the extension of a whitish decalcified zone or a brown zone extending in the direction of the proximal pulp chamber. The following 4-point scale was used for histologic categorization: 0 = sound; 1 = caries in the outer half of the enamel; 2 = caries in the inner half of the enamel and reaching but not crossing the enamel-dentin junction; 3 = caries into dentin.

ROC analysis

With the histologic examination as reference standard, each observer performance was subsequently converted into a receiver operating characteristic (ROC) curve with the program Rockit 0.9B (beta version; University of Chicago, Chicago, IL). The maximum likelihood parameters were determined and the area under each ROC curve (A_z) calculated.

Statistical analysis

Repeated-measure analysis of variance was used to analyze A_z values from each observer and inter- and intraobserver variances, with $\alpha = 0.05$.

RESULTS

Histologic examination revealed that of the 78 proximal surfaces, 37 were sound, 24 showed caries in the outer half of the enamel and 7 in the inner half of enamel, and 10 had dentin caries (Table I).

Figure 3 shows the ROC curves from the combined observer performances. The ROC curve is higher for the digital radiographs obtained under the in vivo than under the in vitro conditions.

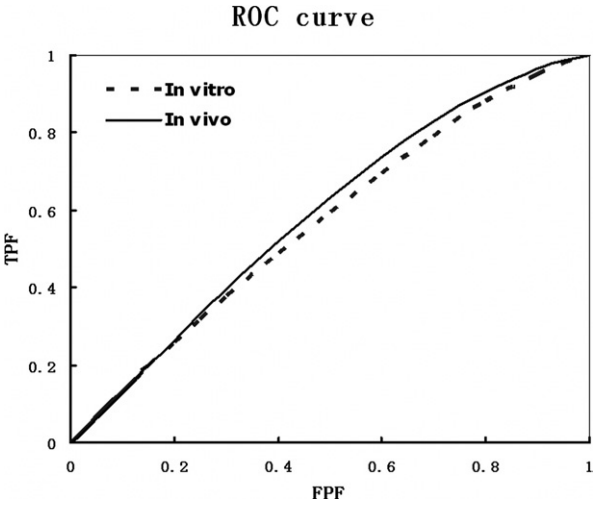

Fig. 3. Receiver operating characteristic (ROC) curve obtained from combined observer performance. *FPF,* False positive fraction; *TPF,* true positive fraction.

Table II. Areas under the receiver operating characteristic curves (A_z values) from each observer

Observer	*In vivo*	*In vitro*
1	0.57	0.61
2	0.58	0.58
3	0.62	0.48
4	0.69	0.68
5	0.59	0.53
6	0.53	0.51
Mean	0.60	0.57
SD	0.05	0.07

Table II shows the area under the ROC curve from each observer. Generally, the A_z values for radiographs taken in patients is larger than those made for the extracted teeth with 1 exception (observer 1). The mean A_z values for the radiographs made on subjects was 0.60, and the A_z values for the radiographs made on the extracted teeth was 0.57. No significant difference was found between the observer performances ($P = .286$). The standard deviations of the A_z values were 0.05 and 0.07 for the radiographs made in vivo and in vitro conditions, respectively.

Inter- and intraobserver variance analysis revealed that there was no significant difference between observers ($P = .63$) and within observer ($P = .33$) for diagnosis of proximal dental caries.

DISCUSSION

With the introduction of digital intraoral radiography to dentistry, many studies have been performed to

validate the reproducibility and reliability of digital intraoral radiography for dental caries diagnosis, especially for proximal dental caries.[1-11] Although the results demonstrate that digital intraoral radiography has a detection accuracy similar to film intraoral radiography regarding dental carious lesions,[1-6] the studies have been largely performed in the laboratory, i.e., in an in vitro condition. Therefore, the question arose of whether the results obtained under such in vitro conditions are a real representation of those obtained from radiographs made in vivo in actual patients.

One in vivo study demonstrated that the caries depth on SPP images was underestimated compared with film-based images.[14] However, the reference standard used in that study was a consensus of a panel of 4 experts using bitewing film images. Wenzel and Hintze[15] indicated in their review that a gold standard should be reproducible, independent of the diagnostic method under evaluation, and reflect the pathoanatomic appearance of the disease. A reference standard obtained from a consensus of a panel of experts by reading bitewings might not fully disclose the real status of the lesions given no histologic proof.

A comparative study of clinical and laboratory radiographic dental caries diagnosis was performed by Hintze and Wenzel.[16] In that study, 130 teeth (122 of which were third molars) were imaged before and after extraction. The results revealed that the diagnostic accuracy of film-based radiograph was as accurate under clinical conditions as when standardized in the laboratory. The caries diagnostic accuracy of digital radiography was not evaluated.

In the present study, the bitewing technique was used when the radiographs were taken from the patients, and the parallel technique was used for the laboratory radiographs. The +8- to +10-degree angulations for projecting bitewing radiographs may have an effect on the appearance of the proximal dental caries. However, earlier studies have revealed that a few degrees of horizontal and vertical angulations has no impact on quantitative evaluations of periodontal disease and root canal length,[17-19] nor therefore to dental caries diagnosis.

The present study showed that the diagnostic accuracy for proximal dental caries as defined by A_z values was not significantly different between the radiographs of the same teeth made clinically in the subjects and in the laboratory in vitro after removal.

Considering the above findings, the conclusion may be made that regarding proximal dental caries diagnosis, detection accuracy obtained from an in vitro study can be considered to be representative of diagnostic accuracy obtained in the real clinical condition.

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