DIAGNOSTIC QUALITY OF CONVENTIONAL AND DIGITAL RADIOGRAPHIC IMAGES OF DENTAL CARIES

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■ ABSTRACT: The aim of this study was to investigate intra and interobserver reproducibility and the validity in occlusal and approximal caries diagnoses using conventional and digital images. Radiographs of sixteen extracted human premolars and molars teeth were taken with conventional films (Kodak Ektaspeed Plus) and storage phosphor plate system (Digora). Two observers read the conventional and digital images by using digital processing modalities such as enlargement, inversion and third dimension effect. The carious lesions was scored by a scale of five points. Histologic sections were the validating criteria. The intra and interobserver reproducibility of radiographic images were determined by Kappa statistics. The validity was verified using sensibility and specificity. The intraobserver reproducibility for the conventional radiography was good for approximal and occlusal surfaces, and the interobserver reproducibility was fair for the approximal surfaces, and good for the occlusal surfaces. The intra and interobserver reproducibility for digital radiography was different for both observers, according to dental surface and digital processing modalities, showing a range between fair and optimum

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results. Considering the validity, there were no significant differences between conventional and digital images for the occlusal and approximal surfaces. Given the different levels of reproducibility offered by the digital images modalities, an individual modality is not recommended.

■ KEYWORDS: Dental radiography; dental caries; digital image.

Introduction

The validity of the radiographic examination increases substantially using digital processing of the radiographic image.[13, 24] Subjectively, most of the observers prefer the digital processing of the radiographic image, and this processing seems to be dependent on the diagnostic procedure. Image treatment must be used in digital radiographies.[23]

Radiographic interpretation has many subjective characteristics and it depends very much on the observer. According to Gröndahl,[6] the decrease of caries prevalence, diagnostic methods with greater specificity are needed, and when considering the radiography, it is necessary to remember that the observer is an integral part of the method. Many authors have shown the variability among the observers' caries diagnoses.[1, 15, 17, 20] Even so, these authors do not evaluate the intra and interobserver reproducibility in the caries diagnosis. To evaluate the quality of the radiographic interpretation using different observers, the intra and interobserver reproducibility is a determining factor for the quality of the diagnostic method.[2]

The disagreement between diagnoses leads to the need of knowing the identity of the interpretations done. Therefore, it is necessary to verify the reproducibility of the approximal and occlusal caries diagnosis according to the conventional and direct digital image, testing some of the digital image processing modalities by the Digora System.

When verifying the diagnostic quality of a method, reproducibility and validity are determinants. Reproducibility determines the intra and interobserver reproducibility, that is, if the same observer is able to make identical diagnoses on different occasions or if different observers can make the same diagnosis. The validity of the method is expressed by the sensitivity, which is the ability to determine the presence of disease, and by the specificity, which is the ability to determine the absence of disease, both proved by a method that determines the true status of the disease. The positive and negative predictive values must also be

considered, since they are affected by disease prevalence in the population being tested and are particularly important if the disease is rare. Although the aspects of reproducibility and validity are independent, a method that presents low reproducibility presents low diagnostic quality, which may compromise its validity.

The aim of this study was to investigate intra and interobserver reproducibility and the validity in occlusal and approximal caries diagnoses using conventional and digital radiography.

Material and method

For this in vitro study, sixteen extracted human premolars and molars were used. The teeth were set in approximal contact, simulating a mouth with the posterior arches. The approximal and occlusal surfaces of the teeth had a spectrum of caries ranging from sound to varying degrees of discoloration to cavitation.

The teeth were radiographed by conventional radiography using Ektaspeed Plus (Eastman Kodak, Rochester, N.Y.) and Digora storage phosphor plates (Soredex/Orion Corp., Helsinki, Finland). A 15 mm acrylic plate was placed adjacent to the teeth to produce a soft-tissue equivalente scattering. The X-ray unit was the "General Electric 100", operating at 70 kVp. The cone was circular with a diameter of 7.5 cm. The target-film distance was 40 cm, 4mAs for the conventional film and 3mAs for the digital phosphor plate. The films were processed by Peri-Pro II 91000 (Air Techniques Inc., U.S.A.).

The image was scanned immediately after the radiographic exposure, resulting in an image with a 416 x 560 pixels size matrix. The digital images were stored in a "TIF" format, occupying a memory of 234 kB each.

The digital and conventional radiographs were read twice, in a 15 day interval, by two observers, A and B. The observers, both radiologists, were calibrated for caries classification using scores of 5 points (0-sound; 1-enamel caries less than ½ way through enamel; 2-enamel caries penetrating at least ½ way through enamel; 3-caries of enamel and dentine penetrating less than ½ way to pulp cavity; 4-caries of enamel and dentine penetrating more than ½ way dentine toward pulp cavity).

The radiographies were read in a reduced illumination room, under the light of a view box. The scores were written in files by two observers, independently, according to the surface of the teeth examined.

The digital images were read on a Pentium 166 mHz computer with a 14" SVGA Philips monitor, with small fonts and 1024 x 768 pixels resolution. The computer was in a reduced illumination room, without any kind of light or shine on the monitor. The observers were within a distance of 50 and 70 cm from the monitor. The Digora System for Windows 3.11 was used for the processing and interpretation of the images. The images were analyzed the normal way with enlargements of 1X, 2X and 3X, in the 3D mode (third dimension effect) with enlargements of 1X (3D) and 2X (3DX), and the inverted mode with enlargements of 1X-, 2X- and 3X-.

The images were shown on the monitor at random, and the observers had the freedom to adjust brightness, contrast and edge enhacement filter. After the adjustment, according to observer's preference, they gave the score for each dental surface examined. Both observers made a total of 1,728 decisions.

After assessment, the teeth were serially sectionated in planes oriented mesiodistally and parallel to the long axis of the crown, resulting in 6-10 sections from each tooth, with a thickness of 800 μm. Each slice was mannually worn down and smoothed reaching 120-150 μm, using a sandpaper under water. The sections were washed in water and dried in air and then, were mounted and fixed onto an object slide and examined using a stereomicroscope (x10 magnification) by one independent examiner. One approximal surface was damage during sectioning and, therefore, excluded from the material which thereafter consisted of a total of 47 surfaces.

The microscopic analysis served as the validation for the presence of caries lesion. In order to estimate the validity, the diagnose of caries disease was classified in a dichotomous scale: negative (score 0) or positive (score 1 to 5).

Kappa (k) statistics was used, according to Light,[11] to obtain the intra and interobserver reproducibility values for the caries diagnosis by the conventional and digital radiographic methods. The value found for this reproducibility was classified, according to the reproducibility level, by the Landis & Koch[9] scale. In addition, a test of hypothesis for reproducibility was performed in order to evaluate the significance of k value, supposing that the k variable has an approximately normal distribution. The significant level adopted was 5% for the decision taken.

Considering microscopic examination as the "gold standard", sensitivity and specificity were calculated.

Result

The intra and interobserver reproducibility results are shown in Figures 1-6. Both observers obtained similar results in intraobserver reproducibility for the approximal surfaces in the conventional radiography (Figures 1 and 2). On the occlusal surfaces (Figures 3 and 4), the values of reproducibility in the conventional radiography were distinct, ranging from good (observer B) to optimum (observer A).

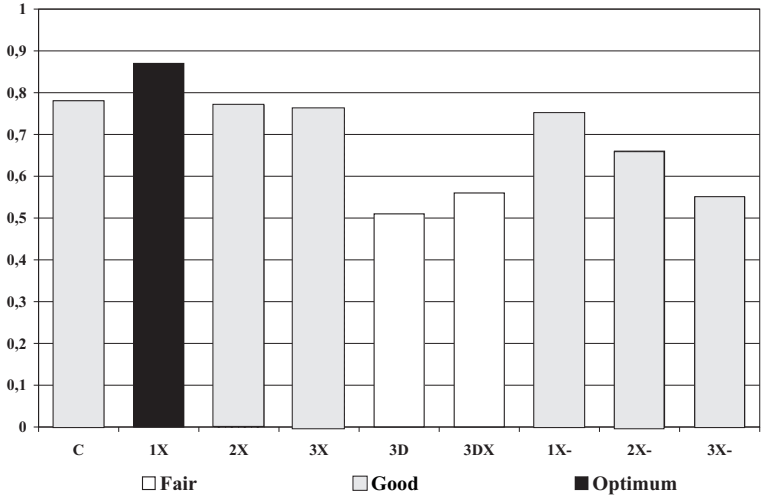

FIGURE 1 – Kappa values for intraobserver reproducibility (observer A) in the conventional radiography (C) of approximal surfaces and for the different digital radiography modalities.

In the digital radiography, the values of intraobserver reproducibility were distinct between the two observers, showing levels of reproducibility that varied between fair and optimum, depending on the dental surface and the digital image processing (Figures 1-4).

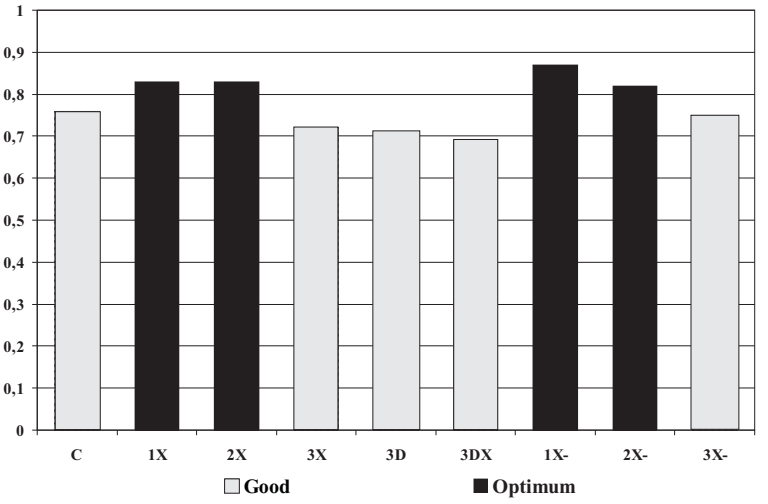

FIGURE 2 – Kappa values for intraobserver reproducibility (observer B) in the conventional radiography (C) of approximal surfaces and for the different digital radiography modalities.

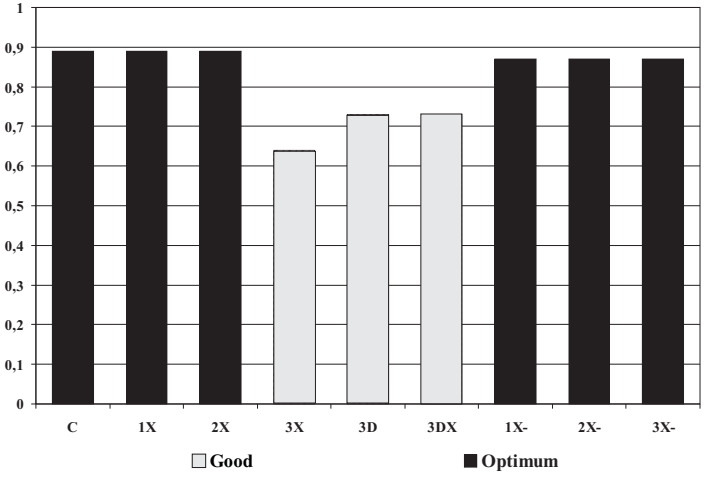

FIGURE 3 – Kappa values for intraobserver reproducibility (observer A) in the conventional radiography (C) of occlusal surfaces and for the different digital radiography modalities.

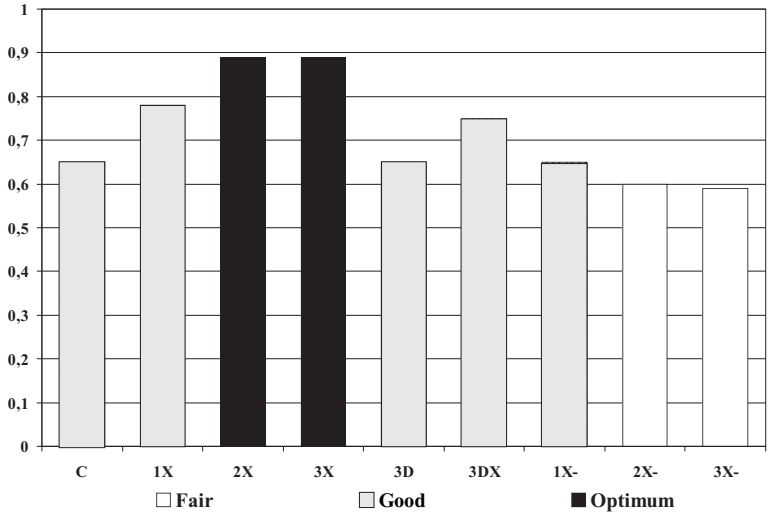

FIGURE 4 – Kappa values for intraobserver reproducibility (observer B) in the conventional radiography (C) of occlusal surfaces and for the different digital radiography modalities.

The conventional radiography presented interobserver reproducibility values on the approximal surfaces of 0.60 and on the occlusal surfaces of 0.63 (Figures 5 and 6). Although, according to the Landis & Koch[9] scale, the approximal surfaces have had fair reproducibility, the value of 0.60 is very close to 0.61, which is characteristic of good reproducibility.

The interobserver reproducibility values varied according to the dental surface and the digital radiography process. The interobserver reproducibility in the digital radiography varied from fair (0.51) to good (0.77) on the approximal surfaces (Figure 5), and from good (0.76) to optimum (0.89) on the occlusal surfaces (Figure 6). The interobserver reproducibility results show that some digital images may present a good quality diagnosis for approximal and occlusal caries regarding the reproducibility.

The true status of the approximal surfaces according to microscopic examination was: 1 sound surface, 20 surfaces with enamel caries and 10 surfaces with dentin caries. The true status of occlusal surfaces was: 7 sound surfaces and 9 dentin caries.

As there was no statistically significant difference between the observers in their assignments, the first classification from observer A was used to prove the radiographic diagnosis before the microscopic

examination. The sensitivity and specificity values for the approximal and occlusal surfaces are shown in Tables 1 and 2, respectively.

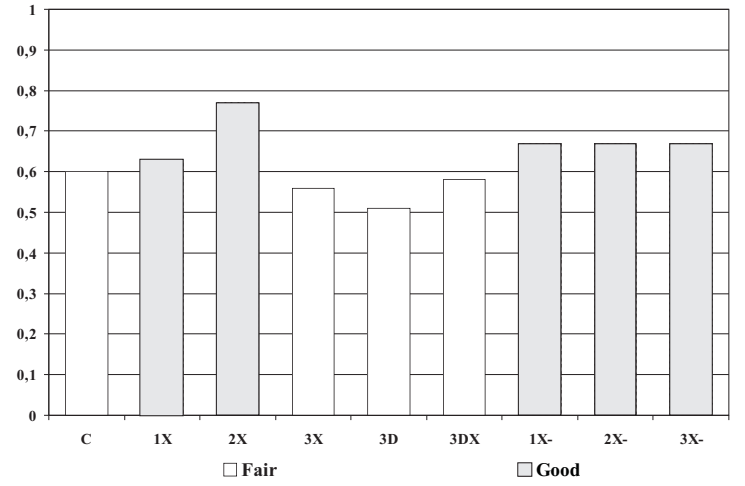

FIGURE 5 – Kappa values for interobserver reproducibility in the conventional radiography (C) of approximal surfaces and for the different digital radiography modalities.

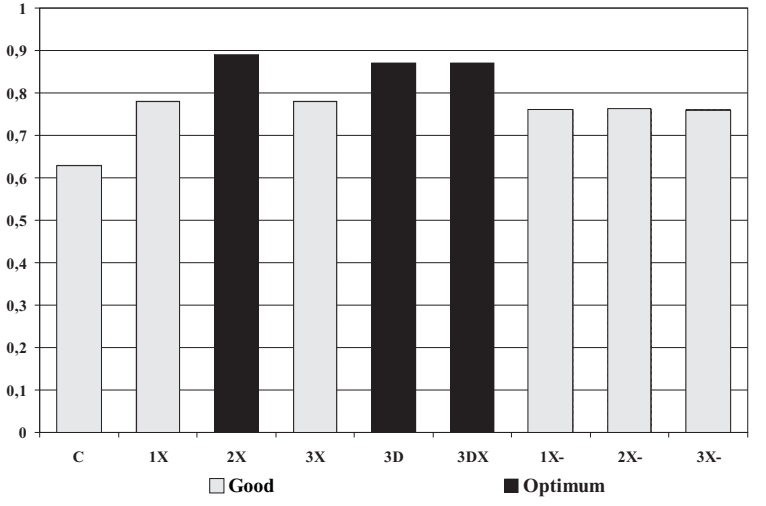

FIGURE 6 – Kappa values for interobserver reproducibility in the conventional radiography (C) of occlusal surfaces and for the different digital radiography modalities.

On the approximal surfaces (Table 1), the sensitivity values were moderate to low. For the conventional image and for the digital images in the 2X and 3X mode, the value was 0.50. The others digital images (1X, 3D, 3DX, 1X-, 2X- and 3X-) values ranged between 0.35 and 0.58.

Table 1 – Sensitivity (S) and specificity (Sp) values for the approximal surfaces according to image modality: conventional (C), normal digital (1X, 2X and 3X), digital in third dimension (3D and 3DX) and inverted digital (1X-, 2X- and 3X-)

	C	1X	2X	3X	3D	3DX	1X-	2X-	3X-
S	0.50	0.38	0.50	0.50	0.42	0.38	0.46	0.54	0.58
Sp	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

On the occlusal surfaces (Table 2), the validity results were more homogeneous: the sensitivity was 0.50 for the conventional and digital images in the 1X, 2X and 3X mode, and 0.42 in the 3D, 3DX, 1X-, 2X- and 3X- images.

Table 2 – Sensitivity (S) and specificity (Sp) values for the occlusal surfaces according to image modality: conventional (C), normal digital (1X, 2X and 3X), digital in third dimension (3D and 3DX) and inverted digital (1X-, 2X- and 3X-)

	C	1X	2X	3X	3D	3DX	1X-	2X-	3X-
S	0.50	0.50	0.50	0.50	0.42	0.42	0.42	0.42	0.42
Sp	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

All the specificity values, for approximal and occlusal surfaces, were 1.00 (Tables 1 and 2).

Discussion

The distinct intraobserver reproducibility results prove the subjectivity of the examination[7] and show that the digital processing images

must be used by the observers on each dental surface, in the radiographic examination of the caries. When the observers used these digital processing modalities, the reproducibility values were similar, higher or lower than conventional radiography.

The interobserver reproducibility values varied according to the dental surface and the digital radiography process. The interobserver reproducibility in the digital radiography varied from fair (0.51) to good (0.77) on the approximal surfaces, and from good (0.76) to optimum (0.89) on the occlusal surfaces. The interobserver reproducibility results show that some digital images may present a good quality diagnosis for approximal and occlusal caries regarding the reproducibility.

The literature mentions the variability of the observers in the radiographic interpretation of the dental caries.[7, 12, 20] However, the degree of intra and interobserver reproducibility, determined by Kappa (k) statistics,[11] is not shown in the radiographic diagnosis of the dental caries.

According to Firestone et al.,[4] the reproducibility between the dentists in the radiographic examination of caries is extremely variable. The present study showed variations in the intra and interobserver reproducibility values for the diagnosis of caries similar to those found in the literature.[3, 4, 5, 8, 10, 13] It should, however, be noted that these studies were not using the whole sample.

The variability in the radiographic interpretation may be the result of: diagnostic task,[7] clinical trends, perception, education, training and experience of the observers.[15] According to Firestone et al.[4] and Lazarchik et al.,[10] the interobserver reproducibility level increases depending on the level of experience and education of the observer, which supports the conclusions made by Dunn & Kantor,[3] who described radiographic interpretation as an activity of high cognitive level based on the knowledge and experience of the observer. In the present study, the two observers interpreted the same images under the same conditions, both have the same specialty and experience and, besides this, were trained and calibrated to use the same scores, only psychophysics,[3] which studies the functional relations between the mind and physical phenomena, could explain this variation.

According to Straub et al.,[18] the radiographic interpretation is composed by a number of physical and psychological phenomena. The perception of image quality by observers and their skills in correctly diagnosing do not depend exclusively on the image quality. Dunn & Kantor[3] reported, as examples of psychophysical tests in oral radiology, the evaluation of view box and ambient light influence in radiographic inter-

pretation, measuring eye movement of observers when looking for essential diagnostic information in the radiographic image, and mapping of neural pathways in the visual cortex during the observation of the image. While conventional radiography presents a static image, once developed, the digital radiographic image is dynamic and may be processed by the observer during the interpretation.[5, 23]

Some studies showed improvement in the diagnosis of caries with the digital processing of the image.[13, 19, 22, 24] However, Wenzel[21] reported that few studies have been published about the clinical application of the digital systems and until now, in vitro studies have not shown significant differences in the performance between the digital systems, including Digora, and conventional films, which is in reproducibility with the validity results of this study.

In the present study, there were no statistically significant differences between the conventional and digital images regarding the validity aspect. The sample size and the high prevalence of caries in the teeth, mainly incipient caries in enamel, were factors that contributed to the validity results of this study. This is in reproducibility with Mileman & Van der Weele,[12] who considered the selection and prevalence of diseases to be important in a battery of diagnostic tests.

Moystad et al.,[13] Svanaes et al.[19] and Scaf et al.,[16] observed greater diagnostic validity in the enlarged images, although there is a limit beyond the diagnostic validity may be reduced. Enlargement increases the apparent size of the image, but the information content of this image is limited to the original resolution when captured.[3] Regarding the validity aspect, our results didn't show differences between image enlargements on the approximal and occlusal surfaces, with exception of inverted images taken on the approximal surfaces, where image enlargement resulted in increased sensitivity.

Related to the interobserver reproducibility, the image enlargement, both on the approximal and occlusal surfaces, resulted in increased reproducibility up to 2X enlargement, decreasing reproducibility value at 3X enlargement. In the inverted images, there was no difference in reproducibility in relation to their enlargements.

An interesting result was found in the 3D and 3DX images of the occlusal surfaces. These images presented a high level of reproducibility, yet they did not show the best sensitivity results. This may be explained by the high specificity of these images,[14] bearing in mind that the validity and reproducibility aspects are independent, although a high level of diagnostic reproducibility does not necessarily imply a correct diagnosis.

The radiographic image of the caries consists of a procedure that may lead to difficulty in interpretation, depending on inherent factors of the image itself, or the subjectivity of the classification. Digital radiography may offer an improvement in the image quality. The increase in the types of images obtained by the digital processing modalities introduce one more factor to be considered. The best result would be obtained if it were possible to standardize caries classification in any of the digital images modalities that, together with the other clinical data, would offer elements for a conduct to be adopted.

Conclusion

Given the different levels of reproducibility offered by the digital images modalities, an individual modality is not recommended. Related to validity, there were no differences between conventional and digital images.

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TOSONI, G. M. et al. Qualidade diagnóstica das imagens radiográficas convencional e digitais da cárie dentária. Rev. Odontol. UNESP (São Paulo), v.30, n.2, p.277-290, 2001.

■ RESUMO: O objetivo deste trabalho foi verificar a reprodutibilidade intra e interexaminador e a validade das radiografias convencional e digital no diagnóstico de cáries proximais e oclusais. Dezesseis dentes foram montados em um modelo e radiografados utilizando-se filmes Kodak Ektaplus e a placa de imagem do Sistema Digora. Dois observadores radiologistas interpretaram as imagens convencionais e as digitais com os recursos de ampliação, inversão e terceira dimensão. As superfícies dentárias foram classificadas com escores de 0 a 5, determinando-se a presença e a extensão de lesão cariosa. Os dentes foram seccionados para validação em exame microscópico. Utilizou-se a estatística Kappa para verificar a reprodutibilidade intra e interexaminador. A sensibilidade, a especificidade e os valores preditivos foram obti-

dos. Pela radiografia convencional, a reprodutibilidade intra-examinador foi boa nas superfícies proximais e oclusais, e a interexaminador foi regular nas superfícies proximais e boa nas oclusais. Pela digital, a reprodutibilidade intra-examinador foi distinta para os dois examinadores, apresentando valores que variaram entre regular e ótimo. Nas proximais, a reprodutibilidade interexaminador da radiografia digital variou de regular a boa e, nas oclusais, de boa a ótima. Considerando o aspecto de validade, não houve diferenças significativas entre as imagens convencional e digitais. Em razão dos diferentes níveis de reprodutibilidade apresentados pelos recursos das imagens digitais, não é recomendada a utilização de um recurso individualmente.

■ PALAVRAS-CHAVE: Radiografia dentária; cárie dentária; imagem digital.

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