

RESEARCH

Comparison of simulated periodontal bone defect depth measured in digital radiographs in dedicated and non-dedicated software systems

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Objectives: To compare simulated periodontal bone defect depth measured in digital radiographs with dedicated and non-dedicated software systems and to compare the depth measurements from each program with the measurements in dry mandibles.

Methods: Forty periodontal bone defects were created at the proximal area of the first premolar in dry pig mandibles. Measurements of the defects were performed with a periodontal probe in the dry mandible. Periapical digital radiographs of the defects were recorded using the Schick sensor in a standardized exposure setting. All images were read using a Schick dedicated software system (CDR DICOM for Windows v.3.5), and three commonly available non-dedicated software systems (Vix Win 2000 v.1.2; Adobe Photoshop 7.0 and Image Tool 3.0). The defects were measured three times in each image and a consensus was reached among three examiners using the four software systems. The difference between the radiographic measurements was analysed using analysis of variance (ANOVA) and by comparing the measurements from each software system with the dry mandibles measurements using Student's *t*-test.

Results: The mean values of the bone defects measured in the radiographs were 5.07 mm, 5.06 mm, 5.01 mm and 5.11 mm for CDR Digital Image and Communication in Medicine (DICOM) for Windows, Vix Win, Adobe Photoshop, and Image Tool, respectively, and 6.67 mm for the dry mandible. The means of the measurements performed in the four software systems were not significantly different, ANOVA ($P = 0.958$). A significant underestimation of defect depth was obtained when we compared the mean depths from each software system with the dry mandible measurements (*t*-test; $P \cong 0.000$).

Conclusions: The periodontal bone defect measurements in dedicated and in three non-dedicated software systems were not significantly different, but they all underestimated the measurements when compared with the measurements obtained in the dry mandibles.

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Introduction

The use of digital radiography is increasing and several systems based on either solid state sensors or photostimulable phosphor plates are available for dentistry with a substantial scientific validation.^{1–4} Despite the advantages offered by these technologies, such as the elimination of chemical processing, lower radiation doses to the patient,

image processing and improved image management, the possibility of easy and fast transmission of image data to third parties over the internet could be considered one of the main advantages, offering easy access for the dentist to second opinions on diagnosis and treatment planning.⁵

The availability of several digital dental radiography systems (www.odont.au.dk/rad/Digitalx.htm) has introduced new problems concerning image exchange since there is no absolute standard in dentistry for image file format. This means that digital images acquired in one

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system are not easily imported into another system's software. Efforts are ongoing to implement the DICOM (Digital Image and Communication in Medicine) standard in dentistry to encourage interchangeability among software systems.⁶ However, few dental digital systems have offered a DICOM solution,⁷ which moreover may not be the right solution for dentistry.⁸ Furthermore, only a minor percentage of dental clinics have yet switched from traditional film-based radiography to digital imaging.^{9,10}

However, increasing numbers of dentists have a personal computer and internet facilities in their offices and there are several low cost software packages available on the market to import and display digital images. These include freeware, *e.g.* Image Tool 3.0 available at <http://ddsdx.uthscsa.edu/dig/itdesc.html>. It may be reasonable to believe that dedicated software that comes with a digital system, responsible for capturing digital radiographic images, would be optimized for image interpretation acquired and displayed with this receptor. However, there is a lack of studies addressing the interoperability among different imaging software systems.

The aims of this study were to compare simulated periodontal bone defect depth measured in digital radiographs in dedicated and non-dedicated software systems and to compare depth measurements in each program with those in dry mandibles.

Materials and methods

Forty dry pig hemi-mandibles were used in this study. Periodontal two-wall bone defects were created at the mesial side of the first premolar in the apical direction using a slow-speed round bur no. 4. The mesial side was chosen because it is the proximal site that gives the best access to create the periodontal bone defect since it presents a diastema between the two contiguous teeth. The bone defect width was determined by the bur diameter and the defect depth was random. Bone was removed corresponding to the bur diameter, and a small chisel was used to refine the defect eliminating all bone chips attached to the root surface. The buccal wall and part of the proximal wall were removed, thus only the lingual wall remained. A tiny mark was made at the cemento enamel

junction with a double-face diamond disc to establish the upper border of the bone defect, and it was used as a reference point because the detection of the radiographic image of the cemento enamel junction was difficult.

Image acquisition

Digital images of the defects were acquired using the CMOS Schick® sensor (Schick Technologies Inc., Long Island, NY). The geometric alignment between the sensor and the hemi-mandible was standardized using a fixing device. A 9.22 mm long aluminium step wedge was fixed to the sensor, and was also used to calculate the magnification and distortion in the further analysis using an object with a known length. The radiographs were taken with the vertical long axis of the hemi-mandible fixed perpendicular to the central ray and parallel to the sensor at a 70 cm focal spot to object distance. The X-ray unit operated at 70 kVp, 10 mA and 18 impulses. A wooden block of 2 cm thickness was placed in front of the mandible to simulate soft tissue.

The images were stored in TIFF (Tagged Image File Format) without compression (8 bits with a resolution of 600 dpi, a file of about 700 KB).

Bone defect measurement

The bone defect depth was measured as the distance from the deepest part of the defect to the cemento enamel junction. A periodontal probe (Williams Probe; Hu-Friedy, Chicago, IL) was used to measure the defects in the dry pig mandibles, positioned by hand at the bottom of the defect with the vertical long axis parallel to the root surface. The cemento enamel junction point could be demarcated on the probe with the aid of a small endodontic rubber ring, and the length between the probe tip and the rubber ring was measured by a digital calliper (Ultra-Call Mark III; Fowler, Switzerland) (Figure 1a). This measurement was considered the true depth (gold standard).

The digital images were evaluated in four image software systems (Figure 1b); one, the dedicated Schick program CDR DICOM for Windows v.3.5, and another three non-dedicated software systems: Vix Win 2000 v.1.2, Image Tool 3.00 and Adobe Photoshop 7.0 (Table 1). The software was installed in a laptop computer (Satellite P25-S507; Toshiba, Taiwan), and the images were evaluated on a 17" WXGA (1440 × 900) monitor.

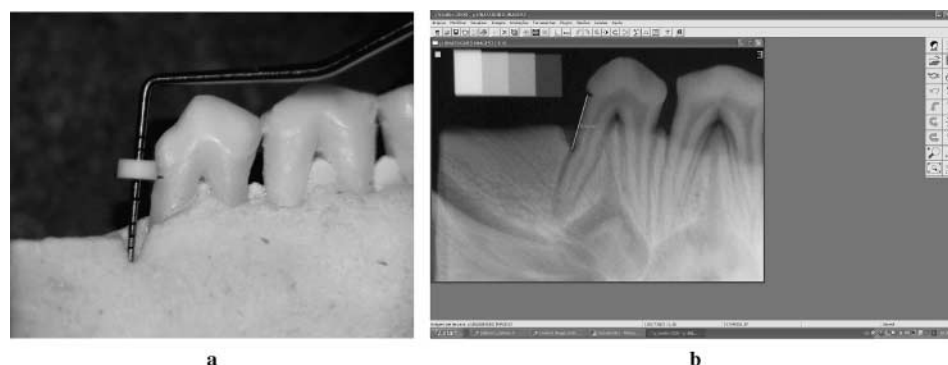


Figure 1 Measurement in a dry pig hemi-mandible (a) using periodontal probe and endodontic rubber ring and (b) digital radiographic image showing the distance from the deepest part of the defect to the cemento enamel junction

Table 1 General information about image software used in this study

Software name	Company	Website	Dedicated	Type	Application
Schick DICOM	Schick Technologies	www.schicktech.com	CDR®	CMOS	Dental
Vix Win PRO	Gendex Dental System	www.gendex-dental.com	DenOptix/VisualiX	PSP/CCD	Dental
Image Tool 3.0	UTHSCSA	ddsdx.uthscsa.edu/dig/itdesc.html	–	–	Dental/biological
Photoshop 7.0	Adobe	www.adobe.com	–	–	General image processing

CCD, charge coupled device; CMOS-sensor, complementary metal oxide semiconductor; PSP, photo stimulable phosphor plate

Prior to the measurements of the defect depths in the digital images, all the images were standardized according to a known length from the step wedge and the ruler tool available in the software system.

The depth measurements were performed by three examiners: one radiologist, one PhD student and one undergraduate student, for both the dry mandibles and the digital images. The examiners were calibrated before reading sessions and performed the measurements together, in three consecutive sessions, in dimmed room light.

Statistical analysis

The three measurements of each defect were averaged, and a mean value was obtained. Analysis of variance (ANOVA) was used to compare the depth measurements from the four software systems. Student's *t*-test was used to compare the depth measurements between each method and the dry mandible. The 95% confidence intervals for the mean depth measurements obtained from each software and dry mandibles were estimated.

STATA software (Stata Corp. 2003. Stata Statistical Software: Release 8.0. College Station, TX: Stata Corporation, TX) was used.

Results

The ANOVA (Table 2) showed that the means of the measurements performed in the four software systems were not significantly different ($P = 0.958$).

Comparing the radiographic measurements performed in each of the four software systems to the dry mandibles, all digital image measurements underestimated the defect depth (*t*-test; $P \cong 0.000$). The mean measurements were 5.07 (95% CI: 4.82–5.32), 5.06 (95% CI: 4.80–5.32), 5.01 (95% CI: 4.75–5.27), and 5.11 (95% CI: 4.84–5.37) and 6.67 (95% CI: 6.30–7.04) for Schick CDR DICOM dedicated software, VixWin, Adobe Photoshop and Image Tool non-dedicated software and dry mandibles, respectively.

The bar graph (Figure 2) shows the difference between the measurements from dry mandibles (gold standard) in each one of the four imaging software systems.

Discussion

There were two important findings in this study: (1) that measurements of simulated periodontal bone defects obtained in one dedicated and three non-dedicated software systems were not significantly different; (2) the bone defect depth measurements in the digital radiographs were underestimated compared with the measurements obtained with the dry mandibles.

It is important to consider the nature and the facilities provided in software systems developed for dental tasks (Schick, VixWin and Image Tool) and for general applications (Adobe Photoshop). For the latter, there is no specific tool for image standardization, and the standardization in the present study was made using a known length of the aluminium step wedge. On the other hand, Schick, VixWin and Image Tool software systems provide a specific tool for standardization, which is automatically prompted by the system in VixWin and Image Tool when the image is opened on the monitor. In the Schick system, it is necessary for the user to search for this function. Thus, considering distance measurements, the professional can choose each of these software systems, both for dental tasks and for general applications.

For radiographic image interpretation using dedicated and non-dedicated software, the results may be dependent on the diagnostic tasks.

It seems that few studies have evaluated the interoperability among software systems. One study assessed the diagnostic accuracy of the morphology and position of mandibular third molars in digital panoramic images using the dedicated software and a general Picture Archiving and Communication System (PACS) software. The results were similar for the dedicated and the non-dedicated software for all diagnostic tasks, except for the interpretation of impacted third molars, for which the dedicated software gave more accurate results.¹¹ However, it is difficult to compare our results with this study, since third molar assessment is a different task from periodontal bone defect measurements.

The results showed that digital radiographic measurements using either of four software systems significantly underestimated the defect depth measured in the dry

Table 2 One-way analysis of variance for depth measurements data according to different software systems

Source of variation	df	Sum of squares	Mean square	F-value	P-value
Programs	3	0.2039	0.0679	0.10	0.9580 ns
Residual	156	102.6754	0.6582		
Total	159	102.8793			

df, degrees of freedom; ns, non-significant

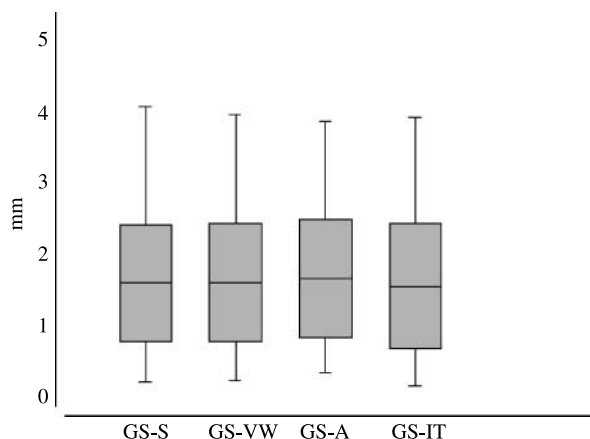


Figure 2 Bar graph of the differences between the gold standard measurements and radiographic measurements in four image softwares. GS, gold standard; S, CDR DICOM v.3.5; VW, Vix Win 2000 v.1.2; A, Adobe Photoshop 7.0; IT, Image Tool 3.0

mandible. The depth measured in radiographs was approximately 25% lower than the dry mandible measurements. Previous reports have demonstrated an underestimation ranging between 5.7% and 21% in bone defects.^{12–14} The explanation for such underestimation

might be related to the two-wall periodontal defect that was created, so that the remaining lingual wall was thick and might have produced a blurred image. In a study conducted by Pepelassi and Diamanti-Kipioti¹³ there was no reference to the type of bone defect (one-, two- or three-wall periodontal defects). In addition, we used a precision digital calliper to measure the bone defects instead of the periodontal probe used in previous reports.^{12,13}

In conclusion, the periodontal bone defect measurements using the Schick dedicated software CDR DICOM for Windows v.3.5 and non-dedicated software Vix Win 2000 v.1.2, Image Tool 3.00 and Adobe Photoshop 7.0 were similar, while there was a considerable underestimation of bone defect depth measured in radiographs compared to dry mandibles.

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Disclosure

The authors claim to have no financial interests in any company or any of the products mentioned in this manuscript.

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