ORIGINAL ARTICLE

Comparison of computer-generated, enhanced and conventional 2-dimensional radiographic imaging

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Introduction: Technological advances have attempted to improve the standard of traditional x-ray imaging. ImageIQ software (LumenIQ, Bellingham, Wash) enhances conventional radiography by producing a computer-generated, enhanced 2-dimensional (2D) image, adding depth and detail. The software converts the scales of gray to topographic height values, which are easier for the eye to see. The purpose of this study was to determine whether the enhanced 2D renderings are as sensitive as traditional 2D radiographs for detecting periodontal defects in cadaver mandibles. **Methods:** Periodontal defects were located and classified on 20 cadaver mandibles. These defects were radiographed, and computer-generated, enhanced 2D topographic renderings were made with ImageIQ software. A panel of evaluators was shown the 2D radiographs and the enhanced 2D renderings in random order. The evaluators classified the defects from these images. **Results:** Significantly better agreement by the evaluators with the intrasurgical classification was found with the enhanced 2D rendering to view periodontal defects vs the traditional 2D x-ray. Enhanced 2D renderings improved the accuracy of radiographic periodontal defect classification by 14.3% over traditional 2D radiographs. **Conclusions:** Computer generated, enhanced 2D renderings of conventional radiographs might provide a reliable diagnostic alternative to conventional 2D radiographs when attempting to classify periodontal defects. (Am J Orthod Dentofacial Orthop 2009;135:463-7)

Orthodontists are routinely involved in the treatment of periodontal bony defects. Molar uprighting and forced eruption are examples of procedures undertaken to treat periodontal defects. In addition, a defect can alter an orthodontic treatment plan. For example, a decision must be made about whether to move teeth associated with a defect or whether to move teeth into an area of bone containing a defect. Therefore, the detection and the diagnosis of such defects are important in prescribing proper orthodontic treatment. An important tool to detect periodontal defects is the use of good quality radiographs. Previous studies have shown the inability of traditional 2-dimensional (2D) radiographs to adequately describe a 3-dimensional (3D) periodontal defect when compared with the gold standard of intrasurgical measurement.[1] Studies have statistically shown that traditional radiographs can significantly underestimate the amount of interproximal bone loss in up to 71% of patients.[2]

A number of technological advances in radiography have attempted to improve the standard of traditional x-ray imaging. Many methods of enhanced visualization involve the computer and some form of imaging software. In general, software allows some of the following modifications: color enhancement, magnification, gamma adjustment, and 3D enhancement. Three-dimensional image enhancement is probably the newest form currently under investigation. One method of producing a true 3D image is by cone-beam computed tomography. The x-ray unit and the image intensifier rotate around the object as the exposure is being completed. A scan generally produces 365 slices as axial projection data.[3] The data are then transferred to the workstation consisting of a computer with imaging software. From these projection data, the workstation can reconstruct any section in 3 dimensions.[3] Although this technology might increase the discriminability over conventional radiography, the high cost has reduced its availability at this time.

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Fig 1. Plaster custom jig for holding dried cadaver mandible.

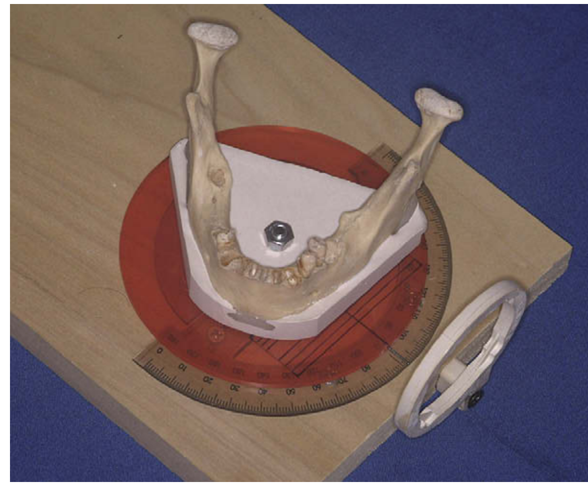

Fig 2. Angulation measuring device with custom jig in place.

A new software platform, ImageIQ (LumenIQ, Bellingham, Wash), enhances conventional digitized radiography by using computer algorithms to produce depth in a 2D film. This produces what can be described as computer-generated topographic mapping, or enhanced 2D imaging. A conventional radiograph contains 256 shades of gray. However, the human eye can discern only about 32 of them at a time.[4] ImageIQ converts all the shades of gray into vertical heights (topographic representation) on an x-y-z visual axis, producing an enhanced 2D image. These vertical heights may be easier for the eye to distinguish. It is hypothesized that this vertical representation of gray scales allows the eye to gain more information from a conventional radiograph by allowing it to see more detail in the image than is possible through pure gray scale color difference. However, the ability of this system to improve on conventional 2D dental radiographs has not been explored. Furthermore, the efficacy of using ImageIQ software to improve the ability of the practitioner to classify periodontal defects radiographically has not been reported in the literature.

This study was undertaken to investigate the discriminability between ImageIQ's computer-generated, enhanced 2D rendering and conventional dental radiology in terms of periodontal defect classification.

MATERIAL AND METHODS

Twenty dentate dried cadaver mandibles were obtained. Periodontal defects were located and classified. In this classification, it is possible to have a 1-, 2-, or 3-walled defect.[5] A total of 63 periodontal defects were found. Their locations and classifications were recorded and called the "intrasurgical classification," or the control value.

The periodontal defects were radiographed by using D-speed #2 size radiographs (Kodak Ultraspeed #2, Eastman Kodak, Rochester, NY). Several recent studies have evaluated the accuracy of various film speeds. D-speed film has been found statistically superior to E-speed film in determining such precise measurements as radiographic endodontic working length both in vitro[6] and in vivo.[7] Resin phantom material was placed over the tube head to represent soft-tissue scatter as in previous studies.[8-10] Conventional radiography with D-speed #2 size radiographs was compared with the computer-generated, enhanced 2D images of the ImageIQ software.

For every specimen, the radiographs were taken with the x-ray beam perpendicular, or 90°, to the specimen in both the horizontal and vertical dimensions. To closely measure the x-ray beam angle to the cadaver mandible, a custom jig was made for each specimen. Each mandible was embedded in a plaster base as shown in Figure 1. These bases could then be attached to an angulation measuring device, shown in Figure 2. The angulation measuring device used a modified protractor assembly that allowed quantification of x-ray beam angulations and the reproducibility of those angulations. The exposure time was the same for these films at 12 impulses; which was determined by trial and error to provide the best quality of the radiographs of the cadaver mandibles.

The #2 size D-speed films were exposed by using an x-ray machine (GX-770, Gendex, Lake Zurich, Ill) at 70 kVp and 7 mA. The films were processed by using a processor (A/T2000, Airtechniques, Melville, NY)

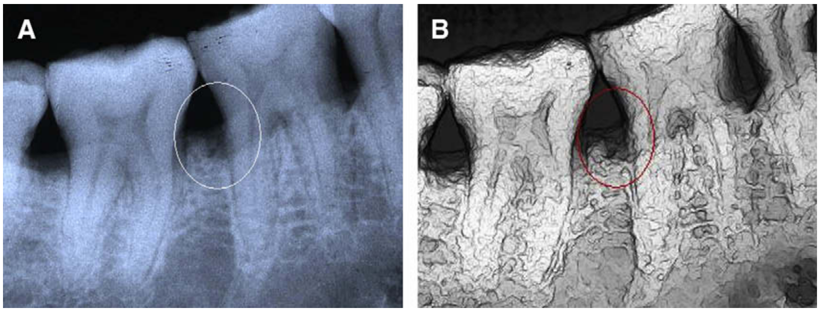

Fig 3. A, Digitized conventional 2D radiograph of periodontal defect; **B,** ImageIQ enhanced 2D rendering of periodontal defect.

Table I. Comparison between evaluators' classifications and intrasurgical classifications for significant agreement

	Evaluator (A, B, C) classification					
	A/2D image	*A/Enhanced 2D image*	*B/2D image*	*B/Enhanced 2D image*	*C/2-D image*	*C/Enhanced 2D image*
Intrasurgical classification	*	*	NS	*	NS	NS

NS, No significant agreement between the groups.
*Significant agreement between the groups ($P < 0.05$).

on a 5.5-minute cycle. Readymatic Dental Chem Pack Processing Chemicals (Eastman Kodak) were used and replenished with fresh solutions after every 100 radiographs.

The processed radiographs were then digitized by using a flatbed scanner (Expression 1680, Epson, Long Beach, Calif). Previous studies have proven the ability of a flatbed scanner to produce high-quality digitized radiographs when compared with other means of digitization.[11-13] The scanner was set to transparency mode, 8-bit gray scale, and resolution of 300 dpi was used as described by Janhom et al.[13] The resultant unmodified digitized radiograph was saved in TIFF and archived on a CD-ROM. Each digitized radiograph was then rendered into computer-generated, enhanced 2D images by using the ImageIQ software on a compatible Windows-based personal computer (Microsoft, Redmond, Wash). The enhanced image was saved as a TIFF and archived on a CD-ROM. Gurdal et al[14] investigated the effects of various file formats on digital radiographs. They concluded that digital radiographs saved as TIFFs were more accurate than those saved in another popular format, JPEG. Figure 3 shows the conventional 2D digitized radiograph and the enhanced 2D rendering.

Each digitized 2D radiograph and its computer-generated, enhanced 2D rendering was compared for discriminability by 2 periodontists and an oral pathologist. These evaluators were standardized for periodontal defect classification using the 1-, 2-, or 3-walled classification system before data collection. All conventional 2D and enhanced 2D images were compiled and arranged randomly. The evaluators were shown the conventional digitized 2D radiographs and the enhanced 2D renderings in this random ordering. Each evaluator then classified the periodontal defects in the images. The evaluator's classifications using the conventional 2D radiographs and the enhanced 2D images were compared with the intrasurgical classifications.

Statistical analysis

To analyze the data, a data table was set up in Excel (Microsoft). The rows were labeled with the specimen identification numbers and periodontal defect locations. The columns were labeled "evaluator A, B, or C" and "standard x-ray" or "topographical map." The evaluator's classification of each periodontal defect was then entered in the corresponding cell. Analysis of variance (ANOVA), the Student *t* test, and the least squares means tests were used to analyze the data. The *P* value was set to 0.05 for 95% significance.

RESULTS

The ANOVA results on the agreement between the evaluator's classification of the conventional 2D, the enhanced 2D images, and the intrasurgical periodontal defect classifications are shown in Table I. Evaluator A

Table II. Comparison of 2D x-ray classifications with intrasurgical classifications

Evaluator	*Perfect matches*	*Kappa*	P *value*
A	26/63 = 46.0%	0.1978	0.01
B	18/63 = 23.6%	−0.0592	0.77
C	21/63 = 33.3%	0.0547	0.24

Table III. Comparison of ImageIQ enhanced 2D values with intrasurgical values

Evaluator	*Perfect matches*	*Kappa*	P *value*
A	37/63 = 58.7%	0.2930	0.01
B	29/63 = 46.0%	0.1978	0.01
C	26/63 = 41.4%	0.1120	0.09

had significant agreement with the intrasurgical classification for both the conventional x-rays and the enhanced 2D images. Evaluator B had poor agreement between conventional x-ray and intrasurgical classifications, but agreement was much better for the enhanced 2D images. Evaluator C did not have significant agreement with the control using either method.

Table II shows the kappa coefficients and the *P* values for the comparison of intrasurgical classification with conventional 2D x-rays. Table III shows the kappa coefficients and the *P* values for the comparison of intrasurgical classification with enhanced 2D images. For evaluator A, agreement was significantly greater than that expected by chance for both procedures ($P = 0.01$). Although the greater percentage of agreements with the topographical map for evaluator A was encouraging, it was not significant ($P = 0.11$). Evaluator B showed improved agreement with the enhanced 2D image; this was significantly greater than chance ($P = 0.01$). The greater percentage of agreement with the enhanced 2D images was significant ($P = 0.03$). Evaluator C's small improvement for the enhanced 2D images was not significant.

When the results for all 3 evaluators were pooled (Table IV), the combined percentages of perfect matches with the control were 34.4% for the conventional x-ray and 48.7% for the enhanced 2D images. The difference between these percentages (14.3%) was significant ($P = 0.01$).

DISCUSSION

Evaluator A had higher percentages of agreement with the intrasurgical classification with both the standard x-ray (46.0%) and the enhanced 2D image (58.7%). This might have been because evaluator A was a periodontist and had 32 years of clinical experience. Evaluator B had poor agreement using the standard x-ray (28.6%) and better agreement using the enhanced 2D rendering (46.0%). Evaluator B was also a periodontist but had fewer years of clinical experience than evaluator A. Evaluator C, an oral pathologist, did not have significant agreement with the intrasurgical control using either the standard x-ray (33.3%) or the enhanced 2D image (41.4%). This evaluator had the least experience with diagnosis and classification of periodontal defects. Despite the efforts of the principal investigator (M.A.H.) to standardize the evaluators and refresh their understanding of periodontal defect classification, the difference in clinical experience and background might have affected the results of this phase of the study. The use of more periodontists to evaluate and classify the defects in the conventional 2D and the enhanced 2D images could have produced more consistent results. This should be considered for similar studies in the future.

Table IV. Combined results for the evaluators compared with the intrasurgical classsifications

Perfect matches for 2D x-ray	*Perfect matches with enhanced 2D rendering*	*Difference (3D–2D)*	P *value*
65/189 = 34.4%	92/189 = 48.7%	14.3%	0.01

Despite the lack of more uniform periodontal clinical experience with the panel used in this study, encouraging results were found when using the ImageIQ enhanced 2D rendering to classify periodontal defects. When the data for all evaluators were pooled, better agreement with the intrasurgical control was seen for the enhanced 2D image (48.7%) vs the standard x-ray (34.4.0%). The difference between these percentages (14.3%) was significant ($P = 0.01$). Therefore, the analysis still shows statistical evidence for improved detection and classification of periodontal defects when using computer-generated, enhanced 2D images. Perhaps the representation of gray scales vertically provides additional information to lead to a more accurate classification of periodontal defects.

The gold standard for in-depth description of periodontal defect classification is still intrasurgical measurement.[2,15-20] It appears that some limitations of 2D conventional x-rays are similar for the ImageIQ enhanced 2D rendering as well. Thick buccal and lingual cortical plates tend to obscure the defect. This thick bone also affects the quality of the rendering. In addition, the ImageIQ software only increases the practitioner's ability to see all gray scales in the image through vertical representation. The software does not produce a true 3D representation of the anatomic structures. The boundaries of the anatomic structures appear to have greater detail in this re-representation of gray scales into a format that is easier for the human eye to see. Therefore, some improvement over conventional radiographs was found. The dentate mandible phase of this study showed that computer-generated enhancement of conventional 2D radiographs can improve the accuracy of defect classification by 14.3% (48.7% vs 34.4%). With further improvement of the technology and its method of use, the computer-generated, enhanced 2D image might prevent the need for some periodontal surgical procedures.

CONCLUSIONS

The use of ImageIQ software to produce enhanced 2D renderings of conventional 2D radiographs can improve a practitioner's ability to classify periodontal defects. A 14.3% increase in accuracy of periodontal-defect classification was seen with the enhanced 2D rendering vs conventional 2D radiographs.

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