Panoramic Dental Radiography Using a Charge-Coupled Device Receptor

Allan G. Farman and Taeko T. Farman

Panoramic radiography using a slit beam and film/screen receptor is standard for the emergency room evaluation of mandibular fractures and also in dentistry. This study compared the spatial resolution, area distortion factors, and the dosage considerations for a panoramic system where standard film/screen and a charge-coupled device were alternatively employed as the image receptor. Resolution and image contours were determined using a lead resolution grid positioned at selected beam projection angulations. Exposure measurements were carried out using a RANDO® average man phantom and a 3 cc beryllium-windowed ionization chamber. The maximum spatial resolution with film approached 5 lp mm⁻¹ whereas with the CCD the maximum resolution was just above 4 lp mm⁻¹. Consequently, the image layer was reduced slightly in width when using the CCD receptor. The use of the CCD resulted in a skin exposure reduction exceeding 70%.

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SEVERAL DIGITAL panoramic radiography systems have been designed. These systems are based either on the use of storage phosphors or charge-coupled device (CCD) technology. Using storage phosphors the film cassette is merely replaced by the storage phosphor receptor. Digital panoramic radiography can also be achieved by use of a narrow two-dimensional detector, such as the CCD array of the DigiPan (Trophy Radiologie, France) receptor for the Instrumentarium Orthopantomograph OP 100 (Instrumentarium Imaging, Finland).

A preliminary overview of the DigiPan system appears elsewhere.¹ The objective of the study reported here is to evaluate the DigiPan modification in terms of spatial resolution, the area distortion

factors at selected image layer contours, and the entrance radiation exposure.

MATERIAL AND METHODS

The X-Ray Generator and Detectors

The Orthopantomograph OP 100 (Instrumentarium Imaging, Finland) is a software controlled high frequency dental panoramic x-ray machine. The DigiPan conversion interchanges with the standard film cassette.

Resolution and Image Layer Contours

For image layer determination, digital images were made of a lead resolution grid, Kyokko No. 1 X-ray Grid (Kasei Optonix Co., Tokyo, Japan) positioned at fractional determined beam projection angulations.

Magnification

An hexagonal nut was used as the test object to determine vertical and horizontal magnifications along each contour line of the mapped focal trough. Measurements were made to two decimal places using the measurement algorithm of the provided software (Trophy Radiologie, France). All readings were made 20 times then averaged. Resolution limits and magnifications at each contour for the horizontal and vertical dimensions were then determined.

Distortion

A comparison between the magnification in the vertical and horizontal axes was made after the method of Sämfors and Welander using the ratio of horizontal to vertical magnifications.² This ratio was used as the index of area image distortion. When the index is at unity there is no disproportion, merely geometrically determined magnification.

Dosimetry

DigiPan images were made of a RANDO average man phantom (Alderson Research Laboratories, CT) at kVcp settings of 60, 66, 70 and 80, with mA settings of 2.0, 3.2, 6.4 and 10.0. Standard film radiographs were also taken using the manufacturer's recommended factors and photo timing. The exposure cycle was set at the manufacturers' recommended standard 17.6 s. Diagnostic image quality was rated by a panel of two oral and maxillofacial radiologists and one oral and maxillofacial pathologist. A Model 11 Dosimeter/Electrometer (CNMC Instruments Incorporated, Nashville, TN) with 3 cc beryllium windowed ionization chamber CNMC Model 303 (Sun Nuclear Corporation, Melbourne, FL) was used for exposure determinations. Exposures were assessed at the beam entry points while imaging the molar, premolar, and anterior teeth both using the DigiPan and conventional film.

From the Division of Radiology and Imaging Sciences, The University of Louisville, Louisville Health Sciences Center, Louisville, KY.

Address reprint requests to Professor Allan G. Farman, PhD(odont.), DSc(odont.), Division of Radiology and Imaging Sciences, School of Dentistry, 501 South Preston Street, The University of Louisville, Louisville, KY 40292.

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RESULTS

Spatial Resolution

The maximum spatial resolution approached 5 lp mm^{-1} for the standard film/screen combination recommended by the manufacturer; for the DigiPan the maximum resolution was above 4 lp mm^{-1} , but did not exceed 4.37 lp mm^{-1} . This reduction in spatial resolution with the DigiPan only slightly reduced the width of the focal trough.

Image Magnification (Horizontal)

At the 1.5 lp mm^{-1} resolution limits, the calculated horizontal magnifications were -19% facial and $+23\%$ lingual to the image layer of maximum resolution in the anterior midline (0° horizontal angulation), -19% facial and $+33\%$ lingual to the image layer of maximum resolution in the first premolar region (47° horizontal angulation), -21% facial and $+23\%$ lingual to the image layer of maximum resolution in the second molar region (76° horizontal angulation), and -19% facial and $+27\%$ lingual to the image layer of maximum resolution in the TMJ region (96° horizontal angulation).

At 4 lp mm^{-1} , midline horizontal magnification was -0.3% facial and $+1.1\%$ lingual to the image layer of maximum resolution, 0% facial and $+0.6\%$ lingual to the image layer of maximum resolution

in the first premolar region (47° horizontal angulation), 0% facial and $+5\%$ lingual to the image layer of maximum resolution in the second molar region (76° horizontal angulation), and -0.7% facial and $+3.4\%$ lingual to the image layer of maximum resolution in the TMJ (96° horizontal angulation).

Image Magnification (Vertical)

For each of the resolution contours and beam angulations studied, the determined vertical magnifications were consistently low when compared with their horizontal magnification counterparts. The greatest vertical magnifications were found at 1.5 lp mm^{-1} lingual to the image layer of maximum resolution in the temporomandibular joint region (9%) and in the premolar region (8%).

Distortion

The of distortion factors at selected horizontal beam projection angulations are displayed in Fig 1. The distortion factors at 4 lp mm^{-1} , for the midline was 0.99 - 1.00 facial and 0.98 - 1.02 lingual to the image layer of maximum resolution. At 3 lp mm^{-1} , the distortion factors were 1.02 - 1.08 facial and 1.00 - 1.12 lingual to the image layer of maximum resolution. At 1.5 lp mm^{-1} , the distortion factors were 1.16 - 1.19 facial and 1.14 - 1.22 lingual to the image layer of maximum resolution. The distortion

Fig 1. Distortion factors at selected horizontal beam angulations.

factors at 4 lp mm⁻¹ approximated unity (ie, little distortion was evident).

Radiation Exposure

With the DigiPan, acceptable image quality was attained with combinations of 60 kVcp and 3.2, 6.4 or 10 mA, 70 kVcp and 2.0, 3.2 or 6.4 mA and not at all for at 80 kVcp irrespective of the mA. Compared to the manufacturer's recommended settings for film, entrance exposure reductions for the DigiPan at 70 kVcp and 2 mA were 75% for incisor imaging, 76% for the premolar area, and 81% for the molar region. At 70 kVcp and 3.2 mA it was 67% for the incisors, 64% for the premolar area and 69% for the molar region. At 66 kVcp with 3.2 mA exposure reductions were 69% when imaging the anterior segment, 69% for the premolar area and 72% for the molar region. Hence, entrance exposure savings were maximized when using a mid-range kVcp of 66 to 70 combined with a low mA setting.

DISCUSSION

CCD-based radiology systems have been criticized for having a poorer resolution in comparison to film.^{3,4} For film-based panoramic radiography, resolution does not exceed 5 lp mm⁻¹ and the contour of the acceptable range of unsharpness is usually selected as approximately 1.5 lp mm⁻¹.⁵ Hence, spatial resolution requirements are not so

demanding for panoramic radiology as they are for intraoral radiography where spatial resolution with direct emulsion film can reach as high as 16 lp mm⁻¹.⁶

While vertical measurements are reliable within certain limits horizontal measurements may be highly distorted using conventional panoramic radiographic receptors. Angular distortion on panoramic exposures result from the combined distortion in the vertical and horizontal dimensions.^{7,8} Area distortion was determined for the selected image layer contours during the present study, however, the effects of spatial resolution combined with distortion factors were not examined in conjunction with the provided measurement algorithm. While these can be extrapolated from the area distortions for the various image contours provided in this paper, there certainly is room for more empirical studies similar to those made earlier with conventional film/screen receptors. Providing an accurate measurement algorithm for digital panoramic systems could prove a difficult task in view of the distortions that are implicit from panoramic radiographic theory.

It can be concluded that charge-coupled devices used in panoramic dental radiography can permit a proportionately substantial reduction in the entrance exposure while not substantially affecting the image qualities measured in the current study.

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