Temporomandibular Joint Pantomography Using Charge-Coupled Device, Photostimulable Phosphor, and Film Receptors: A Comparison

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Our objective was to compare the accuracy and practicality in use of three available imaging receptors for temporomandibular joint (TMJ) imaging; namely, two computer-assisted and one traditional analog x-ray film system. A standardized tissue-equivalent encased human skull specimen was imaged using lateral and posteroanterior (PA) pantomographic projections with the Orthopantomograph OP 100 (Instrumentarium Imaging, Tuusula, Finland) and three different receptor modalities: (1) Ektavision film with Ektavision screens (Eastman Kodak, Rochester, NY); (2) DenOptix photostimulable phosphor screens (Dentsply/Gendex, Chicago, IL); and (3) the charge-coupled device (CCD) receptor, DigiPan (TREX/Trophy Radiology, Marne-la-Vallée, France). The effective focal trough was found for each receptor using lead resolution grids placed at fractional millimeter distances along empirically determined beam projection angulations. The time to acquire and process images was also established. We found that the CCD system permitted real-time display, whereas the use of traditional film took 2 minutes to load the cassette in a darkroom and perform the exposure, and then a further 2 minutes to unload and process. The storage phosphor took 3 minutes to unload the cassette and process the image and a further 20 seconds to clear the plate following laser scanning. Film produced the greatest maximum resolution followed by the storage phosphor and the CCD. In conclusion, CCD-based TMJ pantomography provided an instant image. The photostimulable phosphor system used was the least satisfactory in terms of the time expended to obtain an image, but provided better spatial resolution than the CCD. Ektavision film/screens provided the best spatial resolution in this investigation.

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CHRONIC FACIAL PAIN affects about 10 million adults in the United States, including nearly 7 million who have pain centered around the masticatory musculature and temporomandibular joint (TMJ). Temporomandibular disorders (TMDs) are characterized by a variety of signs and symptoms, including chronic preauricular pain, tenderness involving the masticatory muscles and TMJ, difficulty opening the mouth, and clicking or popping sounds in the TMJ. Causes of chronic pain are often multifaceted and poorly defined, making TMD interpretation a difficult challenge.¹ Radiographic imaging of the TMJ area is needed to help assess stages of TMD and to differentiate between

TMD and other pathoses that might result in similar signs and symptoms.^{2,3} While it is recognized that magnetic resonance imaging (MRI) provides the best view of bony and soft tissue details in the TMJ region, this is not currently a cost-effective first-line diagnostic tool. Furthermore, MRI is not readily available to the clinicians initially consulted, who are generally dental practitioners. On the other hand, dentists usually do have access to panoramic radiographic systems. For this reason, the present report compares different receptors for lateral pantomography and coronal tomography of the TMJ using a panoramic machine.

The objective of this study was to compare the accuracy and practicality in use of three available imaging receptors, consisting of two computer-assisted and one traditional analog x-ray film system, in imaging the TMJ. Standardized tissue-equivalent encased human skull specimens were imaged using lateral and posteroanterior (PA) pantomographic projections with the Orthopantomograph OP 100 (Instrumentarium Imaging, Tuusula, Finland) and three different receptor modalities: (1) Ektavision film with Ektavision screens (Eastman Kodak, Rochester, NY); (2) DenOptix photostimulable phosphor screens (Dentsply/Gendex, Chicago, IL); and (3) the charge-coupled device (CCD) receptor, DigiPan (TREX/Trophy Radiology, Marne-la-Vallée, France). The effective focal trough was found for each receptor.

MATERIALS AND METHODS

X-Ray Generator

The Orthopantomograph OP 100 is a software-controlled, high-frequency dental panoramic x-ray machine operating at variable current (2 to 16 ± 1 mA) and variable potential difference (57 to 85 ± 5 kVcp) with an exposure time of $10.8 \pm$

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0.05 seconds (program 6) for lateral TMJ imaging and 8.0 $\pm$ 0.05 seconds (program 8) for PA TMJ imaging. The standard exposure parameters set by the manufacturer of the panoramic machine for both program 6 and program 8 were 70 kVcp and 12 mA. A range of kVcp and mA settings was attempted manually for exposure of the manikin. The time for exposure to image display was also measured in each case.

DigiPan Image Receptor

The DigiPan conversion interchanges with the standard film cassette for the Orthopantomograph OP 100. The CCD matrix is 1,244 $\times$ 63, with pixel dimensions of 104 $\times$ 104 μ m and an active area measuring 129.4 $\times$ 6.6 mm. The uncompressed image matrix is 2,550 $\times$ 1,244 over an area of 265 $\times$ 129 mm. A rare-earth scintillator converts x-radiation to light. The scintillator is separated from the CCD via a nontapered fiber optic. The acquisition is 12 bit, but storage is of an autocompensated 8-bit TIFF image. The image file size is 3 Mbyte (3,021,616 byte) without compression.

The maximum DigiPan image length of 265 mm is not much different from that with film, where the maximum length is 300 mm. The maximum image height of 129 mm for the DigiPan compares to the range of 125 mm to 150 mm found with film.

DenOptix Photostimulable Phosphor

The DenOptix system is based on Fuji (Tokyo, Japan) computed radiography imaging plate technology, but uses an ALARA drum laser scanner (Palo Alto, CA) for processing the latent image. The plate was cleared using intense fluorescent light ($\pm$ 5,000 lux) for 20 seconds immediately before placing it in the cassette for imaging. The cassette was similar to that used for film radiography, but did not have intensifying screens. Images were scanned at 150 dpi with a processing time of 2 minutes 38 seconds. Images were stored as 16-bit tagged image file format (TIFF) with lossless compression. Uncompressed images averaged 17.8 Mbytes and were compressed to approximately 5.4 Mbytes.

Manikin and Grid

The manikin was a standard 3-M exposure phantom (Minneapolis, MN) with a human skull and jaws embedded in soft tissue equivalent plastic. For image layer determination, digital images were made of two lead resolution grids, a Kyokko No. 1 X-ray Grid (Kasei Optonix, Tokyo, Japan) and a Nuclear Associates Model 07-501 (Carle Place, NY) positioned at fractional millimeters along the selected empirically determined beam projection angulations.

Radiograph/Image Acquisition

Film images were performed using Kodak Ektavision film combined with Ektavision screens. CCD digital images were made using the DigiPan detector for the Orthopantomograph 100 rotational panoramic machine. Photostimulable phosphor images were made using the DenOptix system with panoramic size imaging plates. Images were acquired and stored as 16-bit TIFF files and displayed on a Gateway 2000 Crystal Scan Model No. YE0711-01 (North Sioux City, SD) monitor as 8 bits (minus the 14 colors required for the WINDOWS operating system [Microsoft, Redmond, WA]).

All diagnostic images were found by consensus to be of good overall diagnostic quality, irrespective of whether film-screen, CCD, or photostimulable phosphor in acquisition.

Fig 1. Lateral projection of left TMJ using Ektavision film.

Observers and Observations Criteria

The two evaluators were dentists with experience in general dental practice combined with advanced credentials in Oral and Maxillofacial Radiology. Each film radiograph and digital image was evaluated under subdued ambient lighting. Diagnostic image quality was established using the manikin. Resolution limits were established by consensus.

RESULTS

Exposure Settings

Although different exposures were tried, the manufacturer's recommended levels for use with film (ie, 70 kVcp and 12 mA) proved to be the most satisfactory for all three of the modalities that were tested (Figs 1 through 7). The exposure times were designated by the selected program at 10.8 seconds for lateral and 8.0 seconds for PA projections.

Fig 2. Lateral projection of TMJ using the DigiPan CCD array. Photograph taken of the monitor display.

Fig 3. Lateral projection of TMJ using the DenOptix photo-stimulable phosphor plate. Photograph taken of the monitor display.

Fig 5. PA view of TMJ using Ektavision film.

Procedure Time

The CCD system permitted real-time display, whereas the use of traditional film took 2 minutes to load the cassette in a darkroom and to perform the exposure, and then a further 2 minutes to unload and process. The storage phosphor took 3 minutes to load the processor and process the image and a further 20 seconds to remove the image from the plate following laser scanning.

Focal Trough

For lateral TMJ imaging (Fig 8), film produced a maximum resolution of greater than 6 but less than 8 lp/mm, followed by the storage phosphor (>5 ,

but <6 lp/mm) and the CCD (>4.37 , but <4.86 lp/mm). For PA TMJ imaging (Fig 9), film again produced the greatest maximum resolution (>5 , but <6 lp/mm) followed by the storage phosphor (>4 , but <4.37 lp/mm) and the CCD (>3.19 , but <3.54 lp/mm). PA projections using all three recording modalities showed significant magnification distortion (Figs 2, 4, and 6), making their use only of value for gross morphologic assessment and not for precision in measurement.

DISCUSSION

The finding that the exposure settings for TMJ imaging with the OP 100 were receptor-independent was unanticipated. This finding differs from previous results for normal panoramic dental radi-

Fig 4. Lateral projection of TMJ using the DenOptix photo-stimulable phosphor plate. Photograph taken of the monitor display using the emboss image postprocessing command.

Fig 6. PA projection of TMJ using the DigiPan CCD array. Photograph taken of the monitor display.

Fig 7. PA projection of TMJ using the DenOptix photostimulable phosphor plate. Photograph taken of the monitor display.

ography using program 1.^{4,5} In previous studies, it proved possible to effect a dose savings approaching 70% when using the DigiPan CCD in place of T Mat G film with Lanex Regular screens. Preliminary studies that we have made for panoramic

Fig 9. Focal troughs (image layers) for the 3 modalities during PA tomography of the TMJ. (A) Posterior 1.5 lp/mm resolution limit for DigiPan; (B) posterior 1.5 lp/mm resolution limit for film; (b) posterior 1.5 lp/mm resolution limit for photostimulable phosphor; (C) maximum resolution contour (>3.19 , but <3.54 lp/mm) for DigiPan; (D) maximum resolution contour for film (>5 , but <6 lp/mm) and photostimulable phosphor (>4 , but <4.37 lp/mm); (E) anterior 1.5 lp/mm resolution limit for DigiPan; (f) anterior 1.5 lp/mm resolution limit for photostimulable phosphor; and (F) anterior 1.5 lp/mm resolution limit for film.

radiography using the DenOptix storage phosphor for regular panoramic radiography suggest that an increase in exposure approximating 20% is needed for the storage phosphor in comparison to Ektavision film and screens. Hence, it would appear that radiation dosage is not a deciding factor for receptor selection for TMJ radiography using the OP 100. It should be remembered that the current investigation was not focused on dosimetry. Dosimetry for TMJ radiography using the OP 100 certainly needs further study.

The use of CCD-based TMJ pantomography provides an instant image with good clarity in lateral projections. The photostimulable phosphor system used was the least satisfactory in terms of the time expended to obtain an image, especially as it was not possible to feed additional images into the processor during processing. However, the storage phosphor provided a spatial resolution greater than was possible with the CCD. Both "digital" systems were outperformed by the Ektavision film/screen receptor in terms of spatial resolution. PA projections using all three recording

Fig 8. Focal troughs (image layers) for the three modalities during lateral pantomography of the TMJ. (A) Outer 1.5 lp/mm resolution limit for DigiPan; (B) outer 1.5 lp/mm resolution limit for film and photostimulable phosphor; (C) maximum resolution contour (>4.37 , but <4.86 lp/mm) for DigiPan; (D) maximum resolution contour for film (>6 , but <8 lp/mm) and photostimulable phosphor (>5 , but <6 lp/mm); (E) inner 1.5 lp/mm resolution limit for DigiPan; and (F) inner 1.5 lp/mm resolution limit for film and for photostimulable phosphor.

modalities showed significant magnification distortion, making their use only of value for gross morphologic assessment and not for precision in measurement. While the focal troughs and maxi-

mum resolutions differed when using each of the three different receptors, the subjective opinion of the viewers was that the images were similar in terms of clinical utility.

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