The cadmium telluride photon counting sensor in panoramic radiology: gray value separation and its potential application for bone density evaluation

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Objective. To investigate whether bone mineral density can be evaluated more accurately using a panoramic device with a new cadmium telluride photon-counting sensor and software than 2 panoramic devices with a conventional semiconductor sensor.

Study Design. A fiduciary test object with several known levels of hydroxy apatite mineral concentration was placed in a phantom on the mandibular occlusal plane. Panoramic images were acquired by changing the position of the test object within the dental arch. The gray value, the spectrum deformation index (SDI), and the relative attenuation index (RAI) of the test object were evaluated. The SDI and RAI represent unique energy information as acquired by the QR-Master panoramic machine and the corresponding special QR-MC analysis software. In order to compare the values expressed in the different units (gray, SDI, and RAI values), the percentage discrepancy was calculated.

Results. The cadmium telluride photon-counting fitted machine more consistently separated each of the hydroxy apatite concentrations in all of the different positioning configurations and locations. The SDI function of the QR Master machine produced more stable values than the RAI value and the gray values of the 2 conventional panoramic machines.

Conclusions. The methodologies as developed for this study can be used to test more sophisticated analyses for the determination of bone density. (Oral Surg Oral Med Oral Pathol Oral Radiol 2015;120:636-643)

The cadmium telluride photon-counting (CdTePC) sensor represents a major advancement in digital sensor design. The sensor's outstanding physical characteristics have been described.[1] One of the greatest potentials of photon-counting imaging is the capacity to evaluate or quantify hard tissue mineral density. Although photon counting can also quantify soft tissue density, the focus of this study was on hard tissues consisting of enamel, dentin, cortical bone, and spongy bone. Dual-energy X-ray absorptiometry (DXA) is a gold standard modality of measuring bone mineral density. DXA measures bone mineral density based on the absorption of two X-ray beams with different energy levels. The photon-counting type of sensor divides the X-ray beam into several energy bands (bins). Known as the beam hardening phenomenon, the energy spectrum of the X-ray beam is altered by the composition of objects being imaged. Simply stated, the ratio between adjacent energy bands reveals the degree of the deformation of the X-ray spectrum.

Our goal was to describe a photon-counting application in a newly designed panoramic imaging system, which will enable a more precise density evaluation of hard tissues than traditional panoramic machines. The data on mineral content will be determined on a principle similar to DXA. In panoramic imaging, the radiographic density of an object or detail is not quantifiable, not repeatable, and without absolute meaning. Panoramic radiographic density is determined by the specific local physical density of an object and the linear quantity and density of other tissues and/or materials along the projected line of the X-ray beam as

Statement of Clinical Relevance

The new X-ray detector and analysis software in a panoramic device will enable the clinician to determine the components of an unknown bone-like substance; thus accurate bone density measurements in the regions of the jaws could be readily available.

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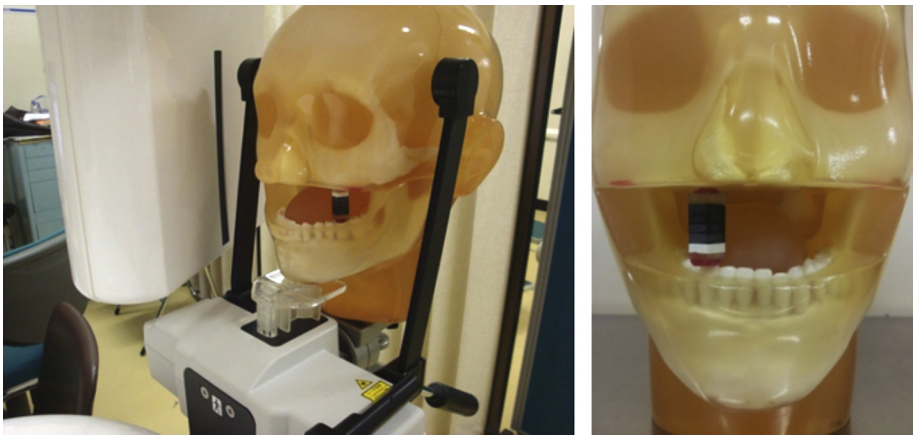

Fig. 1. Hydroxy apatite (HA) crystal fiduciary test object within the head phantom: location is in the right and left molar regions within the head phantom; the 100% $CaCO_3$ layer is white and is in the upright position on the left and upside down on the right side.

in any plain (or two-dimensional) radiographic projection. Variable factors include the topography and thickness of the curved tomographic layer and the over projection of anatomic structures by ghost images other than the desired structures being imaged.[2-4] Including the photon-counting sensor, which is the subject of this study, current high-speed sensor based panoramic imaging results in improved tomosynthesis reconstruction techniques.[5,6]

Tomosynthesis autofocus reconstruction may improve the above stated issues.[7,8] The QR Master panoramic machine and the QR-MC software (Telesystems Co., Osaka, Japan) were developed to incorporate the use of a tomosynthesis-reconstructed image captured with the CdTePC sensor whose features have been described in some detail.[1] The primary objective of the present study was to investigate whether the unique energy information as acquired by the QR-Master panoramic machine, consisting of the spectrum deformation index (SDI) and the relative attenuation index (RAI), will prove to be useful tools for the assessment of the bone mineral density (bone quality) within the jaws. The secondary objective was to assess the reproducibility or stability of the SDI and RAI values in comparison with the gray value density measurements of conventional charge-coupled device sensor-based panoramic systems.

MATERIALS AND METHODS

A specially designed phantom representing the osseous structures of the jaws and surrounding anatomy, some soft tissues, and air spaces was used. A fiducial object containing various concentrations of hydroxy apatite (HA) was imaged in several locations and in the right-side-up and upside-down positions. The QR Master machine was set at the normal adult settings consisting of 4 mA and 80 kV using a direct current generator; the scan time was 11 seconds. The QR-MC software was developed by the Telesystems Company, and currently the CdTePC sensor and software are available to other manufacturers. The authors have postulated that the capacity for the analysis of image data with the QR Master system should allow, for the first time, the possibility of assessing visual bone details due to the superb level of detail in the tomosynthesis-derived imaging plane and quantification of bone (bone mineral density). This means the consistent separation of different concentrations of mineral density in various locations or configurations in the jaws. The QR-MC software is supplied with the QR Master panoramic machine. The CdTePC sensor results in the production of unique data which are processed by new specifically designed algorithms. The result is a very accurate measurement of bone mineral density.

The fiducial HA test device (Figure 1) was manufactured by Professor Shinji Shimoda of Tsurumi University School of Dentistry and Department of Anatomy, Yokohama, Japan. The object consists of 5 layers of calcium carbonate ($CaCO_3$) in different concentrations as follows: 100%: 2.01 mg/mm^3, 80%: 1.48 mg/mm^3, 60%: 1.04 mg/mm^3, 40%: 0.67 mg/mm^3, and 20%: 0.32 mg/mm^3. The sixth row consists of a base plate material containing no HA material. Carbon was used as the matrix for the $CaCO_3$.

The machines used for image comparison were the Telesystems QR Master, the Auto 1000 (Asahi Roentgen co., Kyoto Japan), and the Veraview Epocs (Morita Co., Kyoto, Japan). Both the Asahi Auto 1000 and the Morita Veraview Epocs systems use a semiconductor sensor designed for panoramic imaging. The sensor is