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Crystal-Structure-Concept-Based Modeling of the Human Spinal Column Validated through 3-D-Bone Scanning

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Spinal column, being a 3-D structure, is not completely visualized in ordinary anteroposterior (AP) X rays, which show spinal projection in the frontal plane. Hence, such X rays do not display kyphosis or lordosis. 3-D-spinal models were able to generate full views from projections of spine in the frontal and the sagittal planes obtained from AP- and lateral-X-ray pictures or moiré topographs of patients in the attention position. A parabolic curve was generated from moiré measurements, $x = x(\xi)$, $y = y(\xi)$, $z = z(\xi)$, best fitted to discrete measurements performed at locations of 33 vertebrae of spinal column, ξ_i; $i = 1, \ldots, 33$ (cervical, thoracic, lumbar and sacral regions). Rotation of coördinate system through a suitable angle made the cross term (yz) vanish and represented curvatures as double the coefficients of squares of y and z. These curvatures were used to define degree of correction of spinal deformity (http://www.ngds-ku.org/Papers/J18.pdf). This 3-D-static model was used to study children's postures. The dynamic model was constructed by including spinal-column movements during a gait cycle, linking spinal column in the anatomical position to the first phase of gait cycle (http://www.ngds-ku.org/Papers/J16.pdf) through edge-based algorithm (http://www.ngds-ku.org/pub/confabst0.htm#C42:). The procedure was repeated to link first phase to the second phase and so on. To construct a vertebral-level model, spinal column was visualized as a crystal structure (http://www.ngds-ku.org/Presentations/BZU1.pdf). The center-of-mass of each vertebra was expressed in terms of positional coördinates in the body-coördinate system, just like *form factor* in crystallography. The surface structure of each vertebra could be studied using moiré fringe topography, which gives 3-D-coördinate information (http://www.ngds-ku.org/Presentations/Moire.pdf) and rasterstereography, which gives curvature information (http://www.ngds-ku.org/Presentations/Rasterstereography.pdf). Combined with rotational (in terms of Euler angles) as well as inter-vertebral-spacing information, such an analysis may be considered equivalent to *structure factor*, determined by crystallographers. In order to study the vertebrae of spinal column of a live human being (without cutting open to reach vertebral surface to study using stereophotogrammteric techniques), *bone-surface-structure scanning* was introduced on May 30, 2013 (http://www.ngds-ku.org/Presentations/Backscatter.pdf)by the first author and elaborated in the Syed Firdous memorial lecture (http://www.ngds-ku.org/Presentations/Scan.pdf), expanding upon the backscatter-body-scanning system, employed for passenger security screening at airports (http://www.ngds-ku.org/Presentations/Security.pdf). Increasing the intensity of backscatter-X rays enough to reach to the bone surface and projecting these X rays through a moiré (http://www.ngds-ku.org/Papers/C68.pdf) or a dotted-raster grid (http://www.ngds-ku.org/Papers/J31.pdf), vertebral surfaces could be studied by generating their height and curvature maps. In *grating-hologram-type-backscatter moiré* passive (post-recorded) correction (for misalignment or rotation) was possible. A projected-dotted-raster grid (X rays blocking raster patterns) generated 3-D-curvature map of the spinal column. Holographic images could be generated by recording and processing multiple images in the semi-circular angular range. As regards radiation damage, backscatter-X rays reflected off the bone surface and were not absorbed in its material, it was assumed that there would not be so much damage as from regular-X rays, provided eyes and gonads are, properly, shielded. Discretion is advised, while using these techniques in high-risk groups. Using techniques from physics (image projection/recording), computer science (edge-based and intensity-based algorithms) and information technology (image processing), sterophotogrammetric imaging of humans using moiré fringe topography, dotted-rastersetereography, raster stereophotogrammetry (http://www.ngds-ku.org/Presentations/Anthroimaging.pdf), edge-based moiré and edge-based dotted-raster have the potential to open up new horizons in 3-D imaging of human-skin, -bone and -organ surfaces (sectional-semicircular views) as well as their infinitesimal movements.

Keywords: Human spinal column, static model, dynamic model, crystal-structure-based model, moiré fringe topography, dotted-rastersterography, backscatter-X-ray scanning
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