**Introduction:** The overall objective of this research is to establish the use of plain radiographs as a simple and effective method for assessing bone mineral density (BMD), an important component in the clinical management of osteoporosis. Most clinical assessments rely on one of the standard x-ray densitometric methods, for example dual energy x-ray absorptiometry, which are relatively expensive and require specialized equipment. In contrast, plain radiographic equipment is widely available and could be a valuable resource in osteoporosis screening and management. Although some plain radiographic densitometric techniques exist currently, they have been limited to measurements of the phalanges or more recently the distal radius. The aim was thus to develop a plain radiograph based method for accurately assessing BMD that may be used at a variety of anatomical sites, e.g., the calcaneus.

**Methods:** Eight human calcanei cleaned of all soft tissue were obtained from a commercial supplier. A 1 cm diameter core from the posterior portion of each calcaneus was removed using a low speed drill under constant irrigation. The cores were saturated in a buffered saline solution and placed in a plastic container containing a given height of the solution. Each sample, standing on its medial-lateral axis, was “covered” by a different height of solution, simulating different overlying thicknesses of soft tissue. The solution heights varied from 3.8 cm to 4.4 cm. Each sample in solution was radiographed at a unique exposure (ranging from 48 to 56 keV), alongside a special composite phantom. The composite phantom was constructed from two materials which are superimposed one on top of the other in a checkerboard fashion (Fig. 1). Each rectangular portion of the composite phantom viewed from above thus corresponds to a unique combination of respective thicknesses of plastic and aluminum. A standard x-ray machine was used to transmit a collimated broadband x-ray beam through each of the calcaneal samples in solution and the composite phantom. Each film radiograph was developed and then digitally scanned using a Microtek Scanmaker Model 5. A typical digitized radiograph is shown in Fig. 2. The image data was then interpolatively processed (Image Processing Toolbox, MATLAB, The MathWorks, Inc.) to obtain BMD in g/cm². This interpolation used the grey levels associated with each distinct region of the composite phantom to identify the aluminum equivalent thickness associated with the mean grey level of the bone sample. The processing also utilized the mean grey level associated with the solution only portion of the image, i.e., the solution surrounding the bone sample, in order to identify the total “tissue” thickness (solution height). An independent measurement of the BMD of each sample was also obtained using single photon absorptiometry (SPA), by placing each sample in a constant height water bath prior to scanning.

**Results:** The BMD obtained using the interpolative processing and composite phantom was reasonably well correlated with BMD obtained using SPA. The relationship is shown in Fig. 3, and has associated with it a correlation coefficient of $R = 0.93$.

**Discussion:** A novel phantom was developed that can correct for the two main sources of variation in plain radiography: overlying soft tissue and exposure (machine variations). The key feature of the approach is that the composite phantom provides the "forward solutions" for a large number of configurations of bone and soft tissue thicknesses, respectively. The BMD is then obtained by simply “looking up” (interpolating) the density value associated with a particular region of interest. It should be pointed out that the choice of aluminum and plastic to mimic (radiographically) bone and soft tissue, respectively is one of numerous possible choices, and was made based on simplicity of fabrication. Future composite phantoms could be made from water and calcium hydroxyapatite, to even better model the attenuations of the actual tissues. In conclusion, the novel approach presented here is a valuable new tool for diagnosis and management of osteoporosis, and perhaps also for studies on trabecular architecture and fracture healing, as well.

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