ABSTRACT

Osteoporosis is a major health problem in India and in many other parts of the world. Osteoporosis can result in diminished quality of life, disability, and death. Hip and other fractures are a destructive consequence of osteoporosis. Each year in the United States, 1.5 million osteoporotic fractures occur, 300,000 of which are hip fractures. Other typical fractures are those of the vertebrae (spine) and forearm (wrist).

Bone mineral density (BMD) is the most useful predictor of fracture risk by far, accounting 70% of variance in bone strength. However, bone strength is not only depending on bone mass but also on the internal trabecular bone structure. During ageing, the bone mass is always reduced and sometimes this loss increases due to osteoporosis. In this case, the trabecular architecture is strongly modified which reduces the biomechanical competence. To study this architecture at the scale of the trabecular thickness, two techniques are available: histomorphometry and radiography. The first one is expensive and invasive; this is not the case of radiographs. An X-ray view of a bone is a projection of the 3D complex structure. The resulting image shows a non stationary and anisotropic texture.

Fractal analysis and other second-order, higher-order statistical approach can characterize both the roughness of the texture and its anisotropy. The fractal dimension of fractal images has been shown to correlate strongly with the degree of ‘roughness’ and ‘complexity’ in an image.
The present study was undertaken with the aim of investigating the usefulness of texture analysis of trabecular structure of the calcaneus as it appears on the plain lateral conventional radiograph. Algorithms were developed in Matlab software for computing fractal and other statistical texture characterizations. For the analysis of the trabecular architectures different regions of interests were chosen considering the heterogeneity of the calcaneus bone, evidence from the literature and clinical significance as well.

Dual Energy X-ray Absorptiometry (DXA) and Quantitative Ultra Sonography (QUS) investigations were done for studying osteoporosis in men and women. For the same subjects, lateral view of the calcaneum (heel) bone was taken with fixed X-ray tube settings and exposure condition as well. The subjects are classified into normal, osteopenic and osteoporosis based on the T-Score. Results indicate that mean BMD is found to be low in postmenopausal women and decreases at a faster rate with age compared to premenopausal women and men. Women who encounter early menopause have reduced BMD which is well below the fracture threshold (T-Score <-2.5) and are at a greater risk of developing osteoporosis fracture in subsequent years than normal women after menopause.

The QUS technique is used to evaluate bone status by measuring Broadband Ultrasound Attenuation (BUA) and Speed of Sound (SOS) in the calcaneous and tibial bone respectively in two different equipments at different interval for different group of subjects. Both the groups underwent DXA tests. Kappa score agreement was calculated between these two methods of evaluation of osteoporosis with DXA. The correlation co-efficient
between the BUA and DXA also SOS and DXA found to be 0.561 and 0.089 respectively.

The assessment of the trabecular architecture was done by fractal analysis using the digitized conventional radiographs of the calcaneum bone (heel bone - lateral view). Two methods were adopted for calculating fractal dimension, namely the surface area technique and the semivariance technique. The software for determining fractal dimensions were validated by comparing the fractal dimension with synthetic images of known dimension and the correlation co-efficient (r-value) was found to be 0.98 between the theoretical and calculated values. The discriminant analysis (DA) applied to these DXA classified groups viz., normal, osteopenic and osteoporosis yielded 66.0% correct classification in the case of women and 42.3% in men.

The trabecular bone architecture of the digitized radiographs was also assessed by the second order statistical analysis i.e., the co-occurrence matrix computed by cropping 64 x 64 pixels at three different clinically significant regions of interests in the image of the calcaneum bone. An algorithm was developed to compute the co-occurrence matrix at four orientations i.e., 0° 45° 90° and 135° and at distance ‘d’ with three pixel separations. Eight parameters were computed from the co-occurrence matrix. The co-occurrence matrix computed at 45° orientation yielded higher degree of discrimination than the matrix computed at other angles. However, the correlation co-efficient between femoral neck bone mineral density and texture parameters was moderate (r=0.34). The discriminant analysis (DA) applied to these DXA classified groups viz., normal, osteopenic and
osteoporosis yielded a maximum of 62.3\% correct classification in the case of women and 67.3\% in men. This was achieved when the co-occurrence matrix computed at 45° at the region of interest -3 (ROI-3) compared to other ROIs and matrix orientations.

The trabecular micro-architecture of the digitized radiographs was then assessed by the higher order statistical analysis i.e., the run-length matrix computed by cropping 64 x 64 pixels at three clinically significant regions of interests in the image of the calcaneum bone. An algorithm was developed to compute the run-length matrix at four orientations i.e., 0° 45° 90° and 135° at distance’d’ with three pixel separations. Seven parameters were computed from the run-length matrix and it was found that out of seven parameters six parameters discriminates the DXA classified groups with a correlation co-efficient (r-value) is 0.566 at a significant level of P=0.0001. The discriminant analysis (DA) applied to these DXA classified groups viz., normal, osteopenic and osteoporosis yielded a maximum of 67.9\% correct classification in the case of women and 63.5\% in men. This was achieved when the run-length matrix computed at 90° orientation at the region of interest -3 (ROI-3) compared to other ROIs and matrix orientation.

Finally the comparison of these methods of assessment of osteoporosis namely DXA, QUS and texture-analysis was done by linear regression analysis and Receiver Operating Curves (ROC). The ROC yielded a higher area under the curve for the texture parameter than the BUA method. The correlation co-efficient between DXA and BUA was found to be 0.561 and between DXA and the texture parameter derived from run length matrix was found to be 0.566.