Morphometric Measurements in Radiographic Image Processing in the Assessment of Post Menopausal Osteoporosis

Shankar N[1], Dr V Rajmohan[2], Sankar K[3]
[1,3]*Assistant Professor, Department of Biomedical Engineering, Saveetha Engineering College,India.*
[2]*Professor, Department of Biomedical Engineering, Saveetha Engineering College,India.*
[1]*bmeshankar@gmail.com*, [2]*Rajmohan.vijay@gmail.com* , [3]*sankark10@gmail.com*

Abstract— **Osteoporotic hip fracture is associated with high mortality and morbidity and often results in a loss of mobility and independence. Osteoporosis is diagnosed by measuring bone mineral density (BMD, g cm^{-2}), a measure of the amount of mineral in a bone. Although BMD continues to serve well it does not fully account for bone strength and only partially accounts for the risk of hip fracture. The shape and structure of the proximal femur also help to determine how forces act in the hip in a fall and their measurement can aid the prediction of hip fracture. In this study, the geometrical variables of the right proximal femur in a total number of thirty Indian women were measured from digital x-ray images, and these results were compared with BMD values of the proximal femur measured by Dual energy x-ray absorptiometry (DXA) for same set of women, as a standard. Results obtained by this proposed approach explored how they were related with BMD and anthropometric factors such as body-height, and body-weight. In this study, it was found that 20% and 23% of the study Indian women were found to have osteoporosis and osteopenia respectively. The mean values of thickness of the medial shaft cortex (SC) as well as lesser trochanter thickness of the medial cortex (NC) and width of the acetabular bone (AW) were lesser in the osteoporotic Indian women than in normal Indian women. These values were found to be decreased by -36%, -19%, and -15% respectively, when comparing to normal Indian women.**

Keywords: Osteoporosis, Indian women, DXA, BMD, proximal femur, radiographic hip geometry

I. INTRODUCTION

'Osteoporosis' is one of the major health problems in India and in many other parts of the world. It affects post-menopausal women, and the elderly of both sexes majorly [1]. Hence the number of osteoporotic individuals increases with greater longevity of the general population. In India, currently about 1.15 billion people, representing a full 17% population of the earth. Out of the total Indian population (100%) approximately 6 million (5.5%) people are osteoporotic and 2.3 million (0.2%) people are being added every year. One out of three women (33.33%) and one out of eight men (12.5%) are suffering from osteoporotic bone fracture in India [2]. Osteoporosis is characterized by an absolute decrease in the amount of bone to a level below that required for mechanical support of normal activity and by the occurrence of non-traumatic skeletal fracture. In other words osteoporosis is very much related to the bone strength [3]. More number of research studies have demonstrated that bone mineral density (BMD) correlates well with the strength of the bone, and hence it predicts the future risk of bone fracture. Its predictive capability is comparable in its magnitude to that of blood pressure for stroke, and better than that of serum cholesterol for coronary disease [4]. The prevention of osteoporotic fractures with consequent reductions in health care costs and excess morbidity and mortality is an important clinical goal. The relevance of detecting patients with osteoporosis before they fracture is well recognized, as there are several drugs for prevention [5]. Several quantitative or semi-quantitative techniques are available for the measurement of BMD or bone mass; these range from simple conventional radiography to sophisticated photon absorptiometry techniques. These techniques vary not only in the source of energy used, but also in the skeletal site and type of bone were bone mineral mass or BMD is measured [6]. Dual energy x-ray absorptiometry (DXA) is presently thought to be the 'gold' standard for measuring BMD due its high accuracy and low precision error; but it is expensive and is confined to only a few corporate hospitals and diagnostic centres in developing countries like India [7].

Bone structure can be estimated by observing the changes in shape and size of proximal femur radiograph. By doing morphometry analysis in proximal femur, we can able to detect the changes in the bone structure. The geometry of the proximal femur is the vital components in determining a person's risk of fracture. The observation of structural changes and trabecular changes for diagnosis was first proposed in the 1960s using radiographs of proximal femur. A number of physicians, due to lack of diagnosis equipment like DXA, observe the structural changes and trabecular change visualize in proximal femur recorded in radiographs to asses osteoporosis. On radiographs, bone structure appears as distinct pattern.

A. *Anatomy of the hip*

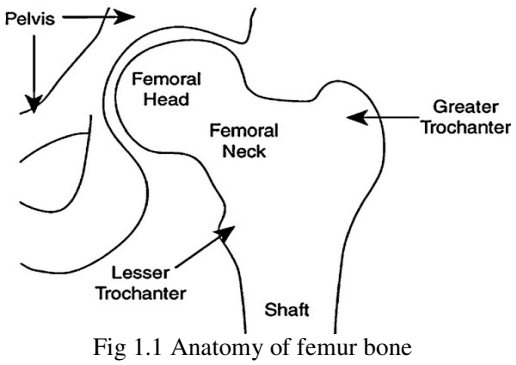

Fig 1.1 Anatomy of femur bone

The hip is a ball and socket joint. This design allows a large range of movement in the hip. The femoral head (the

ball) sits in the acetabulum (the socket), the cup-like recess in the pelvis and the relevant anatomical regions of the proximal femur. In addition to the femoral head and acetabulum, these include the femoral neck, which transmits the body weight from the centre of the body outwards to each leg, the greater and lesser trochanter where the largest muscle groups attach, and the shaft of the femur. The greater trochanter is generally the point of impact in a sideways fall, making the femoral neck particularly vulnerable to fractures .In the proximal femur, the femoral head and neck are predominantly composed of trabecular, or cancellous, bone. Cortical bone forms a shell all around the outside of the bone, but thickens to form the shaft of the femur where there is almost no trabecular bone. In cross-section, the femoral neck has a roughly cylindrical structure, with a varying cortical bone width. The femur is a complicated structure and many different geometrical measures have been tested to see whether they are related to hip fracture or bone strength.

II. BACKGROUND STUDIES

A more widely available and less expensive screening tool is conventional radiography used in conjunction with the Singh's index [9]. The Singh index has been criticized for its low reliability due to the subjective nature of its ill-defined grading and cut-off level for osteoporosis [10]. Digital x-ray radiogrammetry (DXR) is based on the old technique of radiogrammetry [11]. In DXR the cortical thickness of the three middle metacarpal bones in the hand is measured in a digital X-ray image by a computer and is through a geometrical operation converted to the forearm bone mineral density. The BMD is corrected for porosity of the bone, estimated by a texture analysis performed on the cortical part of the bone.

Simple hip geometry measurements made from the plain conventional radiograph is useful in the evaluation of osteoporosis. Hip axis length (HAL) measured from the radiograph has been shown in many research studies to be predictive of osteoporotic hip fracture independent of patient's age, and femoral bone density.

i) Hip axis length (HAL): It is defined as the length measured from greater trochanter to the inner pelvic brim. This measurement appeared to be a sensitive, with a 1 standard deviation (SD) increase in HAL leading to a two fold increase in osteoporotic fracture risk [12-13]. Many studies have noted that HAL is linked to different types of fracture, with longer HAL linked to cervical (intra-capsular) rather than inter-trochanteric fracture. Comparison between spine and hip fracture subjects, both of whom can generally be assumed to have an increased risk of all fractures, the HAL was significantly longer in the hip fracture group. Biomechanically, the link between HAL and fracture risk is intuitive. A longer HAL will create a greater bending moment in the femoral neck in a fall when the greater trochanter makes contact with the floor and the weight of the falling body is applied through the femoral head, making it more likely to fracture. The evidence indicates that HAL is generally a useful addition to BMD for predicting fracture risk [14].

ii) Femoral Neck Axis Length (FNAL): It is the linear distance measured from the base of greater trochanter to the apen of femoral head. Some studies have found that an increased FNAL is linked to an increased fracture risk and this evidence has not been as strong as that for HAL.

iii) Femoral Neck Width (FNW): It is defined as the narrowest distance across the femoral neck often constrained to being perpendicular to the neck axis. It is also called as 'femoral neck diameter'. Many studies have been observed a large neck width in fracture subjects.

iv) Neck Shaft Angle: It is the angle between the femoral neck axis and shaft axis. Also it is called as 'Coput collum diaphysis (CCD) angle'. Sometimes, it can be measured as angle between the vertical extension of the femoral shaft and neck axis. The neck shaft angle should be in range of 120-140 degree. The neck-shaft angle is measured at the intersection of the neck axis (line representing proximal femur length) and the central shaft axis (vertical alignment guide).

v) Other Geometrical Parameters: A number of other hip geometry measures have also been link to the fracture; including a thinner femoral shaft cortex, thinner femoral neck cortex, and narrower trochanteric width, smaller inner and outer pelvic width.

The aim of this study was to test the potential of simple hip geometry variables measured from the conventional hip radiograph in the evaluation of osteoporosis in Indian women, compared with DXA-BMD measurement of the proximal femur as the standard.

III. MATERIALS AND METHODS

A free medical camp for osteoporosis was conducted at private scan centre, Chennai during the month of August 2010. Participants with known kidney diseases, chronic liver, hypo- and hyper- thyroidism, malignancy were excluded. A total number of 30 Indian women (pre menopausal and post menopausal) whose age ranged from 20- 85 years were included in the current study. No one had previous osteoporotic fracture. BMD of the right proximal femur was measured in all study Indian women using a DXA, the total body bone densitometer (DPX Prodigy DXA Scanner, GE-Lunar, USA). It measures BMD at different regions of the proximal femur regions, which includes neck, Ward's triangle, trochanter region (greater and lower), shaft cortex, and total proximal femur. The measured BMD (g cm^{-2}) at these regions of interest (ROI) were denoted as follows: i) N-BMD; ii) W-BMD; iii) Tr-BMD; iv) S-BMD; and v) T-BMD. Also, digital radiograph of the right hip was obtained in all study Indian women for the hip geometry measurements using a digital x-ray machine (Multiphos, Siemens, Germany). The images were taken with 15° internal rotation of the femur region.

WHO's diagnostic criteria for osteoporosis was used in the study; Based on the femur neck BMD values measured by DXA, total women were divided into the following sub-groups: Group-I: Normal Indian females (n=17, Mean ±SD age = 42.8 ±11.1 years); Group-II: Indian women with osteopenia (n= 7, mean ±SD age = 49.6 ±12.5 years); and Group-III: Indian women with

osteoporosis, but no previous osteoporotic fractures (n=6, Mean±SD age = 69.2 ±12.7 years).

As outlined by Gluer et al (1994) and Reid et al (1994) [7-8], the following hip geometry measurements were carried out manually on the digital hip radiograph using Jivex DICOM viewer software.

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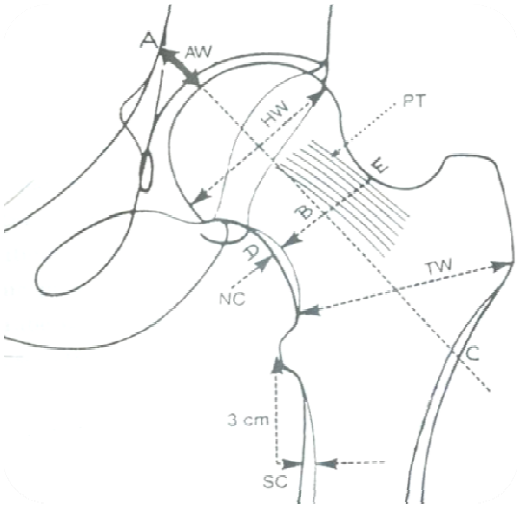

Fig 1.2 Femoral and pelvic bones and placement of selected geometry measurements

A. Femoral Geometrical Measurement

i. Thickness of the medial shaft cortex (SC) at 3cm below the lesser trochanter
ii. Thickness of the medial cortex (NC) at the centre of femur neck
iii. Width of the femoral head (HW)
iv. Width of the inter trochanter region (TW)
v. Width of the acetabular bone (AW)
vi. Hip axis length (AC)
vii. Femoral length (BC)
viii. Femoral width (DE)
ix. Hip axis length/ femur width (AC/ DE)
x. Femoral length/ femoral width (BC/DE)

Data analysis was carried out using SPSS/PC statistical software package. Mean ± SD values proximal femur DXA-BMD measurements as well as radiographic hip geometry measurements were calculated in each group.

IV. RESULTS

i) WHO's Diagnostic Criteria for Osteoporosis Using Measured BMD Values of the Proximal Femur using DXA:

Table 4.1 gives the mean ± SD values of measured BMD values at different ROI in the right proximal femur in various sub-groups of Indian women.

TABLE 4.1 Measured radiographic hip geometry Variables in Indian women

Anthropometric measurements and BMD values of proximal femur using DXA	**Total Indian women, n=30**		
	Normal (n=17, age = 42.8 ±11.1 years)	**Osteopenia (n= 7, age = 49.6 ±12.5 years)**	**Osteoporosis (n=6, age = 69.2 ±12.7 years)**
Body-height (cm)	151.4 ± 5.3	149.1 ± 3.6	147.3 ± 4.8
Body-weight (Kg)	59.1 ± 10.9	47.5 ± 4.7	46.3 ± 4.9
BMI (Kg m^{-2})	25.7 ± 4.3	21.4 ± 2.6	21.4 ± 2.7
N-BMD (g cm^{-2})	0.97 ± 0.21	0.76 ± 0.03	0.60 ± 0 .08
W-BMD (g cm^{-2})	0.81 ± 0.18	0.61 ± 0.08	0.39 ± 0.09
Tr-BMD (g cm^{-2})	0.79 ± 0.11	0.61 ± 0.07	0.41 ± 0.12
S-BMD (g cm^{-2})	1.21 ± 0.13	0.80 ± 0.36	0.63 ± 0.15
T-BMD (g cm^{-2})	1.01 ± 0.13	0.81 ± 0.04	0.54 ± 0.11

In this study, it was found that 20% (6/30), and 23 % (7/30) of the study Indian women were found to have osteoporosis and osteopenia respectively. The measured mean femur neck BMD values in normal Indian women was 0.97 g cm^{-2}, whereas, in osteoporotic Indian women, it was 0.60 g cm^{-2} and it's percentage decrease was found to be -38% [(0.97-0.60)/0.97 x 100]. In osteoporotic Indian women, the percentage decrease in body-height as well as body-weight was -2.7% and -21.7% respectively, when comparing to normal Indian women.

ii). Radiographic Hip Geometry Measurements using Digital right hip AP view radiograph:

Table 4.2 gives the mean ± SD values of measured hip geometry variables from the digitized hip radiograph in various sub-groups of Indian women. The mean values of thickness of the medial shaft cortex (SC) as well as lesser trochanter thickness of the medial cortex (NC) and width of the acetabular bone (AW) were lesser in the osteoporotic Indian women than in normal Indian women. These values were found to be decreased by -36%, -19%, and -15% respectively, when comparing to normal Indian women.

The figure 4.1 shows the hip geometry variables that were measured from the digital hip radiograph in a normal Indian woman, whereas the figure 4.2 shows the same that was carried out in an osteoporotic Indian woman.

TABLE 4.2 Measured radiographic hip geometry Variables in Indian women

S. No	Measured Hip Geo-metrical Parameters (mm)	Total Indian women, n=30		
		Normal (n=17, Mean ±age = 42.8 ±11.1 years)	Osteopenia (n= 7, Mean ±age = 49.6 ±12.5 years)	Osteoporosis (n=6, Mean ±age = 69.2 ±12.7 years)
i)	SC (mm)	7.5 ± 1.7	6.3 ± 1.7	4.8 ± 0 .9
ii)	NC (mm)	5.2 ± 1.0	4.3 ± 0.8	4.2 ± 0.9
iii)	HW (mm)	42.8 ± 10.3	38.3 ± 10	43.6 ± 14.3
iv)	TW (mm)	44.9 ± 11.9	45.4 ± 12.7	43.6 ± 12.1
v)	AW(mm)	7.8 ± 1.8	6.4 ± 2.7	6.6 ± 0 .7
vi)	AC (mm)	92.5 ± 22.1	89.9 ± 21.9	92.4 ± 24.7
vii)	BC (mm)	42.9 ± 11.7	40.2 ± 11.4	41.0 ± 12.9
viii)	DE (mm)	32.2 ± 8.9	31.6 ± 7.7	33.5 ± 7.5
ix)	AC/ DE	2.9 ± 0.4	2.9 ± 0.5	2.7 ± 0.3
x)	BC/DE	1.3 ± 0.1	1.3 ± 0.3	1.2 ± 0.2

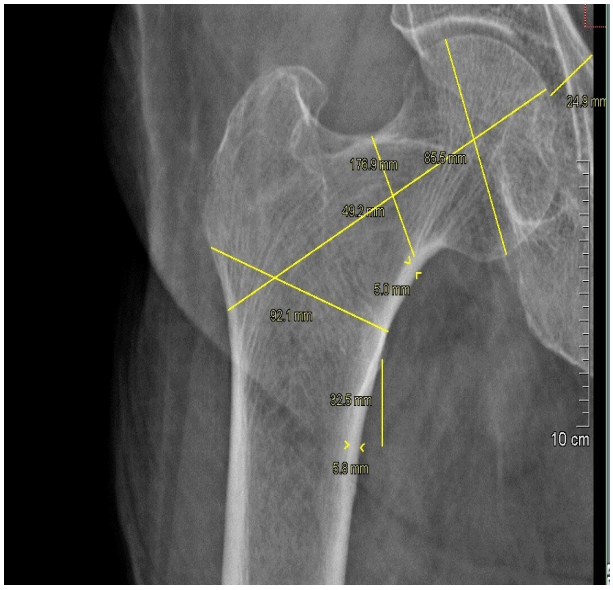

Fig 4.1 Hip geometrical measurements on a digital radiograph of Normal Pre Menopausal Indian woman aged: 28, the measured Total hip BMD by the DXA in the same individual was: 0.966g/ Cm 2

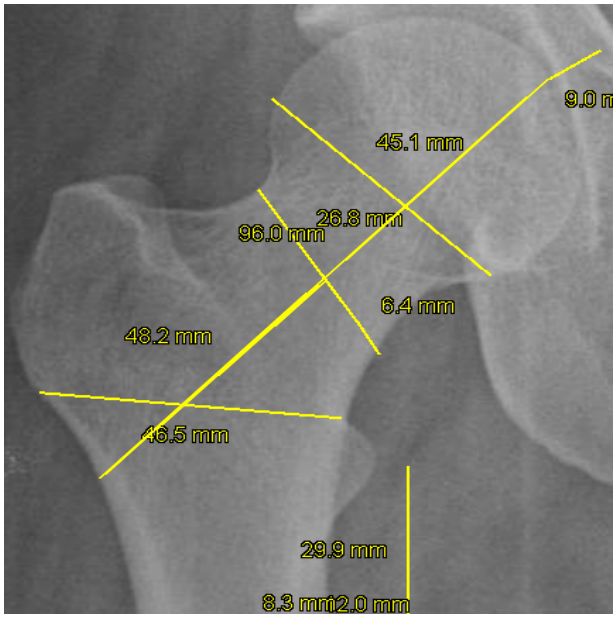

Fig 4.2 Hip geometrical measurements on a digital radiograph of Normal Post Menopausal Indian woman aged: 54, the measured Total hip BMD by the DXA in the same individual was: 1.021 g/ Cm 2

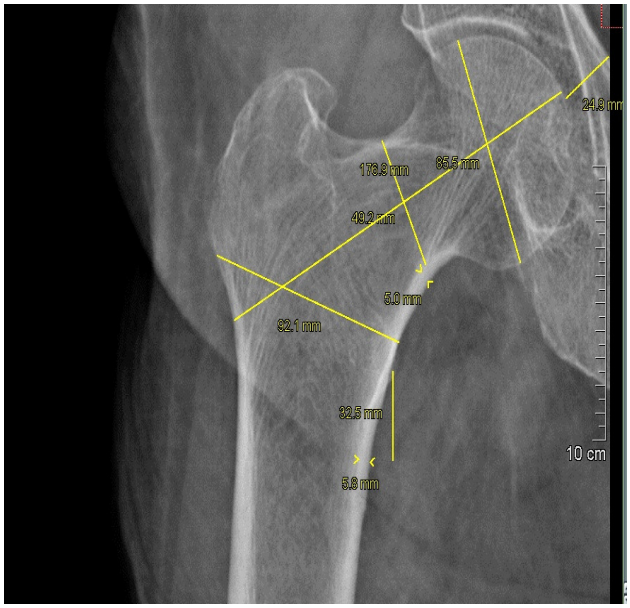

Fig 4.4 Hip geometrical measurements on a digital radiograph of osteopenia Post Menopausal Indian woman aged: 70, the measured Total hip BMD by the DXA in the same individual was: 0.762 g/ Cm 2

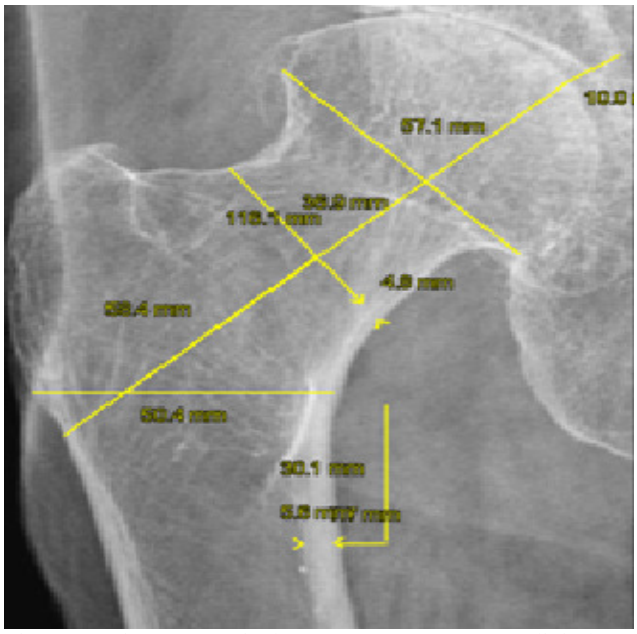

Fig 4.3 Hip geometrical measurements on a digital radiograph of osteoporotic Post Menopausal Indian woman aged: 80, the measured Total hip BMD by the DXA in the same individual was: 0.506 g/ Cm 2

DISCUSSION

In this study, it was reported that 20% of the study Indian women were diagnosed as having osteoporosis. In a earlier study, it was reported that 58.6% of the post-menopausal Indian women were diagnosed as having osteoporosis [7]. Gluer and co-workers [8] have reported that a reduced cortex thickness of the femoral shaft and femoral neck cortex, wider trochanteric width and a lower score for Singh's index predicted osteoporotic hip fractures in women independently. With the exception of trochanteric width, this was confirmed in this study. Using the total hip BMD by DXA as a reference method, the cut-off values apply for diagnosing osteoporosis in Indian women with good sensitivity were establihsed in another study [15] and is given as follows: the medial cortex thickness of the femoral neck and femoral shaft values less than or equal to 3.8 mm as well as 7.1 mm respectively. The accuracy of the radiographic geometry measurements may be affected by magnification and projection of the bones on the radiograph. Despite these limitations, radiographic hip measurements are able to predict hip fractures [8].

The limitation of the study is small number of patients were included. The risk factors for the disease were not considered in this study. Also, there was no woman with previous osteoporotic fracture.

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