CHAPTER 7

SUMMARY AND SUGGESTIONS FOR FUTURE RESEARCH WORK

7.1 SUMMARY OF THE WORK PRESENTED IN THIS THESIS

The present study was undertaken with the aim of investigating the utility of simple conventional X-ray, with estimated empirical formula and research methods for studying osteoporosis in south Indian women. In addition, a possible derived empirical relationship between the radiographic method and advanced technique was derived for diagnosing low bone mass as well as the validation of published empirical formula with fracture risk prediction in the south Indian women population at a low cost with high sensitivity.

7.1.1 Clavicle and Proximal Femur Radiogrammetry

- The calculated cortical bone mass indices of both clavicle and femoral shaft from the low-cost conventional digital radiographs were found to be correlated statistically significant (p < 0.01) with measured T.BMD (g/cm²) by DXA bone densitometer, a ‘gold’ standard for the measurement of BMD, in both all women studied, as well as women having low bone mass.

- When the published threshold values of clavicle bone mass indices were used in this study, it was found that 39.2% of and 61.8% of the women were at greater risk of osteoporosis in total women studied group and older women aged, 50 years.
- The published empirical formula involving simple clavicle radiogrammetry predicted T.BMD with 88.8% sensitivity, and 89.6% specificity in total women studied. Its positive- and negative- predictive values were found to be 88.8% and 89.6% respectively. On the other hand, when the formula was tested in older women, aged 50 years, and above, it had 95.6% sensitivity, and 90.9% specificity, whereas, its positive- and negative-predictive values were found to be 95.6% and 90.9% respectively.

- In this invitro study an aluminium chest phantom was constructed. This study suggested that the accuracy of clavicle radiogrammetry measurements in the calculation of bone mass indices namely \((D-d)\) and \((D-d/D)\) are found to be ranged from 86% to 98.91% and 84.34 to 98.58% respectively.

### 7.1.2 Computer Aided Diagnosis (CAD) approach in proximal femur Radiogrammetry

- The established empirical formula (shown in the equation below) for predicting total hip BMD \((g/cm^2)\) based on the extracted cortical features from the right hip digital radiograph.

\[
Y = 0.645 - 0.007(X_1) + 0.013(X_2) + 0.009 (X_3)
\]

Where ,

- \(Y\) - Predicted Total hip BMD (T.BMD) \((g/cm^2)\)
- \(X_1\) - Patient’s age
- \(X_2\) – CCT (mm) of the femur shaft
- \(X_3\) - % CCT of the femur shaft

- In both total women studied \((n = 36)\), and older women aged 50 years and above \((n = 27)\), the predicted T.BMD using the established formula was correlated statistically significant \((p <\)
0.01) with measured T.BMD by DXA (r = 0.79 and r = 0.82 respectively).

- The established empirical formula, predicted T.BMD from simple digital semi-automated femoral shaft radiogrammetry with 85.7% sensitivity, and 86.6% specificity in total women studied. The positive- and negative- predictive values were found to be 90% and 81.2% respectively. On the other hand, when the formula was tested in older women, aged 50 years, and above, it had 94.7% sensitivity, and 87.5% specificity, whereas, the positive- and negative- predictive values were found to be 94.7% and 87.5% respectively.

- A semi-automated CAD tool was developed using the established empirical formula involving femoral shaft radiogrammetry to predict T.BMD with high accuracy.

7.1.3 Hospital based Screening for Post-Menopausal Women with Low Bone Mass using Low-Cost Conventional Radiographs

- The predicted T.BMD by both clavicle- as well as femoral shaft-radiogrammetry measurements were negatively correlated (p < 0.01) with woman’s age (r = -0.55 and r = -0.53 respectively) in total post-menopausal women screened.

- When a threshold value of T.BMD < 0.9 (g/cm²), based on collected peak BMD data of this study, was used in WHO’s diagnostic criteria, it was found that all women screened, 100% (17/17) of the women were diagnosed as having low bone mass when using predicted T-BMD by clavicle radiogrammetry, whereas, it was only 59% (10/17), when using predicted T.BMD by femoral shaft radiogrammetry.
When the published threshold values of clavicle bone mass indices were used in this study, it was found that 35% of post-menopausal women screened were at future osteoporotic fracture risk.

7.1.4 Forearm Radiogrammetry in Future Osteoporotic Fracture Prediction

- When the feed forward back propagation network (BPN) using demographic, metacarpal-, radius-, and ulna- radiogrammetry variables was used, it was found that, the sensitivity and specificity of this classifier for diagnosing the low bone mass in women were found to be 96.6% and 96.3% respectively. Also, the accuracy of this classifier was found to be 96.4%.

- When the published threshold values of second metacarpal bone mass indices were used in this study, it was found that 92% of the women having low bone mass studied were found to be at greater risk of future osteoporotic fracture.

Recommended best suitable X-ray based method in the evaluation of Low bone mass (Comparison of chapters 3 and 6).

- It was found that (Appendix 4, Table 1), T.BMD measured by DXA in total women studied (n=56), correlated statistically significant (P<0.01) with the following radiogrammetry variables: i). CCT and %CCT of CL; ii). CCT and %CCT of FS; iii). CCT and %CCT of M.

- In all total women studied the calculated CCT and %CCT of the following bone regions: i). Clavicle, ii). Metacarpal, and iii). Femoral shaft were found to be correlated significantly with T.BMD measured by DXA. It was found that the statistical correlation values were greatest in clavicle radiogrammetry
variables (0.87 and 0.86 of CL-CCT and CL-CCT% respectively), compared to other radiogrammetry variables. This suggests that clavicle radiogrammetry can be the best method studied in the evaluation of low bone mass.

- In Appendix 4, Table 2 shows the comparison of data between mean values of clavicle-, forearm-, and hip- radiogrammetry variables in women having low bone mass (Group-II: n = 27) and normal women (Group-I: n = 29). In women with low bone mass (Group-II), the mean values of T.BMD by DXA was lesser significantly by 31% \([ (1.04-0.72/1.04) \times 100] \) when compared to normal women (Group-I). Similarly, the mean values of the following variables (methods) in Group-II were lesser significantly compared to Group-I: i) 41% (CL-CCT), ii) 38% (CL-CCT%), iii) 14% (FS-CCT), and iv) 13% (FS-CCT%), v) 32% (M-CCT), vi) 31% (M-CCT%). In Group-II, the percentage decrement in measured variables were greatest in both CCT and %CCT of the clavicle. Again, this data suggest that clavicle radiogrammetry can be the best method studied in the evaluation of low bone mass.

7.2 SUGGESTIONS FOR FUTURE RESEARCH WORK

Based on the outcomes of the present study on low bone mass, there are some suggestions for further research works in this field are given as follows:

- The established semi-automated CAD tool using the established empirical formula involving conventional femoral shaft radiogrammetry in this study can be tested in large aged population and it can be validated. Thereby, it could be used as a cost effective screening tool for the diagnosis of osteoporosis with high accuracy, especially in India due to non availability of DXA machines.
An automated CAD tool could be implemented for selecting the region of interest of lesser trochanter from the standard digital hip X-ray. It would reduce the manual error, and thereby increase its accuracy significantly. Moreover, it can be tested with even a person with minimum computer knowledge.

The development of an automated CAD tool involving standard conventional digital X-rays of other skeletal sites, namely clavicle, and forearm could be useful as a cost effective mass screening tool in the evaluation of low bone mass.