ABSTRACT

‘Osteoporosis’ is a gradually advancing musculoskeletal disorder resulting in reduced bone mineral density (BMD) and weakening of bone microarchitecture as well as resulting in the frail skeleton and increased fracture risks. Osteoporosis and associated fractures contribute to one of the major causes of disability and the decrease in BMD are usual for both women and men on getting old, especially among women in the post-menopausal period. The limited number of DXA machine due to its huge capital investment and higher scan cost results in its ill-affordability for the most Indian population. The connection between the oral health and bone health have been well documented across the globe over the years. Dental Panoramic Radiographs (DPR) are preferred by dentists for their routine diagnosis and is commonly available in the most parts of the world at an affordable cost. Hence, the research study was aimed to extract the trabecular and cortical bone features from a digital DPR to estimate the BMD at the spine and hip and thereby to find persons at the possible risk of low BMD.

The aim of the first study was to extract the panoramic mandibular measures on a DPR and thereby to detect its age associated and sex-related variations for the studied people. The DPR was obtained by means of a DPR scanner (KODAK 8000C, Carestream Health, Inc., France) at X-ray tube voltage of 70 KV, 6.3mA with an exposure time of one second by adopting the standard protocol and the measurements were made using the software provided by the manufacturer. The study was performed with 279 participants inclusive of 176 female (mean age: 47.2 ± 12.5 years) and 103 male (mean age: 46 ± 11.6 years). The total population was divided into five-decade age groups in men and women separately as follows: (a) 31 to 40 years, b) 41 to 50 years, c) 51 to 60 years, d) 61 to 70 years and e) > 70 years. Furthermore, categorisation was made into three progressive age groups as Young age (31 to 40 years), Middle age (41 to 59 years) and c) Old age (≥ 60 years). Also, the total participants were divided into three groups based on the visual scoring of the mandible endosteal margin as per the Klemetti index (KI) as, “Normal, Mild bone loss and Severe bone loss group”. The Post-hoc tests (Tukey HSD) revealed statistically significant differences at the level (p < 0.05) for the mandibular cortical thickness (MCT) and panoramic mandibular index (PMI) between the women aged above 60 years and below 60 years. The results clearly depict that the onset of cortical bone thinning is
prominent after the fifth decade of a women life. The mean values of the MCT were found to be 3.12 ± 0.4 mm, 2.8 ± 0.5 mm and 2.03 ± 0.4 mm respectively for normal, mild bone loss and severe bone loss groups classified based on the Klemetti index (KI) among the studied women population. The mean values of the MCT and PMI declined by 35 % and 31% among women in the severe bone loss group in comparison with the normal group. While the impact of ageing phenomenon on the mandible endosteal margin were taken into concern, there was a steep rise in the erosion of cortical bone on advanced ageing. When such analysis was carried out among the men population, it was observed that statistically significant differences were not found for MCT and PMI for the decade age groups as well as decade age groups. The outcomes of the work revealed the onset of MCT thinning to be prominent after the sixth age decade of a men life. Chi-square revealed that subject’s age doesn’t play a statistically significant factor in the endosteal margin erosion among men population. The results of our study infer that the decrease of the mandibular measurements are prominent in women only and they are more prone to loss of BMD than men. In conclusion, we noticed that the deterioration was prominent in women than men concerning radio-morphometric indices. Moreover, the panoramic indices showed an eminent decrease after the sixth and fifth age decade for men and women respectively.

The aim of the second study was to study the association of the mandibular measures [MCT, PMI and trabecular bone area (TBA)] and age with the DXA-BMD (gcm⁻²) of the right proximal femur and AP spine (L1-L4) and also to derive an empirical formula to estimate right femur total BMD (T-BMD) and AP spine (L1-L4) BMD. In this study, a semi-automated approach to measure the MCT and calculate the TBA on the DPR was implemented. The study involved 56 women (mean age: 57.24 ± 11.9 years) categorised into two groups separately according to the T– score values of T-BMD and AP spine (L1-L4) BMD. The total subjects were further classified into high-risk group (those with T–score < –1 SD for both right femur total BMD and AP spine (L1-L4) BMD) and moderate risk group (those with T–score < –1 SD for either right femur T-BMD or AP spine (L1-L4) BMD). Moreover, the total population were also classified as Normal, Mild bone loss and severe bone loss groups based on the KI. The BMD measurement at the right femur and AP spine (L1-L4) was performed using a DXA Scanner (DPX Prodigy; GE Lunar Corporation, USA). The BMD measurements were made using the software provided by the equipment manufacturer. The WHO standard classification for diagnosis of osteoporosis was followed to categorize the participants based on their BMD.
DPR was obtained adopting the same machine and protocol as mentioned in the earlier chapter. The MCT measurement was performed at the region of mental foramen and measurements were made using the Manual digital mandibular Morphometry and Semi-automated digital mandibular Morphometry incorporating the digital image processing techniques. The TBA calculation was performed using digital image processing techniques (preprocessing, image enhancement and subsequent segmentation) to reveal the extent of the trabecular bone. The Bland – Altman plot was used to observe the level of agreements between the MCT measurements made using the manual and semi-automated approach. The clinical relevant features extracted from the DPR and the subject’s age were used to develop the empirical formula to estimate the right femur T-BMD and AP spine (L1-L4) BMD. The empirical formula for estimating the BMD using Stepwise multivariate linear regression models are as follows:

Estimated right femur BMD (gcm\(^{-2}\)) = 0.102 × MCT + 3.263 × TBA – 0.871

Estimated AP spine (L1-L4) BMD (gcm\(^{-2}\)) = 0.048 × MCT + 2.222 × TBA – 0.003 × Age – 0.095

Where,

MCT: Mandibular cortical thickness in mm
TBA: Trabecular bone area
Age: in years

The results of the t-test performed between the normal and low BMD groups based on the right femur T-BMD and AP spine (L1-L4) BMD revealed a statistically significant difference at the level (p < 0.01) for age, MCT, TBA, PMI, DXA measured BMD and the estimated BMD. The results clearly imply that panoramic measures (MCT, PMI and TBA) decrease for individuals with low BMD either at femur or spine. Similarly, statistically significant differences were observed for the MCT, PMI, TBA and the estimated BMD at the level (p < 0.01) between the moderate-risk and high-risk groups. Post-hoc tests (Tukey HSD) revealed a statistically significant differences at the level (p < 0.01) between the normal and severe bone loss groups for all the mandibular measurements (TBA, MCT and PMI). The MCT and TBA decreased by about 46% and 4% respectively in the severe bone loss group when compared with the normal group. The derived empirical formula for estimating the right femur
T-BMD and AP spine (L1-L4) demonstrated the accuracy of 93% and 84% respectively in identifying individuals at risk of low BMD. Based on various threshold levels of MCT, it was observed that at MCT = 2.3 mm, the sensitivity, specificity and accuracy values were 92%, 80.7% and 85.8% respectively in identifying individuals with low BMD at the right proximal femur. Similarly, while seeking the optimal threshold levels to ascertain individuals at risk of low spine BMD, it was observed that at MCT = 2.5 mm, the sensitivity, specificity and accuracy values were 82%, 73% and 79% respectively. Therefore, the findings of the study suggest that at MCT = 2.5 mm could be an optimal threshold to ascertain individuals at the risk of low BMD at either right proximal femur or AP (L1-L4) lumbar spine. Thus, the derived empirical formula to estimate right femur T-BMD and AP spine (L1-L4) could be useful in identifying persons at the possible risk of low BMD using cortical and trabecular bone information extracted from DPR.

The aim of the third study was to implement the empirical formula on a sample population to estimate their right femur T-BMD and AP spine (L1-L4) BMD and thereby to screen women who are at the possible risk of low BMD. The study involved (n=18) women (mean age = 57.65 ± 12.1 years) was separated into two groups based on T-score values of proximal right femur T-BMD and AP spine (L1-L4) as low BMD and normal groups. The BMD measurement at the right femur and AP spine (L1-L4) and DPR were taken using the same imaging modalities described in the earlier studies. The MCT measurement was made using the manual digital mandibular morphometry and semi-automated digital mandibular morphometry using the approaches adopted in the earlier study. Similarly, the TBA calculation was performed using digital image processing techniques as mentioned in the earlier study. The derived empirical formula was used to estimate the right femur T-BMD and AP spine (L1-L4) BMD. The results of the t-test exhibited statistically significant differences between the low BMD and the normal groups based on the right femur T-BMD at the level of (p < 0.05) for MCT, TBA, DXA measured BMD and the estimated BMD. This clearly indicates that the MCT and TBA decrease for individuals with low BMD at the right femur. The TBA, MCT and the estimated right femur T-BMD in the low BMD groups decreased by 4.5%, 25% and 16% respectively, when compared with the control subjects. Similarly, the TBA, MCT and the estimated AP spine (L1-L4) BMD in the low BMD groups decreased by 4.5%, 18% and 9% respectively when compared with the control subjects. The derived empirical formula for prediction of right femur T-BMD applied on the sample population yielded a sensitivity of 91%, specificity of 71% and an accuracy of 83% in
identifying individuals at who are at risk of low BMD at the right femur. Similarly, when the proposed empirical formula for prediction of AP spine (L1-L4) BMD was applied on the sample population, they produced a sensitivity of 82%, specificity of 57% and an accuracy of 72% in identifying individuals at who are at risk of low BMD at AP spine (L1-L4). In conclusion, our findings suggest that the proposed method of using MCT, TBA and age to estimate right femur T-BMD and AP spine (L1-L4) BMD could be useful in identifying individuals at risk of low BMD.