ABSTRACT

Bone Mineral Density (BMD) is the amount of mineral per square centimeter of bone. BMD testing is a non-invasive method to diagnose bone disease, low bone density, predicts fracture risk, and monitor changes in bone density over time. 25 million Americans and 61 million Indians are affected with bone disease like Osteoporosis, Rheumatoid arthritis, Crohn, etc. Health care costs for the treatment may exceed $18 billion annually.80% of those affected are women.1 in 2 women and 1 in 8 men over 50 will have an bone disease related fracture according to WHO's statistics. Hence it is necessary to investigate the various measurement systems and give a better solution for assessing the bone quality in order to enhance the sensitivity, accuracy and cost effectiveness in measurements.

Studies show that there are various techniques available for assessing the bone quality or the loss in bone mineral density non invasively. BMD can be measured through the use of various scanning or imaging techniques like Dual Energy X-ray Absorptiometry (DEXA), Single Photon Absorptiometry (SPA), Dual Photon Absorptiometry (DPA), and Quantitative Computed Tomography (QCT)). All the imaging systems are utilizing X-rays as a source to assess the extent of bone disease like osteoporosis at various sites and this may be harm to the subject if the dose is not controlled properly. Generally, in case of DEXA, X-ray films show bone loss only when it exceeds 40% or more.

The non imaging techniques available for this purpose are Ultrasound and Vibration or Impulse response method. Ultrasound studies provide information about the medium (tissue) through which it is being propagated .This works on the fact that Ultrasound wave is modified by

bone’s structure, composition and mass. This technique was considered as simple and immediate test results can be obtained from the setup but the surface of part to be inspected must be accessible to sonic probe, the test method is directional depending on sound beam defect orientation and high degree of skill and experience is required to conduct and interpret results for varied test conditions.

Bone quality was assessed using vibration or low frequency impulses applied on it and the response was analyzed. The change in various structural parameters of the bone structure by stress wave propagation such as frequency and time domain response parameters were analyzed. The existing setup for this purpose utilizes a manual hammer to apply the force on a particular location on leg bone (tibia) and two piezoelectric accelerometers are used to pick the vibration response and analyzed.

This thesis is mainly focused on vibration technique. The aim is to develop a system that can assess the bone quality using vibration method by incorporating Automatic hammer for applying the force of uniform magnitude and MEMS accelerometers to investigate the measurement results. In this setup, the hammer movement for applying impulsive force is controlled automatically by either programming of Microcontroller or by using Lab view software utilizing proximity sensor for its operation. This may enhance the sensitivity and accuracy of the response. The natural frequency, Amplitude ratio and Wave velocity are the parameters of interest for analysis since these are easily obtained and quantified from measured vibration responses.

The experimental arrangement was such that the subject was asked to sit comfortably on a chair by keeping the legs vertically on a vibration free wooden platform. The preselected points for the hammer strike and for the acceleration sensors mounting were marked on the leg bone and then the two acceleration sensors (sensor-I & II) are attached. These sensors are used to

collect the vibration from hammer knock in terms of acceleration signal. Before commencing the experiment the subject was asked to give the feedback for the questionnaire which contains questions mainly about the age, sex, height, weight, medical history, Menopause state for women etc in order to segregate them in to controlled and uncontrolled groups. Data were collected from 35 subjects of men and women under 20-25 years , 45-55 and 56-65 years from each groups .

The time of measurement, the number of recorded values and the frequency range of excitation are configured on the recorder. The frequency range 20 – 100 Hz was tested. The recording time was set as 500ms and 500 values were recorded. Thus, the sampling frequency was kept as 1 KHz. Recorded data was stored in the form of text file and further processing like filtering is done using Mat lab software. Frequency domain analysis were done by taking FFT by considering the sampling frequency as 1 KHz and the peak Power in mean square amplitude was measured for men and women subjects and compared. The natural frequency is also computed from the frequency response curve. It is observed that the natural frequency and peak power values are low in women than men.

Result shows that the peak acceleration value from acceleration sensor-I is higher than sensor-II because of the propagation delay between them. It is observed that the value of peak acceleration is less for men under the age group of 20-25 years comparing with their age matched women subjects. This is because of their good BMD during this stage and also according to the hypothesis that women have less BMD and so their bone gets more accelerated by excitation. This was proved also by statistical tests and significant difference is seen in both the Accelerometer outputs based on the obtained P values. The P value or calculated probability is the estimated probability of rejecting the null hypothesis of a study question when that

hypothesis is true. If the P value is less than the chosen significance level then reject the null hypothesis i.e. accepts that the sample gives reasonable evidence to support the alternative hypothesis. From the time domain response curve, the Amplitude ratio and Wave velocity of the acceleration signals are calculated and the difference is observed for both men and women subjects

In order to observe the relationship between the peak acceleration and the BMI, the BMI of the subjects were calculated by using the standard formula and tabulated by classifying them as Normal and Overweight for interpreting the results. Comparison between men and women subjects under 20-25 age groups with normal and overweight ranges with respect to BMI were made. From the acceleration peak and the BMI values it is found that there is a relationship between both the parameters among various groups. The BMI and the Bone acceleration peak values are inversely proportional to each other and it shows that if the BMI of the subject is high then the acceleration gets reduced. That is when the BMI is increased the acceleration is decreased in both the cases.

The similar relationship is also seen in the pre and postmenopausal women subjects under 45-55 age groups and 56-55 years respectively. Moreover there exists a significant difference in Acceleration range in both the cases. That is in Post menopausal stage, the Bone peak acceleration is less compared to the Premenopausal stage among elderly women subjects ($p<0.05$). In these cases, the acceleration peak is high.

From the investigations made on the impulse response parameters by using the proposed measurement system, the quality of bone may be assessed by simple modifications on existing one. This in-vivo measurement of bone quality using smart sensing technique may improve the sensitivity, accuracy, and reliability, inexpensive and may have diagnostic potential in the assessment of bone quality.