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# DETECTION OF OSTEOPOROSIS AND OSTEOPENIA USING BONE DENSITOMETER – SIMULATION STUDY

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**Abstract**

The bone disorders can happen in two ways accidentally and lack vitamins. These both Osteoporosis & Osteopenia are the bone minute fractures which can be detected through various processes and methods. Especially both these bone disorders are due to Vitamin (D3) deficiency. Here the detection of bone disorders are done with the help of bone densitometer. The bone densitometer uses a technique that the bone density can be measured in-terms of T-score. The derived values were plotted with the help of standard deviation values. Perhaps those standard deviation values (T-score) used as derived values through simulation using Matlab software. In this paper we are suggesting a amenity that can add more values to the results. Earlier the values used in DEXA(Dual Energy X-ray Absorptiometry) machine were not precise in-terms of finding the minimal dissimilarity between Osteoporosis & Osteopenia .Hence here a method is proposed with IDEXA machine which provides more precise value. These values can be processed by simulation to classify which kind of fracture it is in human bone with help of KNN classifier algorithm. By Using KNN classifier the values are compared more easily by getting a standard deviation of derived values whether it is Osteoporosis or Osteopenia affected patient. The association between both Osteoporosis & Osteopenia can identify predominantly.



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## 1. **Introduction**

Bone disease is common now days in human due to major two reasons are low calcium ingestion and lesser estrogen levels at menopause. Research has shown that countries with the highest calcium ingestion have the highest hip fracture rates. Furthermore, it is identified that nearly 19 nutrients in addition to calcium that are essential to bone health. A bone is a stiff structure that becomes a vital part of the vertebral skeleton. A bone holds up and protects various organs of the human body. Bones heels us to maintain and store minerals. The bone helps us in other ways like enable mobility Etc. The following bone diseases are common in human now a day Osteoporosis, Bone Cancers, Osteogenesis Imperfecta, Osteomalacia, Acromegaly, Osteomyelitis and Osteopenia. In the above mentioned list of diseases more common is Osteoporosis and Osteopenia. Since past couple of years Osteoporosis and Osteopenia affected patient increased in very high numbers. [8][2]

There are many ways to detect bone density out of which DXR and DXA are mark-able. Digital X-ray radiogrammetry (DXR) is a method to approximate bone mineral density (BMD) that can be accessible in any area able to take a standard radiograph of the hand. We meant to found the accuracy of this technique and study this with that obtained by dual energy X-ray absorptiometry (DXA) at the hip and spine. We studied DXA and DXR in 28 women with osteoporosis defined by DXA at the femoral neck and in 28 women with normal BMD. We found that DXR has tremendous precision of 0.004 g/cm (2) compared with 0.021 g/cm(2) and 0.015 g/cm(2) obtained by DXA at the hip and spine, respectively. We wind up that DXR measured by the automated Pronosco system has tremendous precision. [1]

Bone remodeling process can be also called as bone metabolism. The bone remodeling is a lifelong process where mature bone tissue is removed from the skeleton or old tissue layer will drained by some chemical process within the bone metabolism process. This type of process is called as bone resorption. In the same way, after the older bone tissue drained away new bone tissue will be formed in the metabolism process of the bone. This formation process called as ossification or it may call as new bone formation. [11] Resorption and Ossification processes also control the reshaping of the bone. These processes also control the replacement of bone during following injuries like fractures, air-line crack and micro-smash up, which occurs during normal activity. Bone tissue is removed by Osteoclast through some chemical processes, and then new bone tissue is formed by osteoblasts. Osteoblasts are the process means group of organized Osteoblasts join together forms a unit of cells called bone. Osteoclast is another type of bone cell that resorbs bone tissue. These types of formations and drains of bone tissue were more related to bone remodeling. The formation ratio or drain ratio between Osteoblasts and Osteoclast should not vary. In case of any variation in the ratio between Osteoblasts and Osteoclast then its leads to a reason for bone diseases. [1][8]

## 2. Effects of disease conditions in defined populations

A normal man is affected by deficiency of minerals then he can be affected by Osteoporosis. Reduced bone density can be a key factor for fragility fracture. Apart from this factor some other factors can also be reason for Osteoporosis. Fragility fracture can be caused because of use of oral or systemic glucocorticoids, family history of osteoporosis, sex, previous fractures, and age. For women, after the menopause there is change of increasing in bone loss and for women and men age-related bone loss can also happen, the prevalence of osteoporosis increases noticeably with age factor. Nearly about 2 percentages chances are there for Osteoporosis at the age of 50 years and 25 percentages chances for Osteoporosis at the age of 80 years especially for women. The data analysis estimates there are 2 million women who have Osteoporosis.

### 2.1. Risk Factors

Along with the age factor and bone mineral density, some other autonomous experimental risk factors for fracture were: Parental history and frequent alcohol intake more than 4 units per day. Risk factors in Female gender are: There are many reasons for reduced BDM for female gender are Cushing's syndrome, Ankylosing spondylitis, Crohn’s disease, Untreated premature menopause, Low body mass greater than 19 kilogram per m2 and anorexia nervosa and also Poor diet (particularly if calcium-deficient), Prolonged immobilization. The major other reasons are Smoking, Primary hypogonadism (men and women), Primary hyperparathyroidism, Hyperthyroidism, Osteogenesis imperfect, Caucasian, Post transplantation and Chronic renal failure. The study state that females are got higher risk than men especially older men are also affected more in percentage and are often inadequately screened for the disease despite having relevant risk factors.[12]

### 2.2. Primary Prevention

Radiography is useful for selection patients in need of machine screening or proper diagnosis. In-case of a fragility fracture ,the fragility fracture should activate bone density measurement ,while in women aged less than or equal to 75 years osteoporosis can be understood and initially treatment initiated without dual-energy X-ray absorptiometry (DEXA) scan unless until clinician feels scan is really required. Patients those were having more than one rick factors for fractures like family history, increased alcohol intake or rheumatoid arthritis should be considered for DEXA scanning. Diagnosis of osteoporosis centers on the evaluation of BMD with Single-energy X-ray absorptiometry which is shortly knows as SXA and DEXA or digital X-ray radiogrammetry which is shortly knows as DXR evaluation of mineral substance of the whole skeleton. With help of SXA and DEXA, we can scan particularly at a specific bone area even in susceptible sites. DEXA is one of the standard techniques for diagnosis of Osteoporosis. The correctness at the hip exceeds about 90%. The remaining 10% is the errors occur for various reasons. Erroneous diagnosis of osteoporosis can be caused by Osteomalacia, soft-tissue calcification or osteoarthritis. DXR is much simpler and less time-overshadowing than DEXA. DEXA can be used anywhere where there is the facility to perform a standard radiograph.[1] DXR appears to have comparable precision and accuracy to DEXA in terms of diagnosing osteoporosis in the bones. This machine is a useful for screening tool for osteoporosis following forearm fractures etc without the need for extra radiographs. DXR seems to be slightly less sensitive than DEXA in detecting osteoporosis .Other ways used include ultrasonic measurement of bone. This can be used for the evaluation of fracture risk, or selection of those in need of DEXA/DXR. [1] It is undependable for diagnosis of osteoporosis and is associated with under diagnosis[4]

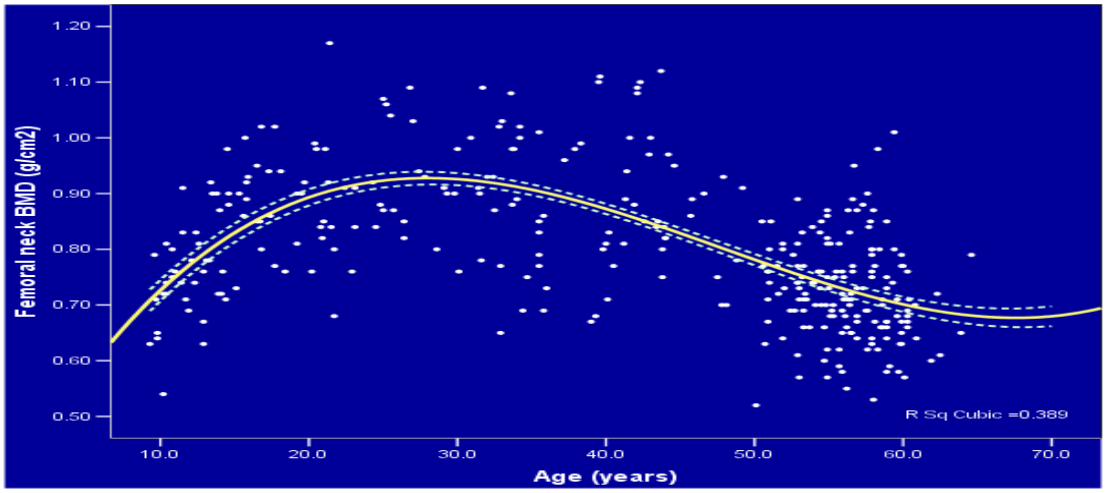



Fig .1. Liaison between BMD and AGE

In the fig.1,the relationship between bone mineral density and age were explained graphically.Nearly about 150 samples were taken from different age groups starting from 10 to 70.The bone mineral density in the graph was detected from the neck bone of the human skeleton structure and the bone density was measued in g/cm$^2$.

### 3. Effects of Osteoporosis in Women & Men

At first tier bisphosphonate can be the only suggested in duration after menopause women aged fewer than 65 with definite osteoporosis but without fragility fractures, if they have a self-regulating clinical risk issue for fracture and at least one additional factor of low bone mineral density. They have to consume bisphosphonates in osteoporotic women without fragility fracture once they reach age 65 in-cases they have any self-regulating clinical risk issue for fracture or more than age of 70 in-case they just have an indicator of low bone mineral density. The responsible doctor may decide for a DXA scan is not needed in women aged 75 years or aged more than whom have two or more self-regulating clinical risk issue for fracture or indicators of low BMD. At Second tier treatments were risedronate and etidronate may be measured in-case of the patient is aged < 65 and not capable to take alendronate.[3] T-score is a measurement-threshold value to compare with normal human being. T-score measuring is the second stage of treatment not including previous fragility fracture stage .Age factor is key point in calculating the T-score. The risk factor can be calculated with considering family history and amount of alcohol consuming in term of units per day. The age consideration for normal fracture is independent of clinical risk factors.

Family history of hip fracture, consuming alcohol more than four units or more than four units in single day and rheumatoid arthritis can be reason. For fragility fractures Raloxifene were not suggested as a treatment for the initial prevention of osteoporosis. As first tier treatment calcium and D-vitamin can be prescribed .More importantly bisphosphonate will be prescribed. Initial alendronate sodium is not tolerated or is unsuitable or there might be not good response for the drugs. In that case bone minerals density can be taken in account and age factors for the inadequate response. Still the case is worse than T-score can measure for next level of treatment methods. The risk factor can be calculated with considering family history and amount of alcohol consuming in term of units per day. The table.1 derives the DEXA results of human bone values in terms of T-score for different age group.[5]

Table.1. Dexa results

| S.NO | AGE | DEXA RESULTS |
|---|---|---|
| 1 | 50-54 | Not recommended -3.0 -2.5 |
| 2 | 55-59 | -3.0 -3.0 -2.5 |
| 3 | 60-64 | -3.0 -3.0 -2.5 |
| 4 | 65-69 | -3.0 -2.5 -2.5 |
| 5 | 70-74 | -2.5 -2.5 -2.5 |
| 6 | 75 & above | -2.5 -2.5 -2 |

In the case were prescriptions like bisphosphonate, calcium and D-vitamin is not an option then raloxifene can be prescribed at second tier treatment. Still no respone in the second tier treatment than third tier can be suggested. The third tier treatment can be assigned to patient those who were having more than 2 risk factors. [6][7]. the table.2 derives the DEXA results of human bone values in terms of T-score for different age group with second set of treatment.

Table.2. Age and T-score

| S.No | AGE | T-SCORE |
|---|---|---|
| 1 | 50-54 | -3.5 -3.5 |
| 2 | 55-60 | -4.0 -3.5 -3.5 |
| 3 | 61-64 | -4.0 -3.5 -3.5 |
| 4 | 65-69 | -4.0 -3.5 -3.0 |
| 5 | 70-74 | -3.0 -3.0 -2.5 |
| 6 | 75&ABOVE | -3.0 -2.5 -2.5 |

In case of raloxifene medicine was not giving best results then considers referral to the secondary tier set of treatment. Secondary tier level treatment can be teriparatide or denosumab. This level of treatment can be considered based on T-Score. Risk factor is based on family history, alcohol consuming more than 3 units per day and age factor for fragility fracture. [2][7]. The table.3 derives the DEXA results of human bone values in terms of T-score for different age group with third set of treatment.

Table.3. Age and T-score

| S.NO | AGE | T-SCORE |
|---|---|---|
| 1 | 50-54 | Not Recommended |
| 2 | 55-60 | -4.0 |
| 3 | 61-64 | -4.0 |
| 4 | 65-69 | -4.0 -3.5 |
| 5 | 70-74 | -4.0 -3.5 |
| 6 | 75 & Above | -4.0 -3.5 |

For the second tier treatment denosumab medicine will not prevent the risk factor increase with the special commands for administering alendronate, and risedronate. Even 70 milligram of Alendronate can be intake for men normally in this treatment. The above mentioned treatment is advised for those patients whose first tier treatments were not successful.

**5. Osteopenia and its effects**

When bone mineral density decreases than the normal level then is considered as osteopenia. Even many times osteopenia can be a beginning to osteoporosis. More over osteopenia will never leads to osteoporosis for compulsory. There are possibilities of osteoporosis for patients those have osteopenia. As same as osteoporosis, ostropenia have some T-score limitations. Generally bone mineral density T-score between 1.0 and 2.5 is declared as osteopenia which was defined by World Health Organization. Any T-score more than <2.5 will be considered as osteoporosis. In those days this will be occurring to human more than 30 years old. [1]

**6. Methodology and Techniques**

Dual X-ray absorptiometry is used scan any bone of the body. Same type of scan can be done with other types of scanning such as portable X-ray machines and ultrasound methods. The research also states that based on the scanning machines osteopenia diagnoses varies up to 28 % to 45%. Based on the research Mr.Merck suggested a scanning machine for cheaper scans and it's was used widely across the world. [6]

**6.2 Causes of the Osteopenia**

As similar as osteoporosis, osteopenia will occurs more often in post-menopausal of women. In those time period woman's estrogen level will reduce notably. Osteopenia's severity can be increased by day toady activities such as be short of exercise, consumption of alcoholmore than 4 units per day, smoking and glucocorticoid medications usage. Osteopenia can also occur due to contact to radiation. Osteopenia is more common in sport personalities. They can be classified into two types' non weight bearing activities and weight bearing activities. These non-weight bearing sport persons have high impact of osteopenia than weight bearing sport persons. This is because of weight bearing sport person activity increases the bone mineral density index. Mainly for female sport persons, this problem can be high comparability with men .Osteopenia occurs due to suppress estrogen level and decrease BDM.

**6.3 Treatment & Controversy**

The treatment of osteopenia is notorious. At present, candidates for therapy include those at the uppermost risk of osteoporotic bone fracture based on bone mineral density and other clinical risk factors. In the year 2008, National Osteoporosis Foundation (NOF), World Health Organization (WHO) and Fracture Risk Assessment Tool (FRAX) suggested few recommendations for both men and woman. According to these recommendations, consideration of therapy should be made for postmenopausal women, and men older than 50 years of age, if any one of the following is present:

1. Hip or vertebral fracture

2. T-score of 2.5or more at the femoral neck

3. T-score between 1.0 and 2.5 at the femoral neck

4. A 10-year probability of hip fracture ≥3%

5. A 10-year probability of major osteoporotic fracture ≥20%

4. Clinicians' judgment in combination with patient preferences indicates treatment for people with 10-year fracture probabilities above or below these levels. Commonly used drugs are bisphosphonates including alendronate, risedronate, and ibandronate; selective estrogen receptor modulators (SERMs) such as raloxifene, estrogen, Calcitonin, and teriparatide.

**7. KNN classifier algorithm**

This is based on pattern recognition of same nodes, here k-Nearest Neighbors algorithm (or k-NN for short) is a non-parametric method used for classification of osteoporosis and osteopenia and their regression. In both cases, the input consists of the k closest training examples in the feature space. The algorithm can be useful to assign weight to the contributions of the neighbor's nodes, so that the nearer neighbor's nodes contribute more to the average than the more distant ones. For example, a common weighting scheme consists in giving each neighbor a weight of 1/d, where d is the distance to the neighbor. [9][10]

Near neighbours should count more than far neighbours. Each neighbour cast vote with weight ($w_i$), depending on the distance (d).Required: distance function on instances.
Model = labelled training data (a1; c1); : : : ; (aN; cN).
Classify new instance a as follows:
- Let (aj1 ; cj1 ); : : : ; (ajK; cjK) be the K training instances whose
Attributes are closest to a.
- Label a with the class label that occurs most frequently among
cj1 ; : : : ; cjK.
Here in this paper (a,c) where two attributes taken for classification.
Where "a" can be a class which represents osteoporosis and "b" can be a class which represents osteopenia.

**7.1. KNN Algorithm Representation**

The fig.2.1 and fig.2.2 represents the real time values of Osteoporosis, Osteopenia and Normal plotted in a 2-dimensions plane of X and Y. The fig.2.1which explains the real time values before forming the classes of their class"k".As per the kNN algorithm the testing vector "k" can included in any one of the classes to which 'K' is near-by in the X,Y-plane. Here all the real time outputs were marked in the XY plane. If any one of node 'K' found to be nearest to its subordinates then the node 'K' will consider within the same group of the subordinate.

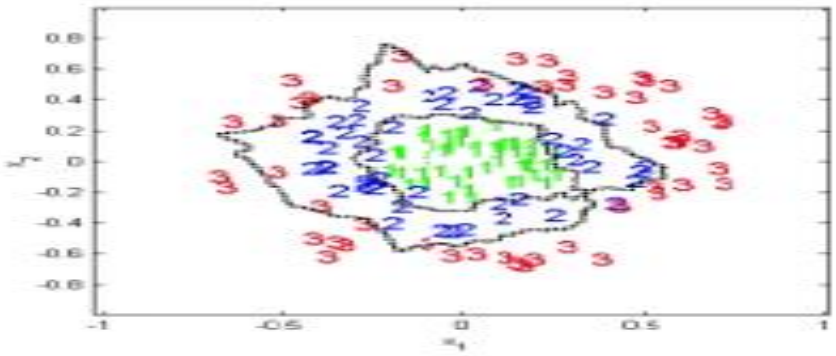


Fig.2. 1 Before KNN comparison

In the fig.2.2, identification of all nearest node of 'K' which are grouped according to the distance the nodes. Based on the distance'd' all node of 'K' were defined with classes. So now it is easy to classify the values of DEXA into different classes like Osteoporosis, Osteopenia and Normal conditions. All numerical values of '1' were identified as normal,'2' were identified as Osteopenia and '3' were identified as Osteoporosis.

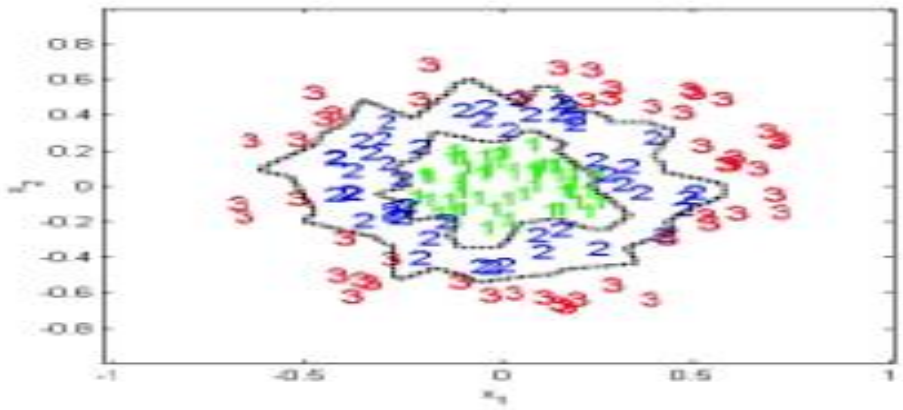


Fig.2. 2 after KNN comparison

**7.1. Weighted Voting**

Can give higher weight to close neighbours: weighted vote for label c:

v(c) =

K

X

i=1: cji=c

d(aji ; a)

Label with the c that has highest v(c) value. [9]

**7.2. Distance Measures in Instance Space**

Some categorization and almost all clustering methods require a distance measure

d (i1; i2)

between any pair a1

a1 = (a1;1; : : : ; a1;k); a2 = (a2;1; : : : ; a2;k) of instances.[9][10]

### 7.3. Signal & Graph Terminology

A signal is a portrayal of how one parameter is related to another parameter. For example, the most widespread type of signal in analog electronics is a voltage signal that varies with time in X and Y domain. In-case both parameters can assume a continuous range of values, we will call this a signal as a continuous signal.

In comparison, passing this signal through an A/D converter forces each of the two parameters to be quantized.

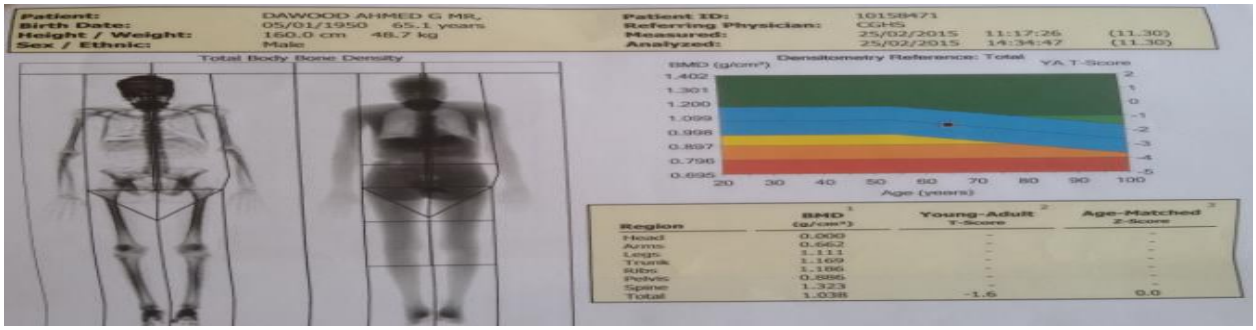
After quantized process, a continue signal was formed with respect to the quantized values. The values of both the site were compared with the help of the algorithm. Based on the algorithm we associate the closeness points can be finalized.

### 8. Results

As we discussed earlier there are many factors that influences bone mineral density. Here we were taken three fields such as BMD,T-score & Age. In the same way three difference classifications were analyzed for Osteoporosis, Osteopenia and Normal condition. The BMD were calculated for different types of bones in the human body. The T-score and ages were irrespective to each other.

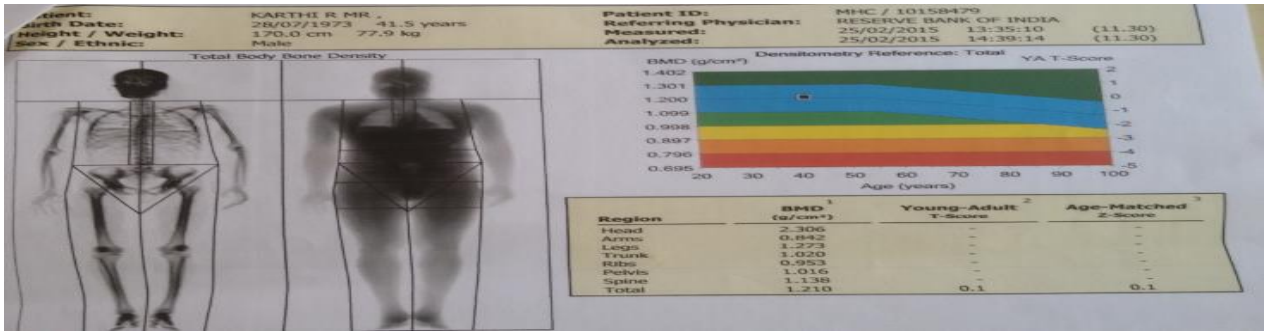
### 8.1 .Output Of Osteoporosis

The result of the patient who was affected by Osteoporosis, who's T-score is almost -2 at the age of 65 were his BMD values were also considerably low at the age of 65 years. In-case if the same BMD value at the age of 55 years then this condition can't be assumed as osteoporosis.




### 8.2 .Output of a Normal Bone

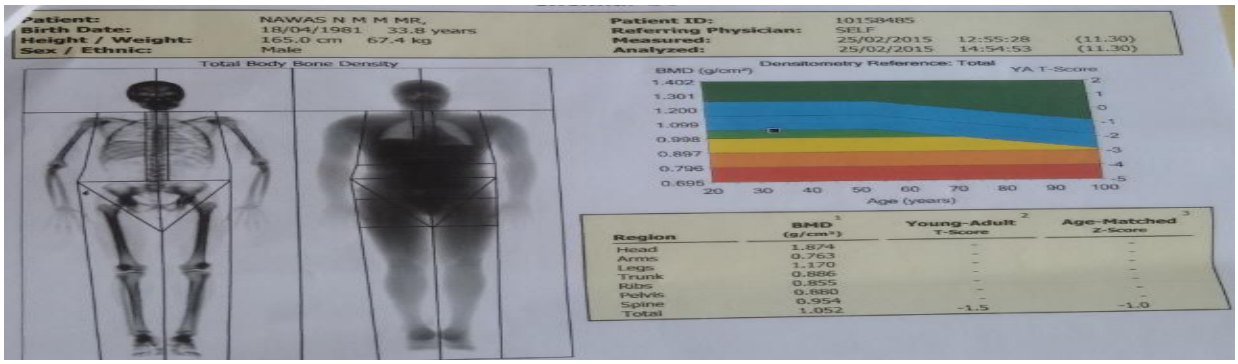
When T-score value lies between (-1 to 1) and condition can be denoted as normal condition. Even in-case the same T-score maintained at the age of 65 then so we can consider as a normal condition. The BMD values will be changing according to different parts of the bone in the body.




### 8.3. Output of Osteopenia

The T-score influences radical change between Osteoporosis and Osteopenia detection. As we state earlier, both of these bone disorder were closely associated with each other. This condition can be Osteopenia because at age of early 30's the T-

score were crossing the limit of (-1 & 1).In-case of slight variation in T-score maintained for next couple of years then it lead to Osteoporosis,




## 9. Conclusion

An initiative is taken to detect the Osteoporosis by using IDEXA machine and the values obtained from it is simulated using MATLAB software & taking the parameters of Mean Median & Standard deviation and fed to KNN classifier and it compares the values, returns the exact value can be achieved and it is useful to detect either it is Osteoporosis or Osteopenia from affected patients. Further it is proposed to work on adapting the different soft computing algorithms to identify the severity of the bone cancer.

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