BMD Related Torsional Strength of Human Femur Bone

Shrikant A. Borkar[1]
Department of Mechanical Engineering,
JSPM'S Rajarshi Shahu College of Engineering, Tathwade, Pune-411033
Shreeborkar5@gmail.com

Prof. Subim N. Khan[2]
Associate Professor, Department of Mechanical Engineering,
JSPM'S Rajarshi Shahu College of Engineering, Tathwade, Pune-411033
Subim_khan@yahoo.com

Prof. Shailesh S. Pimpale[3]
Associate Professor, Department of Mechanical Engineering,
JSPM'S Rajarshi Shahu College of Engineering, Tathwade, Pune-411033
Shailesh_pimpale@rediffmail.com

ABSTRACT

Radio density of bone is measured in Hounsfield unit (HU) by a technique computed tomography, where as bone mineral density (BMD) is measured by Dual-Energy X-ray Absortiometry.

(DEXA) scan aimed at finding correlation between BMD and HU of human bones for their torsional strength evaluation.

In the paper femur bone undergoing both DEXA scan and CT-scan imaging were evaluated to determine if strength correlated with BMD and T-score. As value of BMD increases, the value of Z-score T- score decreases and we get best method to find out BMD by error analysis between CT scan and DEXA.

Aiming to find torsional strength of human femur bone, test is carried out with the help of setup having rectangular frame work in which bone is hold by the clamp which is rotated by hydraulic motor.

Index Terms – DEXA, CT-scan.

I. INTRODUCTION

Biomechanical engineering is a bioengineering sub discipline which applies principles of mechanical engineering to biological systems from the scientific disciplines of biomechanics. The biomechanical evaluation of bone, bone implants, and the bone–implant interface has been carried out for many years. Such investigations nearly always employ the use of mechanical testing systems to generate information on the physical properties of these materials. From simple compression and tension failure testing to fatigue analysis of new total joint prostheses, modern computer-driven machines are commonly used to provide analysis and information. Increased prevalence of debilitating conditions such as degenerative joint disease as well as rising popularity of internal devices for fracture fixation has led to rapid growth of the orthopaedic and biomechanical research communities. Along with this growth has been a commensurate rise in the diversity and production of commercially available testing systems to meet the ever-increasing demand for better and less expensive implants and the specific needs of the modern investigator. Implementation of a materials testing laboratory is neither an easy nor inexpensive endeavor. However, the utility and potential capabilities of even the most basic laboratory can provide the opportunity to perform numerous experiments and far outweigh the initial difficulties or expenses encountered.

A. Theory Of Torsion For Cylinder:

A diaphyseal segment from a long bone might be grossly approximated as a hollow cylindrical shaft made from a homogeneous, linear elastic material. Such a shaft might have a certain inner radius, r_i, an outer radius, r_o, and a length, *L*. If one end, *A*, of the shaft is fixed, and a torsional force, *T*, is applied to the opposite end, *B*, then end *B* will rotate in its own plane through some angle φ with respect to end *A*, as illustrated in Fig.1.

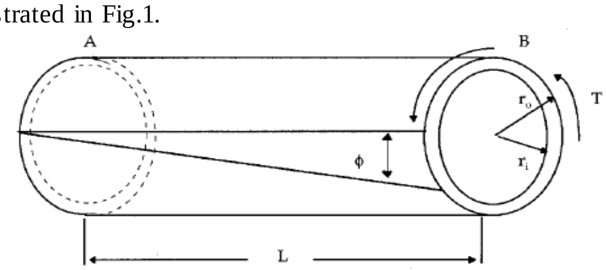


Fig.1. cylindrical bar under torsion

In order to find the shear stress, τ, in the material at any radius within the cross section of the shaft, the following simple formula is used

$$\tau = \frac{T\rho}{J}$$

where Jis the polar moment of inertia, which for a hollow cylinder is equal to (ro4 – ri4)/2,is a specified radius, bounded by r_o and r_i. Thus, the maximum shear stress, τ_{max} is given by

$$\tau_{max} = \frac{T r_o}{J}$$

The relative angle between ends *A* and *B* is similarly given by

$$\phi = \frac{TL}{JG}$$

Hence by using these mathematical equations we can find out the torsional strength of the human femur bone.

B. Horizontal chuck holded bone

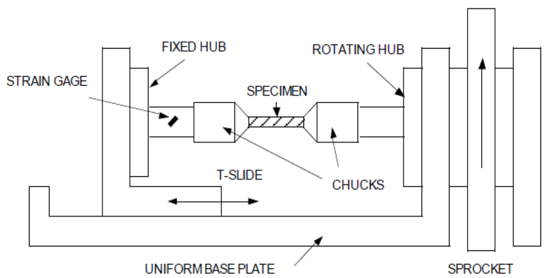


Fig.2. Horizontal chuck holding machine

The machine provides a low cost solution for engineering & engineering technology programs that wish to expand their material testing capabilities but not capable of funding the acquisition of commercially available torsion testing machines. The basic idea for the operation of the machine is shown in fig2. The specimen is mounted between a non-rotating fixed hub assembly and a rotating hub assembly which is connected to a drive train. The non-rotating hub was placed on a T-slide to allow motion along the axis of the specimen to prevent axial loads from developing as the length of the specimen decreased during twisting. The non-rotating hub is also include a strain gauge torque sensor used to measure the applied torque. The rotating hub would be driven using a drive sprocket connected to the drive train. The specimen angle of twist would be determined by measuring the rotation of the rotation hub.The bone specimen is mounted horizontally on the testing setup. Bones are mounted with the help of clamps. The one side is fixed while other is movable. These ideas were implemented by us in our prototype.

C. Mechanical properties of cortical bone:

1) General mechanical properties:

For mechanical testing, cortical bones are used as a whole bone or tailored into beams or rods. A whole diaphysis bone is commonly tested using bending and torsional tests. A beam is a rod with constant cross-sectional shape & area, which can be spherical, square, or rectangular. A variable beam is a beam with inconsistent cross-sectional shape & area, such as long bones. A cantilever beam is a beam that is fixed at one end and usually used for cantilever bending tests. A dumbbell sample is a dumbbell-shaped bone specimen made specifically for mechanical testing, such as tensile or torsional tests. The dense nature of cortical bone determines its strong and stiff mechanical properties compared with cancellousbone.

2) Bone density:

The material density of cortical bone is the wet weight divided by the specimen volume. It is a function of both the porosity and mineralization of the bone materials. Cortical bone has an average apparent density of approximately 1.9 g/cm. For cortical bone, apparent density and material density are basically the same, as there is no marrow space in compact bone. Therefore, “cortical bone density” is commonly used to describe the density of cortical bone. There is a positive correlation between apparent density of cortical bone and its mechanical properties. The true meaning of bone mineral density (BMD) is bone mineral mass per unit bone volume, or “ash density” if an ashing (or burning) method is used. Similarly, the true meaning of bone mineral content (BMC) describes the ratio of unit weight of the mineral portion to dry bone unit weight and is frequently reported as a percentage. BMD and BMC are positively correlated with the strength and stiffness of various bones, such as human femur and tibia, bovine femur and tibia, feline femur,and a wide variety of animal bones.

3) Porosity:

The strong effects of porosity of cortical bone on mechanical properties have been well studied. It is easy to understand that a more porous bone has a weaker mechanical strength. Porosity (*p*) is defined as the ratio of void volume to total volume, which is commonly measured on two dimensional histologic sections (traditionally point counting) or X rays. In cortical bone, the mechanical properties are affected by relatedresorption cavities and vascular channels.

D. Bone specimen:

Fig.3.Bone specimen

Bone specimen was created from the femur bone, the research paper data was considered while cutting into pieces of length specified in research paper .

Length of bone : 70mm

II. OBJECTIVES

1) To collect data from C.T. Scan and DEXA, like BMD, Z-score, and T-score.

2) Manufacturing of testing set-up to calculate torsional strength.

3) To generate correlation between BMD and Strength.

4) To generate correlation between HU and Strength.

5) To perform error analysis between C.T. Scan and DEXA and to select best among them.

6) The model prepared in UNIGRAPHICS will be imported in ANSYS and analysed.

III.LITERATURE REVIEW

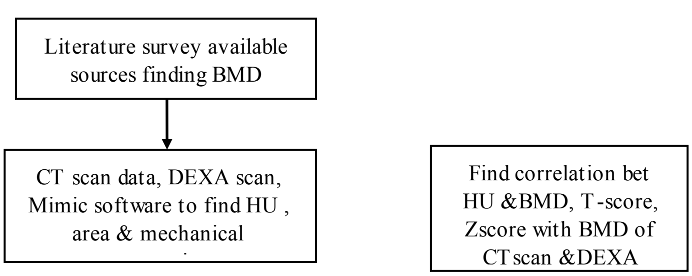
[1] BenjaminR.Furman1,Subrata Saha2, "Torsional testing of Bone". Torsional testing is a uniquely capable technique for examining the *in vitro* mechanical properties of a wide variety of bones. Servo hydraulic testing equipment can be a straight forward means to obtain a large amount of torsional data using different loading modes.

[2] Yuehuei H. An, "Mechanical Properties of Bone". Bone is an elastic, anisotropic, heterogeneous, and composite material. The determinants of bone mechanical properties include (1) its density (apparent density and mineral density); (2)porosity & (3) microscopic structure.

[3] Christopher V. Bensen1 , Yuehuei H. An 2, "Basic Facilities and Instruments for Mechanical Testing of Bone".
Mechanical testing systems offer the orthopaedic researcher the ability to measure numerous properties of a bone specimen or construct. A large variety of machines are commercially available from several companies; it is up to the individual researcher or team to decide which model is appropriate for the research being carried out in the respective laboratory.

[4] J.Y.Rho1, M.C.Hobatho 2,R.B.Ashman 3, "Relation of mechanical properties to density and CT numbers in Human bone" Mechanical properties of cortical and cancellous bone from eight human subjects were determined using an ultrasonic transmission techniques raw computerized tomography values obtain from scans of the bones in water were corrected to Housfield units.

IV. METHODOLOGY



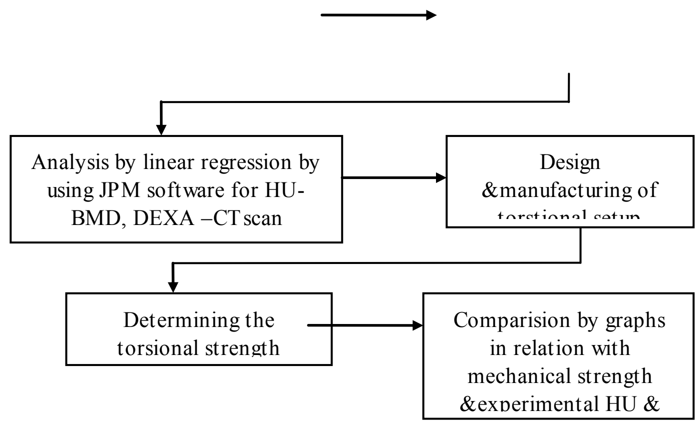


Fig.4. Flow chart of the process

A. Bone properties obtained from CT scan

Bone density (or bone mineral density) is a medical term normally referring to the amount of mineral matter per square centimetre of bones. Bone density (or BMD) is used in clinical medicine as an indirect indicator of osteoporosis and fracture risk.

This medical bone density is not the true physical "density" of the bone, which would be computed as mass per volume. It is measured by a procedure called densitometry, often performed in the radiology or nuclear medicine departments of hospitals or clinics. The measurement is painless and non-invasive and involves low radiation exposure. Measurements are most commonly made over the lumbar spine and the upper part of the hip. The forearm may be scanned if the hip and lumbar spine is not accessible. Average density is around 1500 kg m^{-3}.

The Hounsfield scale, named after Sir Godfrey Newbolt Hounsfield, is a quantitative scale for describing radio density. The Hounsfield Unit (HU) scale is a linear transformation of the original linear attenuation coefficient measurement into one in which the radio density of distilled water at standard temperature and pressure (STP) is defined as zero Hounsfield units (HU), while the radio density of air at STP is defined as -1000 HU.

1. *Z-SCORE*:

Z-score is the number of standard deviations away from the average value of the reference group.A person who is average has a Z-score of 0 and is at the 50th percentile. If the Z-score is -0.84 then 20% of people have a lower bone density.
Calculation of Z score-
Z-score = (patient's BMD – excepted BMD) / SD
To calculate BMD if you know the Z-score, use the same equation by just rearranging it as:
BMD = Expected BMD + (Z-score * SD)

2. T-SCORE:

On the T-score scale, 0 represents normal, healthy bone density of a 30-year-old person (the age of peak bone density).

T-scores above 0 and slightly below 0 are within the normal range. It works like a temperature scale. A temperature of -2 is lower than a temperature of -1. In the same way, a T-score of -2.3 shows lower bone density than a score of -1.8.

A T-score of -1 to 0 and above is considered normal bone density, while a T-score between -1 and -2.5 is diagnosed as Osteopenia. A score of -2.5 or below is diagnosedas osteoporosis. The T-score is a radiographic diagnosis, meaning it is an X-ray diagnosis and doesn't imply anything about the cause of osteoporosis.

B. Bone mineral density test:

Dual-energy x-ray absorptiometry (DEXA) :

Dual-energy X-ray absorptiometry (DXA, previously DEXA) is a means of measuring bone mineral density (BMD). Two X-ray beams with different energy levels are aimed at the patient's bones. When soft tissue absorption is subtracted out, the BMD can be determined from the absorption of each beam by bone. Dual-energy X-ray absorptiometry is the most widely used and most thoroughly studied bone density measurement technology.

C. Procedure for finding BMD & HU by MIMICS software:

C.T scan data subjected was taken in DICOM format and imported to MIMICS software. MIMICS software automatically stacks the slice in manner of selection. Area and Hounsfield unit of each slice is calculated. Based on this calculation density and modulus of elasticity is calculated for each slice using expression given in user manual of MIMICS software with the help of MS-Excel. The femur length is available up to 135mm.

D. Bone model in Mimics software:

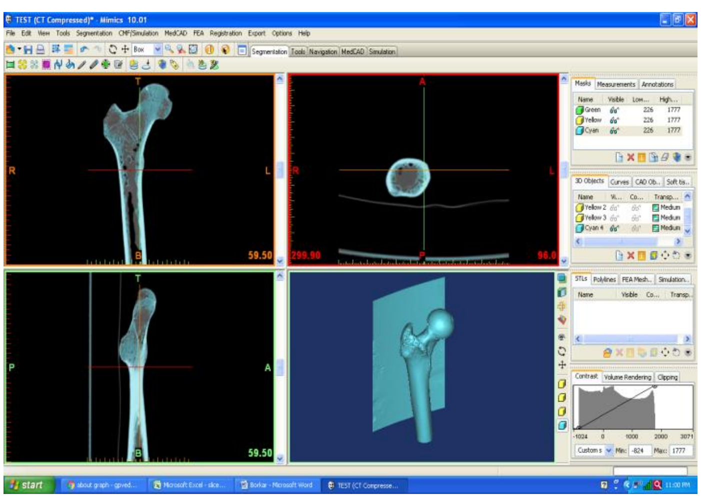


Fig.5.3DBone model

The Mimics software gives HU (Hounsfield number) of bone slice at distance of 1.5mm.

TABLE I

DATA OF C.T. SCAN IMAGE

Distance of slice	HU	Diameter
0.6	335.2962	40.782
1.2	340.3635	40.549
1.8	345.4308	40.316
2.4	350.4981	40.083
3	355.5654	40.039
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
378.6	401.1711	39.993
379.2	398.4895	39.997
379.8	396.1038	40.021
380.4	394.018	40.039
381	393.1235	40.045

Mechanical properties which are the outcome from MIMICS software.

TABLE II

Mechanical properties from MIMICS software

Diameter(D)	Moment of inertia(I)	Apperent density(p)	Modulus of elasticity(E)
40.782	139343.122	488.7610454	1016.586006
40.549	138547.0122	494.1678545	1039.316253
40.316	137750.9025	499.5746636	1062.299078
40.083	136954.7927	504.9814727	1085.534511
40.039	136804.4544	510.3882818	1109.022578
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
39.993	136647.2825	559.0495637	1331.78807
39.997	136660.9497	556.1882965	1318.12289
40.021	136742.9524	553.6427546	1306.025117
40.039	136804.4544	551.417206	1295.494046
40.045	136824.9551	550.4627745	1290.990898

V. WORKING PRINCIPLE

When one end of bone specimen is hold firmly and another end is subjected to measurable torque, the breaking angle of the bone so obtained can be used for calculating the torsional strength of bone.

A. Working setup:

The objective of the project is to find BMD related torsional strength, considering that we designed and manufactured the setup. The fig. above shows the idea of the set up. The specimen of human cortical bone is hold firmly by the two clamps. The fixed clamp is welded on the movable bracket which is free to slide over the base plate. As per the specimen length the movable bracket is adjusted and fixed with the help of bolts.

The rotating clamp rests on the shaft of gear motor. The clamp is locked on shaft with the help of key. The bone specimen is fixed on the clamp by the bolts, screwed on the clamp radially. After the proper clamping of bone on two respective clamps, the function of hydraulic system comes into picture.

Before starting the motor, the various parameter of motor are calculated/monitored viz. torque, rpm, and pressure from the hydraulic system. After fixing all the arrangement, we need to start the hydraulic motor with the help of 4/3 Direction Control valve. The torque of motor is too low. The angle Protector is mounted on shaft which rotates along with the same. After certain degree of rotation of shaft the bone breaks. The instant at which the bone breaks, the motor is stopped.This obtained angle is further used for calculating strength, plotting graph. The torque can be calculated by using the values of pressure obtained using the pressure sensor.

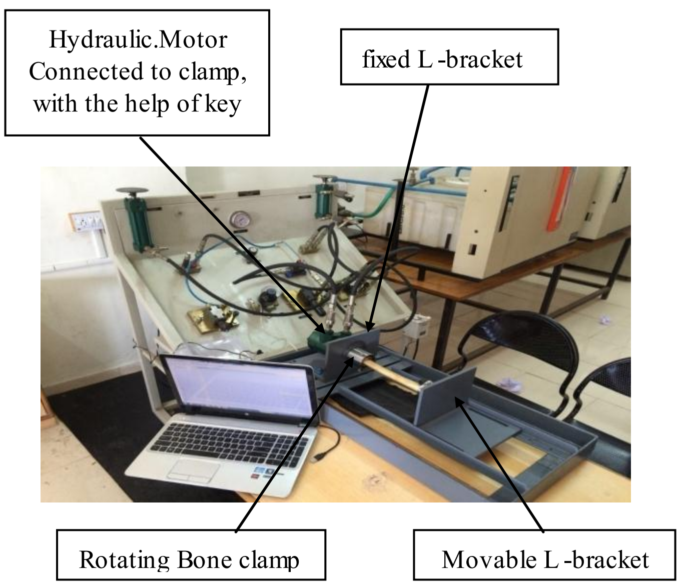


Fig.6.Assembly of all components with motor

B. Experimental procedure:

For carrying out the experiment, one end of bone specimen is to be hold firmly and another end is to be subjected to torque, the breaking angle of the bone and the respective values of torque so obtained can be used for calculating the torsional strength of bone. The torque can be applied using hydraulic gear motor which was fixed to base plate using bolts. The torque can be varied by controlling pressure and speed can be varied by controlling flow. Observations are to be recorded for the breaking angle and torque. The measured breaking torque and angle were further used for calculating torsional strength of femur bone.

TABLE II
OBSERVATION TABLE

Pressure	Torque	Angle
1.189	0.271092	2
2.925	0.6669	4
3.997923077	0.911526462	6
4.999077592	1.139789691	8
5.9872301	1.365088463	10
6.988384615	1.593351692	12
7.98953913	1.821614922	14
8.990693645	2.049878151	16
9.978846154	2.278141381	18
10.99300268	2.50640461	20
11.99415719	2.734667839	22
12.99531171	2.962931069	24
14.13191811	3.222661238	26
15.16467262	3.458181091	28
16.19742712	3.693700945	30

C. Calculations:

Considering a cylindrical bone with one end being twisted as shown in setup, the twisting moment MT is resisted by shear stress τ existing across the specimen section. This shear stress is zero at the centre of the bar, increases linearly with its radius and finally reaches its maximum value at the peripheral of the bar. If the cylinder bar with a length of L, the twisting moment can be related to the shear stress as follows

$$\frac{M_T}{J} = \frac{G\theta}{L} = \frac{\tau}{r} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

Where,

J is the Polar Moment of inertia, mm2
G is the shear modulus, N/mm2
θ is the degree of rotation, radian
r is the radius of the cylindrical bar, mm or in
L is the length of the cylindrical bar, mm.

According to the graphical relationship of torque and degree of rotation, we can notice that the torsion specimen deformed elastically and then plastically similar to the case of the tension tested specimen. Beyond the proportional limit, specimen deformed in a plastic manner and the relationship betweenthe torque and the degree of rotation is no longer linear.

Since the stress vary across the section of the specimen from the centre towards the peripheral of the specimen as mentioned previously, the reduced effect of stress distribution in the thin walled specimen is therefore beneficial for the calculation of stress. Within the elastic range of deformation, the shear stress can be calculated according to equation

$$\tau = \underline{M_T r} \quad \ldots\ldots\ldots\ldots(2)$$

J

For a tube specimen, the maximum shear stress at the peripheral of the tube can be calculated from equation,

$$\tau = \frac{16M_T D1}{\pi(D1^4 - D2^4)} \quad \ldots\ldots\ldots\ldots(3)$$

Where,

D1 is the outer diameter of the tube

D2 is the inner diameter of the tube

Therefore, if the torque and the degree of rotation are known according to the experimental results, the shear stress and shear strength can be determined from the equation 2&3.

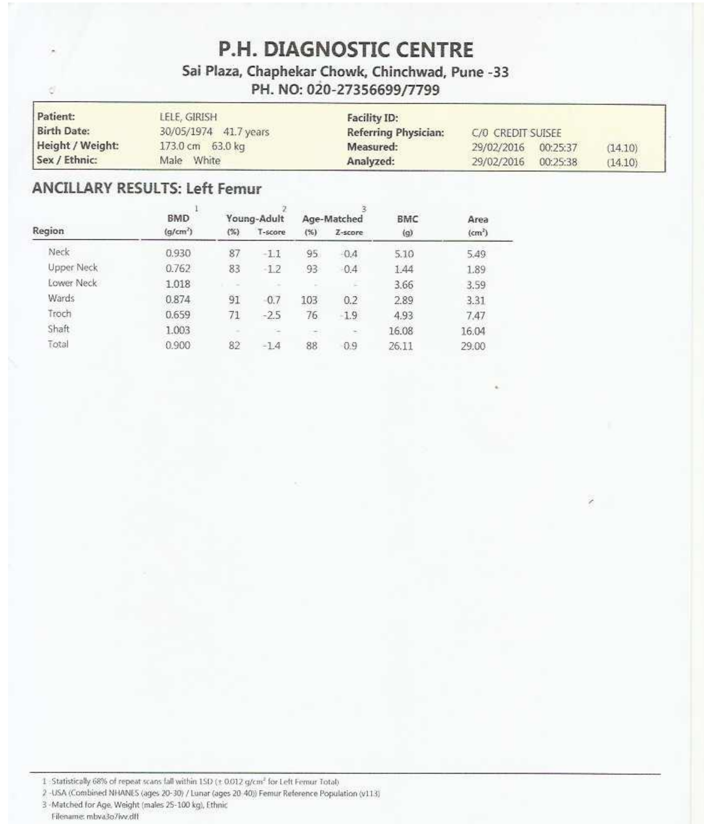
TABLE III

RESULT TABLE

Pressure	Torque	Torsional strength	Angle
1.189	0.271092	40298.2632	2
2.925	0.6669	98569.36819	4
3.997923077	0.911526462	133951.575	6
4.999077592	1.139789691	166527.5338	8
5.9872301	1.365088463	199225.5917	10
6.988384615	1.593351692	232271.9341	12
7.98953913	1.821614922	265241.73	14
8.990693645	2.049878151	298209.6981	16
9.978846154	2.278141381	331333.6616	18
10.99300268	2.50640461	364112.0914	20
11.99415719	2.734667839	397262.5324	22
12.99531171	2.962931069	430378.9095	24
14.13191811	3.222661238	467624.2565	26
15.16467262	3.458181091	501648.1026	28
16.19742712	3.693700945	535355.1449	30

From the calculated strength we find strength and BMD relation using the JMP software so that one can calculate strength if the BMD is known and by Z-Score.

VI. DEXA REPORT



P.H. DIAGNOSTIC CENTRE

Sai Plaza, Chaphekar Chowk, Chinchwad, Pune -33

PH. NO: 020-27356699/7799

Patient:	LELE, GIRISH	Facility ID:	
Birth Date:	30/05/1974 41.7 years	Referring Physician:	C/0 CREDIT SUISEE
Height / Weight:	173.0 cm 63.0 kg	Measured:	29/02/2016 00:25:37 (14.10)
Sex / Ethnic:	Male White	Analyzed:	29/02/2016 00:25:38 (14.10)

ANCILLARY RESULTS: Left Femur

Region	BMD[1] (g/cm²)	Young-Adult[2] (%)	Young-Adult T-score	Age-Matched[3] (%)	Age-Matched Z-score	BMC (g)	Area (cm²)
Neck	0.930	87	-1.1	95	-0.4	5.10	5.49
Upper Neck	0.762	83	-1.2	93	-0.4	1.44	1.89
Lower Neck	1.018	-	-	-	-	3.66	3.59
Wards	0.874	91	-0.7	103	0.2	2.89	3.31
Troch	0.659	71	-2.5	76	-1.9	4.93	7.47
Shaft	1.003	-	-	-	-	16.08	16.04
Total	0.900	82	-1.4	88	-0.9	26.11	29.00

1 -Statistically 68% of repeat scans fall within 1SD (± 0.012 g/cm² for Left Femur Total)

2 -USA (Combined NHANES (ages 20-30) / Lunar (ages 20-40)) Femur Reference Population (v113)

3 -Matched for Age, Weight (males 25-100 kg), Ethnic

Filename: mbva3o7ivv.dfl

Fig.7.Dexa report

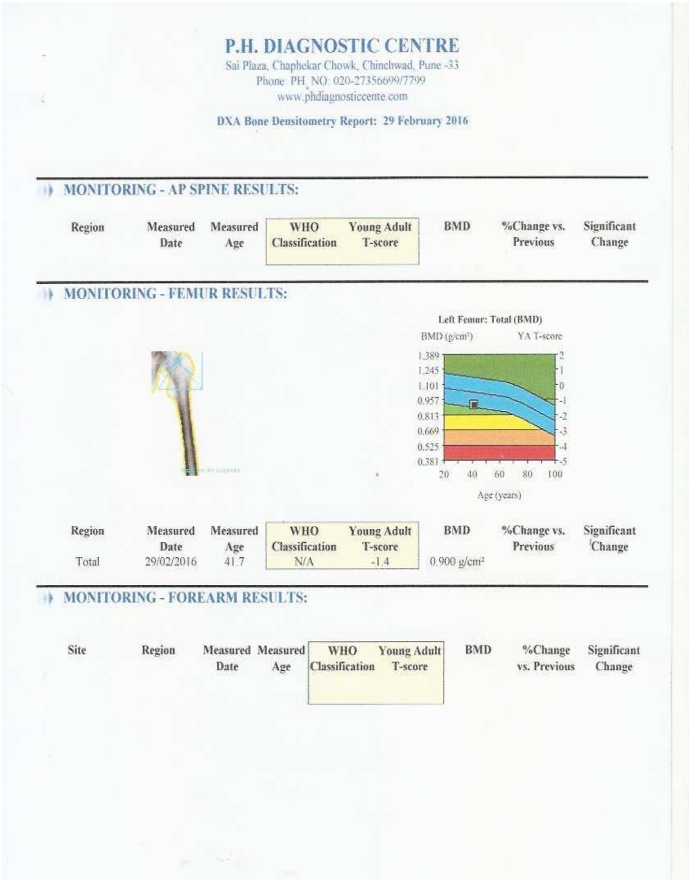


Fig.8.Dexa report

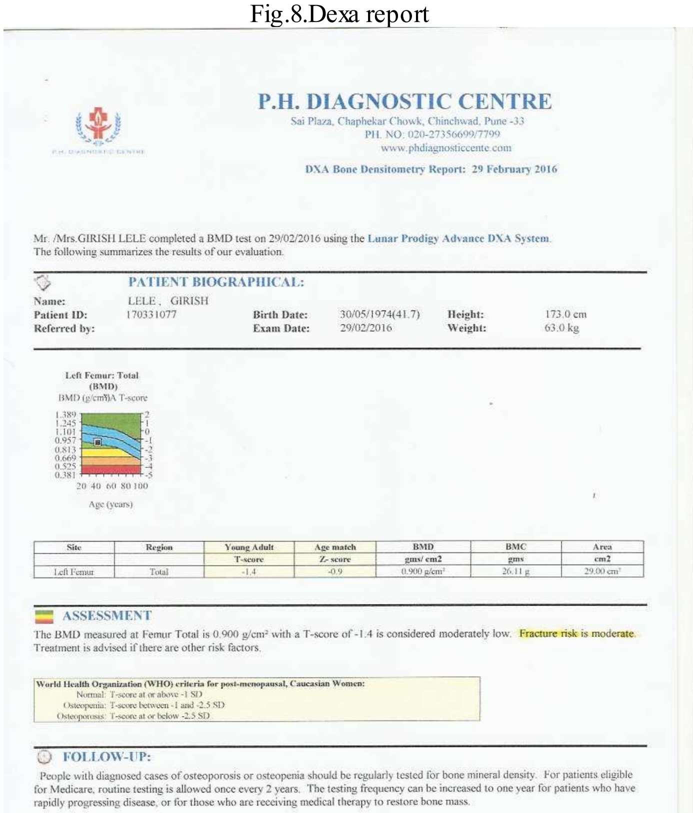


Fig.9.Dexa report

VI. VALIDATION OF RESULT

$R^2=0.984715$

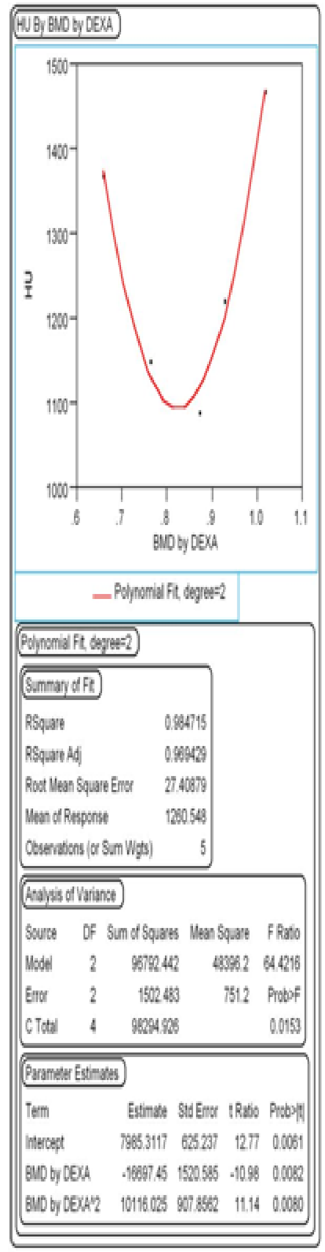


Fig.10.HU by BMD by DEXA

Y=24780.36X^3-64972.3X^2 +55864.13X -14551.6

$R^2=0.877835$

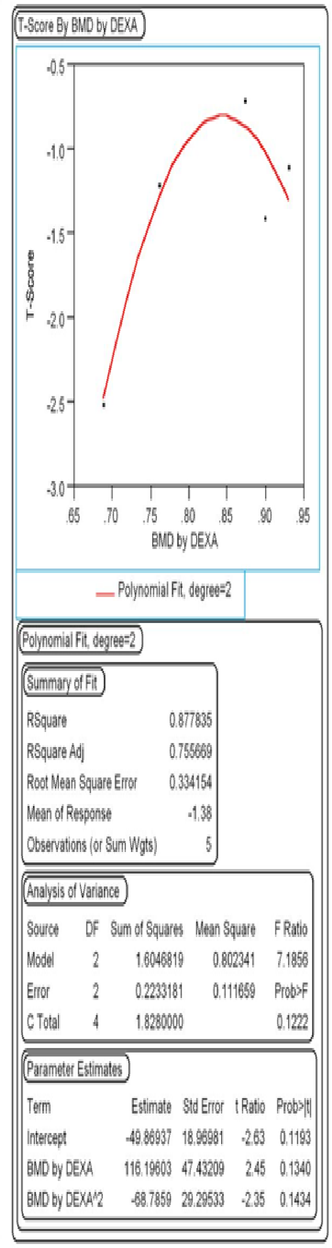
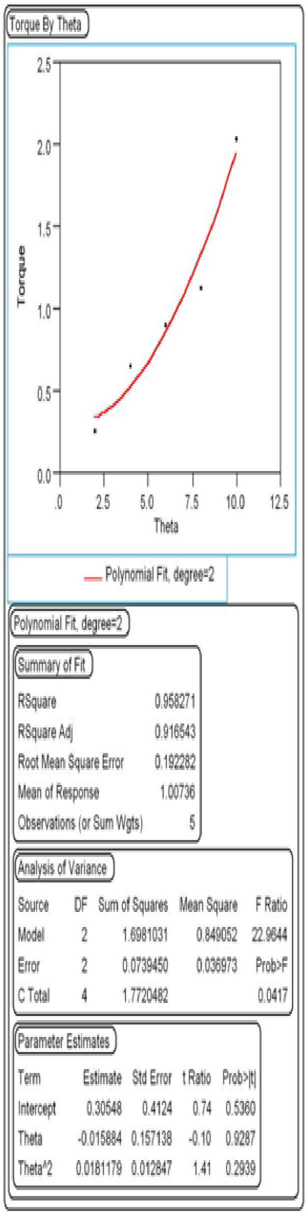


Fig.11.T score by BMD by DEXA

Y=28.66X^3-44.78X^2 +15.22X-0.0016

R^2=0.958271 R^2=0.998098



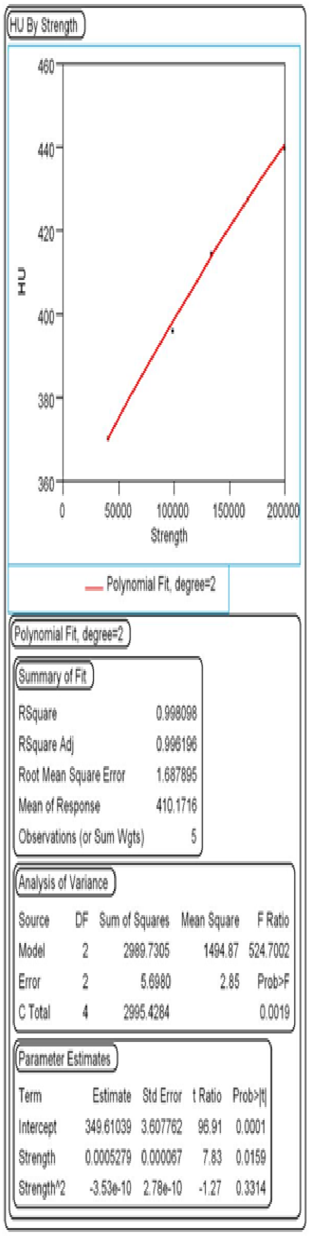


Fig.16. Torque by Theta
Y=-0.0027X^3+0.0496X^2 -0.1274X+0.1934

Fig.18.H.U. By Strength
Y=(-1.06e-14)X^3+(5.557e-9) X^2-0.00022X +374.121

A. Error analysis:

TABLE IV.
ERROR ANALYSIS

BMD			ERROR	
Sr No	DEXA	CT SCAN	DEXA AND CT	CT AND DEXA
1	0.93	1.001	-0.076344086	0.070929071
2	0.762	0.869	-0.140419948	0.123130035
3	1.018	0.589	0.421414538	-0.728353141
4	0.874	0.568	0.350114416	-0.538732394
5	0.659	0.922	-0.39908953	0.285249458
6	1.003	1.586	-0.581256231	0.367591425
7	0.9	0.939	-0.043333333	0.041533546
Total mean percentage error			-0.468914173	-0.378652001

VII. CORRELATION

A. Between BMD and strength:

TABLE V
Correlation of BMD and strength

Sr No	Y	Tortional strength	X^2	X^3	X^4	X*Y	X^2*Y
1	1.001	40298.2632	1623950017	6.54424E+13	2.63721E+18	40338.56146	1625573967
2	0.86	98569.36819	9715920345	9.57692E+14	9.43991E+19	84769.65664	8355691497
3	0.58	133951.575	17943024438	2.4035E+15	3.21952E+20	77691.91349	10406954174
4	0.56	166527.5338	27731419515	4.61804E+15	7.69032E+20	93255.41893	15529594928
5	0.92	199225.5917	39690836405	7.90743E+15	1.57536E+21	183287.5444	36515569492
6	1.58	232271.9341	53950251351	1.25311E+16	2.91063E+21	366989.6558	85241397134
7	0.93	265241.73	70353175308	1.86606E+16	4.94957E+21	246674.8089	65428453037
8	0.96	298209.6981	88929024041	2.65195E+16	7.90837E+21	286281.3102	85371863079
9	1.19	331333.6616	1.09782E+11	3.63745E+16	1.20521E+22	394287.0573	1.30641E+11
10	0.93	364112.0914	1.32578E+11	4.82731E+16	1.75768E+22	338624.245	1.23297E+11
11	1.01	397262.5324	1.57818E+11	6.2695E+16	2.49064E+22	401235.1578	1.59396E+11
12	1.01	430378.9095	1.85226E+11	7.97174E+16	3.43087E+22	434682.6986	1.87078E+11
13	12.60	467624.2565	2.18672E+11	1.02257E+17	4.78176E+22	5892065.632	2.75527E+12
total	24.20	3425007.145	1.11401E+12	4.0298E+17	1.55194E+23	8840183.661	3.66416E+12

X= Strength, Y=BMD

By using Linear Least square Regression Method:-

ΣY=AΣX^2+BΣX+C*n ………….. (1)

ΣXY=AΣX^3+BΣX^2+CΣX ………….. (2)

ΣX^2Y=AΣX^4+BΣX^3+CΣX^2 ………….. (3)

By substituting the values of ΣX, ΣX^2, ΣX^3, ΣX^4, ΣY, ΣXY, ΣX^2Y & n we get,

A= 1.0190*10^-10 B= -4.1070*10^-5 C=3.9497

Modified Final Correlation is:BMD= {(1.0190*10^-10 *S^2} + {(-4.1070*10^-5*S} +3.9497

B. *Correlation between HU and Strength:-*

TABLE VI.

CORRELATION OF HU AND STRENGTH

Sr No.	X	Tortional strength	X^2	X^3	X^4	X*Y	X^2*y
1	370.171	40298.2632	137026.6	50723262	1.88E+10	14917248.39	5.52E+09
2	376.133	98569.36819	141476	53213805	2.00E+10	37075192.16	1.39E+10
3	382.094	133951.575	145995.8	55784129	2.13E+10	51182093.09	1.96E+10
4	385.075	166527.5338	148282.8	57099982	2.20E+10	64125590.08	2.47E+10
5	391.037	199225.5917	152909.9	59793442	2.34E+10	77904577.72	3.05E+10
6	394.018	232271.9341	155250.2	61171367	2.41E+10	91519322.91	3.61E+10
7	399.979	265241.73	159983.2	63989921	2.56E+10	106091121.9	4.24E+10
8	405.941	298209.6981	164788.1	66894244	2.72E+10	121055543.1	4.91E+10
9	407	331333.6616	165649	67419143	2.74E+10	134852800.3	5.49E+10
10	413	364112.0914	170569	70444997	2.91E+10	150378293.8	6.21E+10
TOTAL	3924.448	2129741.447	1541930.6	6.07E+08	2.39E+11	849101783.3	3.39E+11

X= HU, Y=Strength

By using Linear Least square Regression Method:-

ΣY=AΣX^2+BΣX+C*n ………….. (1)

ΣXY=AΣX^3+BΣX^2+CΣX ………….. (2)

ΣX^2Y=AΣX^4+BΣX^3+CΣX^2 ………….. (3)

By substituting the values of ΣX, ΣX^2, ΣX^3, ΣX^4, ΣY, ΣXY, ΣX^2Y & n we get,

A= 4.5646 B=2623.6955 C=-1520524.244

Modified Final Correlation is:-HU={(4.5646*S^2} + {(2623.6955)*S}-1520524.244

Where S=Strength

C. *Correlation between BMD,Z-Score & T-Score:-*

TABLE VII

CORRELATION BETWEEN BMD,Z-SCORE & T-SCORE

Sr No	N	BMD(Y)	Z score	T score
1	1	0.93	-0.4	-0.435
2	2	0.762	-0.4	-1.019
3	3	1.018	0.3	-0.691
4	4	0.874	0.2	-1.363
5	5	0.659	-1.9	-4.0705
6	6	1.003	0.3	-2.1985
7	7	0.9	-0.9	-3.95
TOTAL	28	6.146	-2.8	-13.727

By using linear least square regression method:

Y=MX+C

Where,

M= {(n*ΣXY)-(ΣX*ΣY)}/{(n*ΣX^2)-(ΣX)^2}

C={(ΣY/n)-[(M*ΣX)/n]}

BMD correlation:-

1) BMD & T-Score

BMD=0.13036*(T-SCORE) +0.93014

2) BMD & Z-Score

BMD=0.03913*(Z-SCORE) + 1.13364

VIII. RESULTS& CONCLUSION

1) BMD of bone can be find by using various methods. E.g. from CT scan data, From DEXA scan.

2) T Score, Z score of femur bone can be find by this investigation.

3) Regrassion model developed in this investigation could be used for find out correlation between BMD and torsional strength

4) Regrassion model developed in this investigation could be used for find out the BMD and HU directly by considering the value of torsional strength of bone without using different machines.

5) The investigation used to get the maximum torque required for Break the Femur Bone during torsion test.

6) By using experimental setup we will find different properties of bone, which is also useful in orthopedic sector for design and manufacturing of implants, research and many other fields.

REFERANCES

[1] BenjaminR.Furman1,Subrata Saha2, "Torsional testing of Bone" in mechanical testing of bone and bone implant interface.

[2] Yuehuei H. An, "Mechanical Properties of Bone".

[3] Christopher V. Bensen1 , Yuehuei H. An 2, "Basic Facilities and Instruments for Mechanical Testing of Bone".

[4] J.Y.Rho1, M.C.Hobatho 2,R.B.Ashman 3, "Relation of mechanical properties to density and CT numbers in Human bone" in mechanical testing of bone and bone implant interface.

[5] Yvonne haba 1,Ralpha skripitz 2,Tobias lindner 3,Martin kockerling 4, "Bone Mineral Density and mechanical properties of retrieved femoral bone samples in relation to bone mineral densities measured in respective patient".

[6] Adeeb Rahman 1,Shirin Selmi 2,Chris Papadopoulos 3, "CT-Scan based FEA For the assessment of the effect of bone density on femurs fracture" in mechanical testing of bone and bone implant interface.

[7]Yegireddi shireesna 1,Dr.S.V. Ramana 2,P Govind Rao 3, "Modeliing and static analysis of femur bone by using imolant materials" " in mechanical testing of bone and bone implant interface.

.

[8]Jae-Young Rho,"Ultrasonic Methods ForEvaluating Mechanical Properties of Bone" " in mechanical testing of bone and bone implant interface.