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ORIGINAL ARTICLE

The Efficacy of Porosity and Bone Composition on the Amount of Impact Energy Absorbency in Femoral Cortical Bone

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Farid Hosseini Mansoub, Mahdi Koohdaragh and Navid Hosseini Mansoub**;** The Efficacy of Porosity and Bone Composition on the Amount of Impact Energy Absorbency in Femoral Cortical Bone

ABSTRACT

Ten fresh femoral bovine bone were prepared from 11 cows, aged eighteen months and weight range of 500–600 kg at the time of massacre. Sixty two blocks of cortical bone were cut from the medial part of the femoral shaft in the longitudinal direction. All specimens were prepared from the blocks by machining according to ASTM-E36. The specimens were kept wet during machining with saline solution and stored in a freezer at -20°C till testing. The wet density (2.0519±0.0465 g/cm^3), dry density (1.8137±0.0641 g/cm^3), percent of mineral content (%Min=69.8292±1.9073), percent f ash (%Ash=61.8141±2.4280), percent of organic (%wet organic=26.5622±1.9523, %dry organic=28.5686±2.4888), and percent of water nearly content (%H_2O=12.7155±2.6157) were determined for each specimen. Charpy tests were carried out for the specimens and the amount of fracture energy was recorded for each one. All tests were done with the same initial angel (45) and the same initial energy (11.5j). The absorbed energy divided by the cross section of the specimens was recorded j/cm^2 (12.1572±2.6971$^)$. Statistical analysis of the results showed a positive and significant relationship between the dry density (r_d) and absorbed energy ($p<0.005$, r=+0.757) and between %Ash and absorbed energy ($p<0.005$, r =+0.749), and also a negative and significant relationship between %H_2O and absorbed energy ($p<0.005$, r = - 0.707) was found, but no significant correlation between %Organic (wet and dry) and absorbed energy and between the wet density (r_w) and absorbed energy was detected. In order to designing statistic graphs and analyses simple linear model is utilized & all the statistic analyses are done via SPSS.

Key words: Femoral cortical bone, Porosity and Bone Composition, Impact Energy.

Introduction

Femoral bone is the longest, strongest and heaviest bone of the body. Just like as other bones, it is composed of the following parts

1. Diaphysis: The long and axial part of bone
2. Epiphysis: Two ends of a bone which is the joint to the other bones and is covered by a layer of hyaline cartilage. This cartilage decreases the friction in joint and absorbs the incoming impacts toward joint.
3. Metaphysis: The area between diaphysis and epiphysis
4. Medullary Canal: it is the hollow space of diaphysis that contains yellow marrow in adults.
5. As it is shown in figure, femoral bone is composed of head, neck, greater and lesser trochanter, body, medial and lateral condyles.

Osteoporosis is a kind of disease that appears as aging and decreases the mass and density of bone and its hardness and strength against fracture. It also changes the structure of bone tissue [1]. Distribution

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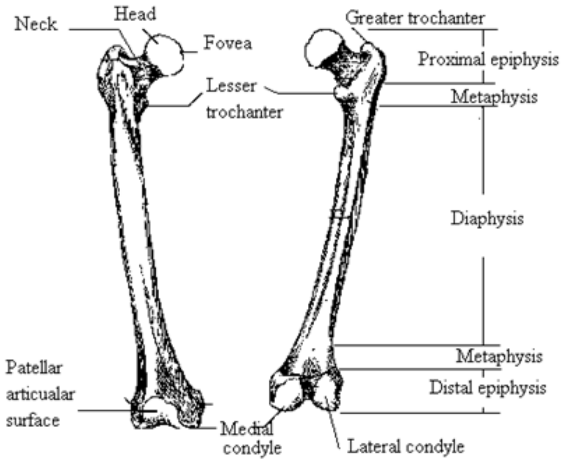

of bone organic and mineral material on the strength and elasticity coefficient in experiments on human and animal bone has been shown [2-6]. Various results are reported over the effect of mineral material of bone on its strength and hardness, but it has not been significant about cow's femoral bone [7]. In addition, studies over femoral and great trochanter bone of cow showed that the increase of density will lead to the increase of shear strength [8,9]. Via some experiments of X-ray [10] and Ultrasound [11], it is shown that the mineral density of human femoral neck is a determining factor in strength of bone against fracture. Investigation and evaluation of cortical bone are of high importance since its mechanical characteristics and relation with density and composition decreases and prevents possible fractures [12-14]. On the other side, the kind of failure and incoming pressure on femoral bone in the strengths of bone against fracture is of a key role [15-17]. In this paper the efficacy of density on energy absorption is investigated. Since, change in bone composition (organic, mineral and water) causes a change in bone density; it is decided to recognize the relation between above factors.

Materials and methods

10 femoral bones of 16-18 months aged cows from local race of black and white were chosen. Immediately they were sent to laboratory in order to separating the soft tissues. The bones were cut through their two heads by an arched saw and their marrows were emptied. Then, prepared bones in order to make samples were wrapped in gauze soaked with serum 0.9% and kept in freezer of -20° C. 24 h before machine and sampling, the bones were taken out of freezer and again put in serum 0.9%. 62 samples were made from cortical of diaphysis lengthways according to ASTM E26 standards of Charpy Test. On averagely, 5-7 samples were shaved from every bone. When carrying out experiments cares should be taken into attention that there would not be any impact on bone and the temperature of samples not increase. In order to prevent this problem, serum 0.9% is utilized.

Each of shared samples were coded and weighed accurately via scale of 0.0001 gr accuracy. The volumes of samples were estimated through Archimedes method. The samples were afloat in distilled water by a string whose other end was connected to a scale (plus estimating the density of distilled water). Because the density of distilled water was one, the weight of sample was equal to the volume of sample.

After measuring wet density, the samples were again wrapped in salty water gauze and saved in -20° C freezer.

24h before experiment the samples were taken out of freezer and kept in salty water of 0.9% in environment temperature. Impact test is shown in fig.3 through Charpy tester with digital indicator and its maximum energy is 70 j.

All the experiments are carried out with first equal angle and energy (45°, 11.5 j).

The causing difference of first energy and energy shown in digital indicator were registered for each sample after releasing pendulum and breaking bone sample (second energy) on the basis of j divided onto the surface of broken section on the basis of cm^2 (j/cm^2).

In order to be sure about no change of wet mass, they were measured after each experiment but no change was found before and after experiment. Then, the samples were degreased by Acetone and the samples were put into oven of 60° C for 24h in order to determining dry mass. After that duration the samples were taken out of oven and kept in Dessicator for an hour. Then, their dry masses were measured by accuracy of 0.0001 g for several times until gaining a fixed amount of every dry mass. In order to determine ash mass, the samples were put into furnace of 600° C. After 24 hours, the samples were taken out of furnace & again put into Dessicator until reaching environment temperature.

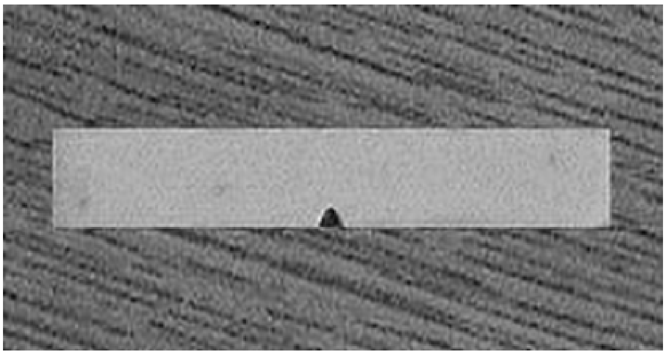

Fig. 1: Shared sample of cow femoral cortical bone for experiment of impact according to ASTM E26 standards in the size of 55´10´5 mm and Notch of 45° in the width of 2 mm in middle.

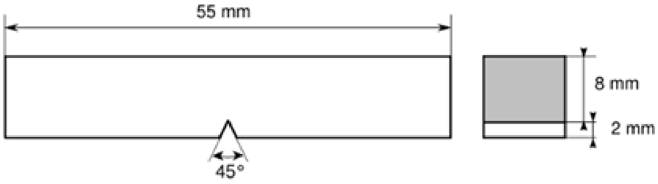

Fig. 2: The size of sample in order to impact test of Charpy according to ASTM E26 standards.

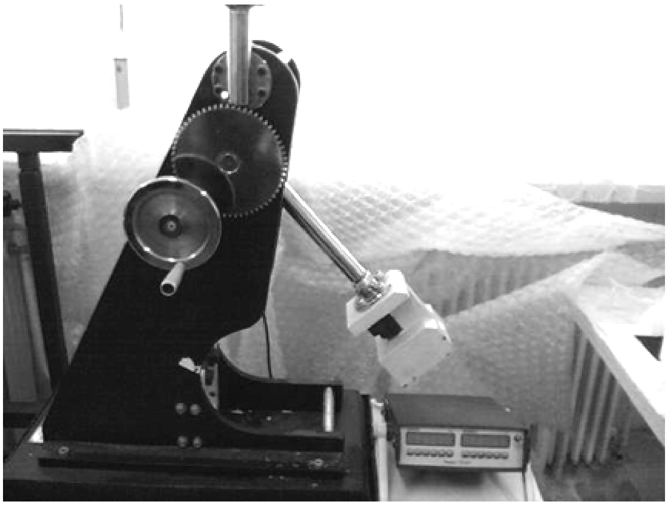

Fig. 3: Charpy impact tester in biomechanics laboratory.

The mass of samples' ashes were weighed and following parameters were clarified [8]:

Dry Density = Dry Mass / Volume
Wet Density = Wet Mass / Volume
Percentage of Minerals = (Ash Mass / Dry Mass) ´ 100
Percentage of Dry Organic = (Dry Mass – Ash Mass) / Dry Mass ´ 100
Percentage of Ash = (Ash Mass / Wet Mass) ´ 100
Percentage of Wet Organic = (Dry Mass – Ash Mass / Wet Mass)´ 100
Percentage of Water = (Wet Mass – Dry Mass) / Wet Mass ´ 100

As it is shown the percentage of mineral materials determines the amount of mineral material of bone which is normalized by dry mass and ash percentage of bone minerals which are normalized by wet mass. Respectively, this definition is represented for dry organic percentage & wet organic percentage. In order to designing statistic graphs and analyses simple linear model is utilized & all the statistic analyses are done via SPSS software.

Results and Discussions

Table 1 shows estimated parameters, the amount of impact energy absorbency in the shape of mean and standard deviation. In addition, fig.4 shows dry density-impact energy absorbency, fig.5 percentage of water- impact energy absorbency, fig.6 ash percentage- impact energy absorbency, fig.7 mineral percentage- impact energy absorbency.

As it is shown in fig.4, there is a positive and significant relation between dry density and amount of impact energy absorbency which determines that increase of dry density increases impact energy absorbency and cortical bone impact strength. Besides, fig.5 proves that there is a reverse relation between water in bone and impact energy absorbency. In that case as percentage of water increases the amount of energy decreases. Fig.6 shows the percentage of ash and impact energy absorbency effect, as ash increases energy absorbency demanded for fracture increases. Although in fig.7 as impact energy absorbency increases by increase of mineral density, it is not significant and definite. Through statistic process on gained parameters, impact energy absorbency, r coefficient and p-value between them are shown in table 2.

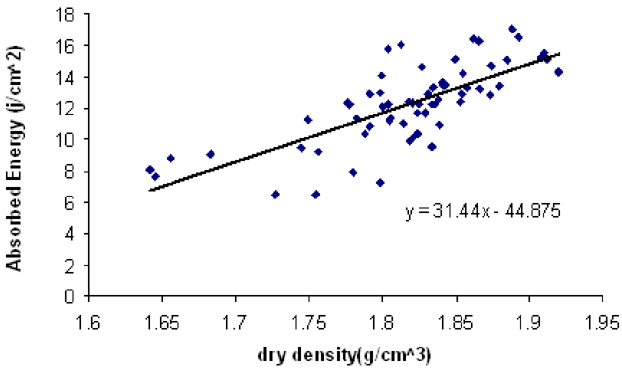

Fig. 4: The graph of impact energy absorbency changes with dry density which shows that as density increases the energy absorbency increases too.

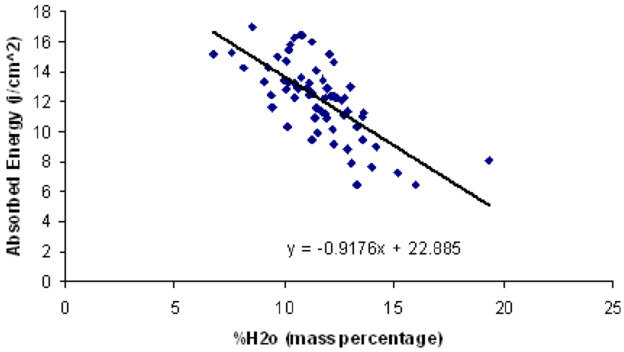

Fig. 5: The graph of impact energy absorbency changes with water percentage which shows that through increase in water percentage the amount of energy absorbency decreases.

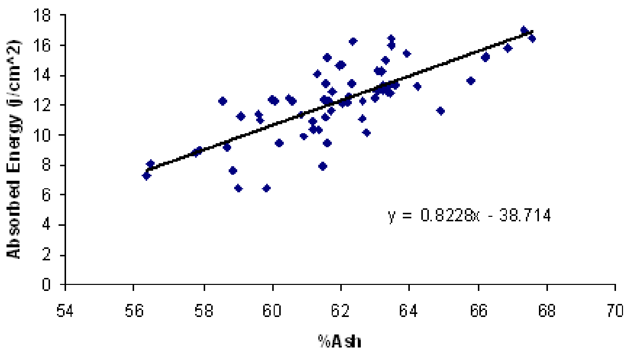

Fig. 6: The graph of impact energy absorbency changes with ash percentage which shows that as ash percentage increases the amount of energy absorbency increases too.

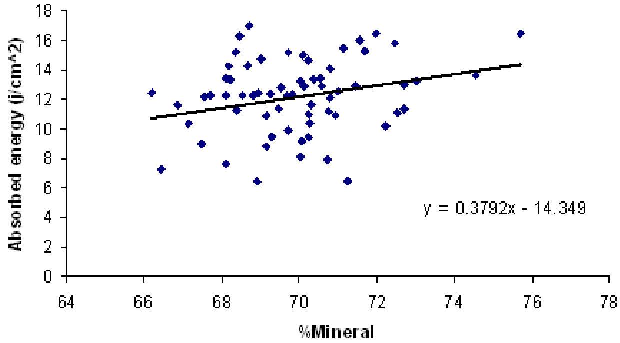

Fig. 7: The graph of impact energy absorbency changes with mineral percentage which shows that there is no significant relationship between them.

Table 1: Mean and Standard Deviation of Density and Compositions of Samples and Amount of Energy.

Parameter	N	Minimum	Maximum	Mean	Std. Deviation
Wet D	62	1.9035	2.1724	2.051963	.0465341
Dry D	62	1.6411	1.9200	1.813758	.0641043
%Water	62	6.78	19.35	11.7026	2.00926
%Min	62	66.1867	75.7105	69.829206	1.9072740
%Ash	62	56.3481	67.5788	61.814148	2.4279680
%Org(d)	62	21.1284	33.5570	28.568613	2.6156803
%Org(w)	62	21.1284	30.6393	26.562198	1.9523297
Energy	62	6.5000	17.0000	12.157263	2.6970659

Table 2: Statistical analysis of the results.

Parameter		Wet D	Dry D	%Water	%Min	%Ash	%Org(d)	%Org(w)	Energy
Wet D	r Correlation	1	.358	-.047	.220	.103	-.084	-.363	.154
	P-Value		.004	.719	.086	.425	.517	.004	.231
Dry D	r Correlation	.358	1	-.761	.145	.712	-.065	.024	.757
	P-Value	.004		.000	.259	.000	.616	.853	.000
%Water	r Correlation	-.047	-.761	1	.018	-.778	.192	-.179	-.707
	P-Value	.719	.000		.890	.000	.134	.163	.000
%Min	r Correlation	.220	.145	.018	1	.392	-.413	-.543	.232
	P-Value	.086	.259	.890		.002	.001	.000	.069
%Ash	r Correlation	.103	.712	-.778	.392	1	-.409	-.267	.749
	P-Value	.425	.000	.000	.002		.001	.036	.000
%Org(d)	r Correlation	-.084	-.065	.192	-.413	-.409	1	.648	-.218
	P-Value	.517	.616	.134	.001	.001		.000	.088
%Org(w)	r Correlation	-.363	.024	-.179	-.543	-.267	.648	1	-.088
	P-Value	.004	.853	.163	.000	.036	.000		.497
Energy	r Correlation	.154	.757	-.707	.232	.749	-.218	-.088	1
	P-Value	.231	.000	.000	.069	.000	.088	.497	

This study focuses attention on the efficacy of density and cow's femoral cortical bone compositions in relation to impact energy absorbency in some samples of femoral cortical bone of cow.

Experiments carried out by *Wright and Hayes* [18] on the samples of human femoral bone in femoral neck parts and subtrochanteric corresponded with results from this paper in efficacy of density on impact energy absorbency. Results from density and bone compositions corresponds previous experiments too [19-20]. As it is shown in fig.4 through increase of dry density energy absorbency increases but there is no significant relation between wet density and impact energy absorbency in table 2. This is proven when ash mass is normalized with dry and wet mass because there is positive and significant relation between ash percentage and energy absorbency but no significant relation between mineral percentage and energy absorbency. In other words, there is no relation between these two parameters in the presence of water [7,21,22].

Since the percentage of bone water determines bone hollows, it can be concluded that as water percentage increases the hollows increase too and as a result, porosity increases [7,23]. On the other hand, in fig.5, as water percentage increases the impact energy absorbency decreases; so it can be concluded that there is a reverse relation between porosity and impact energy absorbency.

References

1. Legrand, E., D.C. Chappard, M. Pascaretti, S. Duquenne, V. Krebs, M.F. Rohmer and M. Basle, 2000. Audran, Trabecular bone microarchitecture, bone mineral density and vertebral fractures in male osteoporosis. J. Bone Miner. Res., 15: 13-19.
2. Burstein, A.H., J.M. Zika, K.G. Heiple and L. Klein, 1975. Contribution of collagen and mineral to the elastic-plastic properties of bone. J Bone Jt Surg., 57A: 965-961.
3. Hesagava, K., C.H. Turner and D.B. Burr, 1994. Contribution of collagen and mineral to the elastic anisotropy of bone. Calcif Tissue Int., 55: 386.
4. Saha, S., 1977. Longitudinal shear propertiesof human compact bone and its constituents and the associated failure mechanisms. J Mater Sci., 12: 1798- 1806.
5. Shah, K., M.J.C.H. Goh, R. Karunanithy, S.L. Low and S. Das De, 1995. Effect of decalcification on bone mineral content and bending strength of feline femur. Calcife Tissue Int., 56: 78.
6. Currey, J.D., 1975. The effects of strain rate, reconstruction and mineral content on some mechanical properties of bovine bone. J Biomech., 8: 81-86.
7. MacCalden, R.W., J.A. McGeough, M.B. Barker and C.M. Court-Brown, 1999. Age related changees in the tensile properties of cortical bone: The relative implication of changees in porosity, mineralizaion. J Bone J Surge, 75A: 1139-1143.
8. Yeni, Y.N., C.U. Brown, T.L. Norman, 2000. Influence of bone composition and apparent density on fracture toughness of the human femur and tibia. J. Bone, 22.
9. Wang, X., N.S. Masilamani and C.M. Agrawal, 1997. Relation of mineral density and tensile properties of bone with its fracture toughness. In: Transactions of the 43rd annual meeting, Orthopaedic Research Society. February 9-13, San Francisco, CA, 331.
10. Greenspan, S.L., E.R. Myers, L.A. Maitland, *et al*., 1994. Fall severity and bone mineral density as risk factor for hip fracture in ambulatory elderly. J AM Med Assoc., 12(271): 128-33.
11. Hayes, W.C., E.R. Myers, J.N. Morris, *et al*., 1993. Fall severity and bone mineral density as risk in eldery nursing home resident who fall. Calcif Tissue Int., 52: 192-8.
12. Werner, C., B.F. Iversen, H. Therkildsen, 1988. Contribution of the trabecular component to mechanical strength and bone mineral content of the femoral neck: an experimental study on cadaver bones, Scan. J. Clin. Lab. Invest., 48: 457-460.
13. Lotz, J.C., E.J. Cheal, W.C. Hayes, 1995. Stress distribution within the proximal femur during gait and falls: implications for osteoporotic fractures, osteoporosis International, 5: 225-261.
14. Ferretti, J.L., H.M. Frost, J.A. Gasser, *et al*., 1995. Perspectives on osteoporosis research: its focus and some insights from a new paradigm, calcify. Tissue Int., 57: 399-404.
15. Pinilla, T.P., 1996. Bouxsein ML, et al. Impact direction from a fall influences the failure load of the proximal femure as much as age-related bone loss. Calcif Tissue int., 58: 231-5.
16. Dalen, N., L. Hellstron, B. Jacobson, 1976. Bone mineral conyent and mechanical strength of femoral neck. Acta Orthop Scand, 47: 503-8.
17. Bouxsein, M.L., A.C. Countery, W.C. Hayes, 1995. Ultrasound and densitometry of the colcaneus with the failure load of cadaveric femurs .Calcific Tissue Int., 56: 99-103.
18. Behiri, J.C. and W. Bonfield, 1986. Fracture mechanic s of bone-the effects of density specimen thickness and crack velocity on longitudinal fracture. J Biomechanic, 17: 25-34.
19. Wright, T.M. and W.C. Hayes, 1977. Fracture mechanics paremetersfor bone-effect of density and specimen thickness. J. Biomech., 10: 419-430.
20. Schaffler, M.B., E.B. Burr, 1988. Stiffness of compact bone: Effect of prosity ans density, J. Biomech., 21: 13-16.
21. Currey, J.D., 1979. Changes in the impact energy absorption of bone whith age. J Biomech., 12: 459-469.
22. Currey, J.D., K. Brear and P. Zioupos, 1996. The effect of ageing and changes in mineral content in degrading the toughness of human femora. J. Biomech., 19: 257-260.
23. Yeni, Y.N., C.U. Brown, Z. Wang and T.L. Norman, 1997. The influence of bone morphology on fracture toughnes of human femur and tibia. Bone, 21: 453-459.