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The aim of the article is to explain in more detail the biomechanical methods used in determining bone quality as well as to describe basic characteristic bone qualities resulting from the.

Bring fact-checked results to the top of your browser search. Chemical composition and physical properties Depending upon species, age, and type of bone, bone cells represent up to 15 percent of the volume of bone; in mature bone in most higher animals, they usually represent only up to 5 percent. The nonliving intercellular material of bone consists of an organic component called collagen a fibrous protein arranged in long strands or bundles similar in structure and organization to the collagen of ligaments, tendons, and skin , with small amounts of proteinpolysaccharides, glycoaminoglycans formerly known as mucopolysaccharides chemically bound to protein and dispersed within and around the collagen fibre bundles, and an inorganic mineral component in the form of rod-shaped crystals. These crystals are arranged parallel with the long axes of collagen bundles and many actually lie in voids within the bundles themselves. Organic material constitutes 50 percent of the volume and 30 percent of the dry weight of the intercellular composite, with minerals making up the remainder. The major minerals of the intercellular composite are calcium and phosphate. When first deposited, mineral is crystallographically amorphous , but with maturation it becomes typical of the apatite minerals, the major component being hydroxyapatite. Carbonate is also presentâ€"in amounts varying from 4 percent of bone ash in fish and 8 percent in most mammals to more than 13 percent in the turtleâ€"and occurs in two distinct phases, calcium carbonate and a carbonate apatite. Except for that associated with its cellular elements, there is little free water in adult mammalian bone approximately 8 percent of total volume. As a result, diffusion from surfaces into the interior of the intercellular substance occurs at the slow rates more typical of diffusion from surfaces of solids than within liquids. Together these materials give bone a unique combination of strength and elasticity. The mineral crystals are responsible for hardness, rigidity, and the great compressive strength of bone, but they share with other crystalline materials a great weakness in tension, arising from the tendency for stress to concentrate about defects and for these defects to propagate. On the other hand , the collagen fibrils of bone possess high elasticity , little compressive strength, and considerable intrinsic tensile strength. The tensile strength of bone depends, however, not on collagen alone but on the intimate association of mineral with collagen, which confers on bone many of the general properties exhibited by two-phase materials such as fibre glass and bamboo. In such materials the dispersion of a rigid but brittle material in a matrix of quite different elasticity prevents the propagation of stress failure through the brittle material and therefore allows a closer approach to the theoretical limiting strength of single crystals. Compact cortical bone specimens have been found to have tensile strength in the range of â€"1, kg per square cm 10,â€"20, pounds per square inch and compressive strengths in the range of 1,â€"2, kg per square cm 20,â€"30, pounds per square inch. These values are of the same general order as for aluminum or mild steel, but bone has an advantage over such materials in that it is considerably lighter. The great strength of bone exists principally along its long axis and is roughly parallel both to the collagen fibre axis and to the long axis of the mineral crystals. Estimates of modulus of elasticity of bone samples are of the order of to kg per square cm 6, to 10, pounds per square inch , a value much less than steel, for example, indicating the much greater elasticity of bone. The modulus of elasticity in bone is strikingly dependent upon the rate at which loads are applied, bones being stiffer during rapid deformation than during slow; this behaviour suggests an element of viscous flow during deformation. As might be anticipated from consideration of the two-phase composition of bone, variation in the mineral-collagen ratio leads to changes in physical properties: Optimal ratios, as reflected in maximal tensile strength, are observed at an ash content of approximately 66 percent, a value that is characteristic of the weight-bearing bones of mammals.

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Chapter 2 : - NLM Catalog Result

Osteoporosis is a biomechanical problem. It is not a problem by itself â€" on the contrary, osteoporosis gives you less weight to carry around. But osteoporotic bone is less strong than normal bone, and it is only the prospect of a fracture that gives it an undesirable aspect. Fracture is a matter.

Sports biomechanics In sports biomechanics, the laws of mechanics are applied to human movement in order to gain a greater understanding of athletic performance and to reduce sport injuries as well. It focuses on the application of the scientific principles of mechanical physics to understand movements of action of human bodies and sports implements such as cricket bat, hockey stick and javelin etc. Elements of mechanical engineering e. Proper understanding of biomechanics relating to sports skill has the greatest implications on: As noted by Doctor Michael Yessis, one could say that best athlete is the one that executes his or her skill the best. This assumption breaks down when the length scales of interest approach the order of the micro structural details of the material. One of the most remarkable characteristic of biomaterials is their hierarchical structure. In other words, the mechanical characteristics of these materials rely on physical phenomena occurring in multiple levels, from the molecular all the way up to the tissue and organ levels. Mechanical deformation of hard tissues like wood , shell and bone may be analysed with the theory of linear elasticity. On the other hand, soft tissues like skin , tendon , muscle and cartilage usually undergo large deformations and thus their analysis rely on the finite strain theory and computer simulations. The interest in continuum biomechanics is spurred by the need for realism in the development of medical simulation. An often studied liquid biofluids problem is that of blood flow in the human cardiovascular system. Under certain mathematical circumstances, blood flow can be modelled by the Navierâ€"Stokes equations. In vivo whole blood is assumed to be an incompressible Newtonian fluid. However, this assumption fails when considering forward flow within arterioles. At the microscopic scale, the effects of individual red blood cells become significant, and whole blood can no longer be modelled as a continuum. When the diameter of the blood vessel is just slightly larger than the diameter of the red blood cell the Fahraeusâ€"Lindquist effect occurs and there is a decrease in wall shear stress. However, as the diameter of the blood vessel decreases further, the red blood cells have to squeeze through the vessel and often can only pass in single file. In this case, the inverse Fahraeusâ€"Lindquist effect occurs and the wall shear stress increases. An example of a gaseous biofluids problem is that of human respiration. Recently, respiratory systems in insects have been studied for bioinspiration for designing improved microfluidic devices. When the two surfaces come in contact during motion i. Biotribology is a study of friction, wear and lubrication of biological systems especially human joints such as hips and knees. If the performance of tibial component needs to be analyzed, the principles of biotribology are used to determine the wear performance of the implant and lubrication effects of synovial fluid. In addition, the theory of contact mechanics also becomes very important for wear analysis. Additional aspects of biotribology can also include analysis of subsurface damage resulting from two surfaces coming in contact during motion, i. Animal locomotion, has many manifestations, including running , jumping and flying. Locomotion requires energy to overcome friction , drag , inertia , and gravity , though which factor predominates varies with environment. Comparative biomechanics is often applied in medicine with regards to common model organisms such as mice and rats as well as in biomimetics , which looks to nature for solutions to engineering problems. Computational models and simulations are used to predict the relationship between parameters that are otherwise challenging to test experimentally, or used to design more relevant experiments reducing the time and costs of experiments. Mechanical modeling using finite element analysis has been used to interpret the experimental observation of plant cell growth to understand how they differentiate, for instance. One of the main advantages of computational biomechanics lies in its ability to determine the endo-anatomical response of an anatomy, without being subject to ethical restrictions. Antiquity[edit] Aristotle, a student of Plato can be considered the first bio-mechanic, because of his work with animal anatomy. Da Vinci was an artist and mechanic and engineer. He contributed to mechanics and military and civil engineering projects. He had a great understanding of science and mechanics and studied anatomy the a mechanics context. He analyzed muscle forces and movements and studied joint functions. These studies could be considered studies in the realm of biomechanics. Leonardo da Vinci studied anatomy in the context of mechanics. He analyzed muscle forces as acting along lines connecting origins and insertions, and studied joint function. Da Vinci tended to mimic some animal features in his machines. For example, he studied the flight of birds to find means by which humans could fly; and because horses were the principal source of mechanical power in that time, he studied their muscular systems to design machines that would better benefit from the forces applied by this animal. Vesalius published his own work called, On the Structure of the Human Body. In this work, Vesalius corrected many errors made by Galen, which would not be globally accepted for many centuries. With the death of Copernicus came a new desire to understand and learn about the world around people and how it works. On his deathbed, he published his work, On the Revolutions of the Heavenly Spheres. This work not only revolutionized science and physics, but also the development of mechanics and later bio-mechanics. Galileo spent many years in medical school and often questioned everything his professors taught. He found that the professors could not prove what they taught so he moved onto mathematics where everything had to be proven. Then, at the age of 25, he went to Pisa and taught mathematics. He was a very good lecturer and students would leave their other instructors to hear him speak, so he was forced to resign. He then became a professor at an even more prestigious school in Padua. His spirit and teachings would lead the world once again in the direction of science. Over his years of science, Galileo made a lot of biomechanical aspects known. Consequently, bones must also increase disproportionately in girth rather than mere size. This is because the bending strength of a tubular structure such as a bone is much more efficient relative to its weight. Mason suggests that this insight was one of the first grasps of the principles of biological optimization. Giovanni Alfonso Borelli embraced this idea and studied walking, running, jumping, the flight of birds, the swimming of fish, and even the piston action of the heart within a mechanical framework. He could determine the position of the human center of gravity , calculate and measured inspired and expired air volumes, and showed that inspiration is muscle-driven and expiration is due to tissue elasticity. Borelli was the first to understand that the levers of the musculoskeletal system magnify motion rather than force, so that muscles must produce much larger forces than those resisting the motion. Influenced by the work of Galileo, whom he personally knew, he had an intuitive understanding of static equilibrium in various joints of the human body well before Newton published the laws of motion. Using the works of Galileo and building off from them, Borelli figured out the forces required for equilibrium in various joints of the human body. His work is often considered the most important in the history of bio-mechanics because he made so many new discoveries that opened the way for the future generations to continue his work and studies. It was many years after Borelli before the field of bio-mechanics made any major leaps. After that time, more and more scientists took to learning about the human body and its functions. There are not many notable scientists from the 19th or 20th century in bio-mechanics because the field is far too vast now to attribute one thing to one person. However, the field is continuing to grow every year and continues to make advances in discovering more about the human body. Because the field became so popular, many institutions and labs have opened over the last century and people continue doing research. With the Creation of the American Society of Bio-mechanics in , the field continues to grow and make many new discoveries. In Germany, the brothers Ernst Heinrich Weber and Wilhelm Eduard Weber hypothesized a great deal about human gait, but it was Christian Wilhelm Braune who significantly advanced the science using recent advances in engineering mechanics. During the same period, the engineering mechanics of materials began to flourish in France and Germany under the demands of the industrial revolution. This led to the rebirth of bone biomechanics when the railroad engineer Karl Culmann and the anatomist Hermann von Meyer compared the stress patterns in a human femur with those in a similarly shaped crane. Some simple examples of biomechanics research include the investigation of the forces that act on limbs, the aerodynamics of bird and insect flight , the hydrodynamics of swimming in fish , and locomotion in general across all forms of life, from individual cells to whole organisms. With growing understanding of the physiological behavior of living tissues, researchers are able to advance the field of tissue engineering , as well as develop improved treatments for a wide array of pathologies. Such research utilizes force platforms to study human ground reaction forces and infrared videography to capture the trajectories of markers attached to the human body to study human 3D motion. Research also applies electromyography to study muscle activation, investigating muscle responses to external forces and perturbations. Biotribology is a very important part of it. It is a study of the performance and function of biomaterials used for orthopedic implants. It plays a vital role to improve the design and produce successful biomaterials for medical and clinical purposes. One such example is in tissue engineered cartilage.

Chapter 3 : Bone - Chemical composition and physical properties | racedaydvl.com

Contents: Slovak logistic regression predictive model in estimate of femoral neck fracture by fall -- Expected frequency of femoral neck fractures by fall in the osteoporotic and osteopenic East Slovak female population -- Expected frequency of biomechanically adverse values of proximal femur geometric variables in the East Slovak female.

For most studies of limb-bone adaptation, the following mechanical parameters are the most important to thoroughly understand: These parameters are usually considered in terms of material properties, but to some degree can describe how well the whole bone can bear loads, which is measured via structural strength tests. In fact, as argued below, regional material variations e. Structural properties of bone Much of the following paragraph is paraphrased from van der Meulen et al. What is a whole-bone structural test and what does it measure? The structural stiffness is a measure of the resistance to deformation under the applied load, and the structural strength is the load required to cause the whole bone to fail. These two whole-bone measurements are structural properties and are influenced by both the material from which the structure is composed the tissue material properties, see below as well as how and where that material is distributed the geometric form of the tissue. Therefore, both material and geometric properties are required to assess the structural integrity of a long bone, and neither material nor geometry alone is sufficient to predict the structural failure load. As emphasized by van der Meulen et al. Measures of diaphyseal shape and robusticity: Moments and axes of inertia. This includes the second moment of area, or inertia I as many also call it. The second moment of inertia helps describe the mechanical consequences of cross-sectional shape and mass distribution of a cross-section from a tubular structure such as the diaphysis of a long limb bone. Tubular structures have a larger moment of inertia both in bending and torsion than cylindrical structures with the same amount of mass Fig. This is essentially a measure of how the material is distributed about a given axis. Although bar A and B have the same area 1 square unit , bar B has a greater moment of inertia because it has a hollow interior and greater outer diameter. Bar C has twice the mass or area in the cross-section; 2 square units and therefore a much greater moment of inertia. Note that the cross-sectional areas of the bars are directly proportional to their tensile and compressive strengths. By contrast, because the moment of inertia is to the 4th power, the bending and torsional strengths become exponentially greater from bar A to C. Structural and material characteristics of a limb-bone diaphysis reference: Consequently, across the Imax and Imin axes are, respectively, the directions of greatest and least bending resistance rigidity. Also shown are the angles that these axes deviate from the anterior-posterior AP axis. More specifically, the ratio of the principal cross-sectional moments e. Studies by Carlson and co-workers Carlson, ; Carlson and Judex, provide good examples of how these measures of robusticity and ellipiticality are defined and used in anthropological studies that are aimed at deciphering load history. What this means is that the greatest bending rigidity occurs when the direction of bending is across i. These definitions can be confusing in the anthropological literature because some prominent investigators have adhered to them e. Material properties of bone. At the most basic level, bone is a composite of type 1 collagen and mineral typically a carbonated hydroxyapatite , and this composite is enriched with non-collagenous proteins that also have important biochemical and biomechanical functions. Important mechanical and biophysical interactions of the collagen-mineral composite for elastic and plastic behaviors are described by Burstein et al. Bone material properties are the tissue-level mechanical properties that describe the constituent material and are independent of the size and shape of the bone. These material properties are determined by machining precise samples from the bone of interest and testing them in a particular loading mode. With respect to material properties, it is important for all students of bone adaptation to memorize all features of a typical stress-strain curve, which shows the results of a material test Fig. Beyond the yield point B is where permanent deformation of the specimen occurs. The strain at any point in the elastic region of the curve is proportional to the stress at that point. Therefore the slope of the elastic region A-B is the material stiffness or elastic modulus; increased steepness of the A-B slope represents increased stiffness.

The ultimate failure point C is the point beyond which failure of the specimen occurred. Total energy absorbed is a sum of elastic and plastic energy. Brittle materials have shorter B-C regions than more ductile materials longer B-C regions. This material heterogeneity and its directionality e. Bone tissue is also viscoelastic â€" it has stress-strain characteristics that are dependent upon the applied strain rate. In other words, a specimen of bone tissue that is exposed to very rapid loading will absorb more energy than a specimen that is loaded more slowly. Therefore, bone tissue is both anisotropic and viscoelastic. Because of these characteristics one must specify the strain rate and the direction of applied loading when discussing bone material behavior. As noted, mechanical behaviors defined by stress and strain deal with material properties; the corollaries for structural properties are load and deformation, respectively. Stiffness and strength are the chief properties of a bone whether it is considered as a structure or as a material. The modulus of elasticity shows how stiff the bone material is. Yield stress strength at initial failure and strain determine how much energy can be absorbed before irreversible changes take place in the material. Ultimate stress is the strength at final failure. Post-yield stress and strain 1 see footnotes determine mainly how much energy can be absorbed after yielding but before the material fractures Fig. Irreversible changes occur at the yield point and are caused by accumulating microdamage. The total area under the stress-strain curve is equivalent to the work that must be done per unit volume of the bone specimen before it breaks. The total area under the stress-strain curve can be divided into two portions: As described below, regional CFO variations typically correlate more strongly with energy absorption than with stiffness elastic modulus or strength Skedros et al. Fracture mechanical properties show the extent to which bone Footnote 1. Among various stimuli, available data suggests that strain is the mechanical parameter most directly involved in causally mediating bone adaptations Rubin and Lanyon, ; Lanyon, ; Ehrlich and Lanyon, Mechanical strain is the change in length of a loaded structure as a percentage of its initial unloaded length Note: This dimensionless ratio is a measure of material or tissue deformation. In vivo strain data from a variety of animals suggests that physiological strains are generally between and 3, microstrain i. The upper limit may be only 1, microstrain in tension Fritton et al. Crack travel resistance is indicated by post-yield stress and strain. The more compliant material at right requires more energy to break it. Energy absorption is proportional to the area under each curve; hence the less compliant material at left absorbs less energy than the more compliant material even though it has higher yield stress YS and ultimate stress US. In addition to stiffness, strength, and toughness, fatigue resistance is one of the four most-important mechanical parameters that must be considered when interpreting the load history and adaptation of a bone or bone region. Fatigue failure is when a structure is loaded repeatedly and breaks at a lower load than would cause it to fail if it were loaded only once. Fatigue resistance is when fatigue failure is prolonged or avoided altogether. Ritchie Ritchie et al. Using the stress-strain curve for considering mechanisms of bone adaptation produced by remodeling-induced affects on CFO, osteon morphotypes, and osteon population densities. The final portion of this section is an exercise that considers how primary modifications for pre-yield elastic behavior can secondarily have beneficial consequences for post-yield behavior. Another way to think about this is to ask: This depiction is based on data and observations described by Bigley et al. Three drawings depicting an energy absorption toughness test in tension T of a machined specimen at top loaded at each end with a force F. Energy is absorbed as the osteons debond, pullout, and bridge the forming crack middle drawing. Adapted from Martin et al. These primary adaptations can have beneficial perhaps serendipitous effects for post-yield behavior. Osteon size might also play a role in this context Hiller et al. This figure helps to conceptualize the putative shifts in the temporal importance of genetic, epigenetic, and extra-genetic influences, especially with respect to varying histocompositional characteristics within or between bones. From the pre-natal phase and well into the attainment phase, the adaptive growth response of cartilage, or chondral modeling not discussed in this chapter , has a profound influence on the growth and form of limb bones, especially at their epiphyses where articulations are formed with adjacent bones Hammond et al. Shown is also the second bone mass growth spurt that occurs in humans, which has not been demonstrated in any other amniote. These images are reproduced from the original study of Martin et al. The numerical values of each of the six morphotypes are used to calculate the osteon morphotype score MTS of entire microscopic images that contain many osteons Skedros et al. Images are reproduced from Martin et al. Images are reproduced with permission granted by Lanny Griffin and Elsevier Ltd. This refers to a material with a grain whose properties or technical constants are different when measured in different directions, most having some degree of symmetry to their internal structure. Bone is anisotropic, but examples of limited anisotropy can also be found in bone orthotropic and transversely isotropic Martin et al. If the properties are the same in different directions, then the material is isotropic. Adaptation in cortical bone commonly refers to either: This section primarily deals with identifying correlations between structure, material, function, and load history. These correlations might be produced by: We have suggested that the non-uniform strain distribution experienced in the early development of most limb bones is proximate to the historical origin i. Fatigue failure is when a structure is loaded repeatedly and breaks at a load that would not cause it to fail if it were loaded only once. Consequently, modeling is a concept describing a combination of non-proximate, though coordinated, resorption and formation drifts whose net result is, typically, to change the distribution of bone. Such drifts are called macro-modeling in cortical bone and mini-modeling in cancellous bone. The re-alignment of trabecular tracts along the lines of stress would be a consequence of mini-modeling. Tough materials resist damage propagation but do not necessarily resist damage formation. Toughness tests typically involve propagating a crack in a controlled direction through a specimen machined into a specific shape for this test. On the effect of X-ray irradiation on the deformation and fracture behavior of human cortical bone. Biol Rev Camb Philos Soc Mechanical loading and bone growth in vivo. Bone, Volume 7, Bone Growth â€” B.

Chapter 4 : Bone quality: what is it and how is it measured?

The incidence of fractures increases with age. This is partly due to extraosseous factors and partly to the increased fragility of the bone material itself. Ageing adversely affects the "quality" of human bone material, its elastic and ultimate properties.

Anna Williams journal of the mechanical behavior of biomedical materials]]]]]]]] â€”]]] Available online at www. Determination of age-at-death AAD is an important and frequent requirement in Received 12 June contemporary forensic science and in the reconstruction of past populations and societies Received in revised form from their remains. Its estimation is relatively straightforward and accurate 73 yr 8 October for immature skeletons by using morphological features and reference tables within the Accepted 15 October context of forensic anthropology. However, after skeletal maturity yr estimates become inaccurate, particularly in the legal context. In line with the general migration of Keywords: We explore here whether well-known changes in the biomechanical properties Estimates of bone and the properties of bone matrix, which have been seen to change with age even Forensics after skeletal maturity in a traceable manner, can be used to provide a reliable estimate Biomechanical features of AAD. This method produced successful age estimates on a cohort of 12 donors of age 53â€”85 yr 7 male, 5 female , where the age of the individual could be approximated within less than 71 yr. This represents a vastly improved level of accuracy than currently extant age estimation techniques. Journal of the Mechanical Behavior of Biomedical Materials , http: Introduction Age at death is one of the main four physical attributes that a Forensic Anthropologist may be called to estimate when attempting to identify unknown skeletal or decomposed human remains, along with an estimation of sex, stature during life and ethnic ancestry. In infants, juveniles and adolescents, these skeletal changes are governed mostly by intrinsic genetic and hormonal factors, which mean that there is little variation between the chronological age at which certain recognisable milestones, such as epiphyseal fusion of long bones, are reached. This makes age at death estimation of sub-adults much easier and more likely to be accurate than in skeletally mature individuals Scheuer and Black, In juveniles, dental eruption occurs at regular intervals to allow quite accurate 73 yr age estimation. However, the reliability of age estimation declines with increasing age. This means that it is unlikely for two individuals of the same chronological age to show exactly the same age related skeletal changes. This variation between individuals means that age estimation of adults is notoriously unreliable Scheuer, AAD estimates based on these methods are not usually more accurate than yr, and lead at best to an approximate age range and not an actual age. There have been several attempts in the past twenty years to improve quantitative methods of AAD estimation, and to introduce methods that do not rely as heavily on the expertise and experience of the investigator, as is often the case with the observational morphometric techniques. These methods have been found to be of only limited value as errors for age estimation exceeded 78 yr in over half of the cases in these studies. This method is very laboratory and protocol-dependent Waite et al. An age-dependent accumulation of D-aspartic acid has also been demonstrated in bone osteocalcin Ritz et al. However, as a forensic technique, aspartic acid racemisation is complex, slow and inherently inaccurate for mature female remains Ohtani et al. Bone tissue and the chronological donor age In contrast to previous histomorphometric studies of bone, which are only based in phenomenological changes in the bone cortex, Zioupos and Currey , Zioupos et al. These physical measures were the bone stiffness and strength in relation to its porosity, mineral content, calcium to phosphorus ratios, the dry density Zioupos, a , the condition of collagen thermal shrinkage and content in mature x-links Zioupos et al. It was observed that meaningful relationships could be established that can predict some of these age related biomechanical bone characteristics as a function of others. In a similar study Rho et al. If the chronological age of the donor is known and is added in as an extra independent variable, the R2 increased to 0. By adding the other two physical characteristics the R2 increases to 0. Darker areas are those that have been more recently remodelled and contain relatively lower mineral content. Indentations at three different impression weights were performed in osteonal and interstitial matrix areas Rho et al. From these previous studies it becomes obvious that there may be a number of physical features and microstructural characteristics, which are traceable with the age of the donor and most importantly in cohorts extending beyond the maturity threshold 35 yr and older where most AAD determination methods become inaccurate. The obvious question to ask is: This paper presents efforts made in the quest for an age estimation technique based on bone matrix features those produced by material characterisation techniques such as porosity, mineral content, organic fraction, collagen thermal Please cite this article as: Materials and methods The bone received from the tissue bank was from 7 males 55â€”85 yr and 7 females 53â€”79 yr who had died from causes that did not affect the bone condition and had not been hospitalized for any length of time. Cylindrical bone disks pellets approximately 5 mm in diameter were drilled, from the cortical bone area at the anterior part of each specimen to be used in the different tests Fig. This was achieved by the use of a diamond coring-tool under continuous irrigation with saline solution. Two specimens, both females aged 70 and 56, were found to have too thin and irregular cortices and were used as material for setting up the experiments. The apparent density Dap , bone matrix material density Dmx and the Porosity Pvol of bone were measured in the disk size specimens diameter 5 mm , which were reduced to a pellet of 1. Pellets were weighed wet and dry and they were then placed in the furnace for 20 h at a temperature of C in porcelain crucibles. Images were converted to grey scale and a mask was applied by using the segmentation command that segregates the areas of interest within the same colour histogram [details in Zioupos et al. Once the mask was applied it converts the image into black and white areas of interest. The white areas of the images were Please cite this article as: The optical porosity data was then obtained by subtracting the white from the black area. One pellet sample from each donor was dried out as described previously and embedded in epoxy resin Metprep Kleer-Set Type SSS with the cross sectional surface facing up visible histological features. The indentation loads used in each location were 10 gf, 50 gf and gf. In total indentations were performed, thirty indents per sample. Different weights were used for selection purposes due to the fact that different weights produce different indentation diagonals, and therefore the ease of measuring under the microscope varies accordingly to weight. The error observed during these processes was found to be approximately 71â€”2 Vickers hardness units. During experimentation, great care was undertaken to avoid confounding factors such as, levelling the sample thus allowing the indenter to penetrate in right angles, keeping the loading mechanism free of any vibrations, and discarding any asymmetric or problematic readings. The nanoindentations were made next to microhardness ones in osteonal and interstitial areas Fig. This produced 20 nanoindentation readings for each sample and indentations in total. Differential scanning calorimetry DSC was used to determine the thermodynamic parameters of the denaturation of bone collagen, in the mineralized and demineralized state. It is a standard chemical technique used to characterise compounds that exhibit thermal transitions. DSC has successfully been used to investigate the heat-induced degradation of collagen Nielsen- March et al. The samples under investigation were initially Fig. Please cite this article as: One pellet sample was used in its native state fully mineralised and the second one used was demineralised. This second pellet sample provided the demineralised DSC results. The temperature inside the central furnace of the machine was raised uniformly at a rate of 5 1C per minute from 30 to 1C. The reference sample was an identical, empty aluminium crucible. Four calcium to phosphorus ratio values were obtained from each sample. Two values were obtained from secondary osteons and two from interstitial lamellae. The ratio values were then calculated by dividing the calcium Table 1 â€” Descriptive statistics of age and the various parameters are shown in groups for histomorphometry, composition, DSC, EDAX, microhardness and nanoindentation. EDTA demineralised tissue; Please cite this article as: The accelerating voltage used was 10 keV, with a take-off angle of , for the period of s in each location measured. The ratio values were calculated automatically from the spectra produced, by the PGT software used by the detector. We are seeking to establish correlations between the various parameters, to observe trends in the data and subsequently to promote multifactorial regressions to predict the known chronological age of the donors from the experimentally measured parameters. As such it is probably too small to allow meaningful separate analysis for males and females. We will therefore, do the analysis for the mixed cohort. That is not necessarily a drawback as knowledge of sex in forensic remains is not always known, or it cannot be easily determined from just fragments of bone, or sections. That in essence may show a link to the plasticity characteristics of bone and we know that these are affected by age at both the macroscopic Zioupos and Currey, ; Zioupos, a and microscopic level Zioupos, a; Rho et al. The other parameters showed some weak trends with age going up and down as expected i. When looking separately in male and female data there were also some hints present Fig. Stepwise regressions The main tool we use here is stepwise regressions performed in Minitab v. These have demonstrated in the past Zioupos and Currey, ; Zioupos, a; Rho et al. These effects are not immediately obvious, as illustrated by the lack of strong correlations in Table 1. B with which it links in a rationalistic manner. A good example is mineral content, bone material stiffness and age. It can be argued that modern powerful computer programmes churn out a number of equations with no underlying knowledge of the causal links between the parameters. Unrestricted global analysis Multifactorial stepwise regressions were attempted with different intents in mind so as to satisfy different interests such as: The error was on average 0. The R2adj was 0. The error was on average 2. The error was on average 1. Tests and analysis with limited resources We further considered two useful permutations in the forensic context, one where resources may be a problem and one where a lab is well resourced but we are seeking a rapid answer within 24 h. In that case the 16 selected parameters would be: The resulting best performing equations are: Again statistics show that matrix areas carry some valuable age related information not necessarily the osteons and therefore the mechanical characteristics of the material are on the whole more important than the histomorphometric features density, porosity, mineral content etc. Tests and analysis that can be completed within 24 h Next we considered tests that can give a result within 24 h as for instance in police work where initially a quick even though less accurate answer is often required. This application would require several operators working in parallel. The 27 selected parameters were: The R2adj is 0. This is certainly, and as far as we know, the most successful algorithm for AAD that has ever been reported in the literature. The great majority of the AAD methods are based on gross morphological features of the skeleton and as such they become increasingly inaccurate beyond the age of skeletal maturity yr old. They can, in the best of cases, classify the deceased only to within a certain decade of life i. However, these gross morphology based methods have some advantages. They can be used in situations where the remains have been exposed to harsh environmental conditions or are otherwise physically compromised, and they are not reliant on expensive equipment. These methods have shown promise and can in the best of cases produce estimate values within 75 yr of the actual age Helfman and Bada, ; Csapo and Csapo-Kiss, ; Ohtani et al. Table 2 shows the relative performance of various methods in the literature.

Chapter 5 : The Mechanical Properties of Bone | O&P Virtual Library

In conclusion, we suggest that a prediction of AAD based on a combination of biomechanical properties of human bone offers a viable and accurate quantitative alternative to other existing quantitative and qualitative methods used in forensic medicine and archaeo-anthropology.

The Mechanical Properties of Bone F. Consequently, some knowledge of its mechanical properties is of importance for an understanding of the mechanism and management of fractures, as well as the design of prosthetic or orthotic appliances and protective gear, e. The behavior of a body under a load or force is a function not only of the form and structure of the body, but also of the mechanical properties of the material composing the body. For example, a steel beam will support a higher load before breaking and will behave differently under loading than will an oak beam of exactly the same shape and dimensions because of differences in the mechanical properties and structure of steel and of wood. The mechanical properties of bone are determined by the same methods used in studying similar properties of metals, woods, and other structural materials. These methods are based on certain fundamental principles of mechanics, a knowledge of which is essential for understanding the terminology employed. Mechanics, the science dealing with the effect of forces upon the form or the motion of bodies, has two subdivisions- statics and dynamics. Statics is the study of bodies at rest or in equilibrium as a result of the forces acting upon them. Dynamics is the study of moving bodies. The mechanical properties of materials are usually studied under static conditions, i. A force is anything which tends to change the state of a body with respect to its motion or the relative position of the molecules composing the body. More simply stated, a force is a push or a pull. There are three primary kinds of forces: When a force is applied to a body, it produces stress and strain within the body. Stress is generally computed in terms of pounds per square inch psi or kilograms per square millimeter ksm. Recently, some investigators of the strength characteristics of bone and other biological materials have been recording stress values in terms of kiloponds, dynes, or newtons per unit area, instead of pounds or kilograms because pounds and kilograms are units of mass as well as units of force. There will be no misunderstanding, however, if one specifies that stress values are in terms of pounds force or kilograms force per unit area. Stress is often used synono-mously with strength, but the term has little value unless the kind of strength, i. All strength values in the following discussion are in terms of pounds force per square inch. Strain is a change in the linear dimensions of a body as the result of the application of a force Fig. Strain can be seen if it is sufficiently large, e. The kind of stress and strain in a body is the same as the kind of force producing it. When stress is plotted against strain, a stress-strain curve is obtained Fig. From a tangent drawn to the straightest part of the stress-strain curve the modulus of elasticity of the material, or the ratio between unit stress and unit strain, can be computed. The modulus of elasticity is a measure of the stiffness of a material, not its elasticity as one might assume from the name. Elasticity is the property of a material that allows it to return to its original dimensions after the removal of a force or load. The energy the specimen absorbs to failure can be determined by measuring the area below the stress-strain curve. The method of choice in determining the tensile or compressive strength of a material is to make a test specimen of a standardized size and shape and test it under a pure tensile or a pure compressive force. Furthermore, the force is uniformly distributed over the cross-sectional area of the specimen. If the specimen is tested like a simple beam i. Tensile forces develop on the convex side of the bent specimen while compressive forces occur on the opposite concave side Fig. Both types of forces are maximum at the surface and decrease inwardly to zero at the neutral plane or axis. There are also shearing forces which, like the tensile and compressive forces, are not uniformly distributed over the cross section of the specimen. Under bending conditions, the force responsible for failure as well as its magnitude is more difficult to determine. The bending forces in the neck of the femur, as a result of the load applied to the head of the bone Fig. The speed at which a force is applied to a specimen influences the values obtained for some of its mechanical properties. Mc-Elhaney and Byars found that the ultimate compressive strength and the modulus of elasticity of fresh and embalmed femoral cortical bone from cattle and man increased with higher strain rates of loading while the energy-absorbing capacity and the strain at failure decreased. The effect of high strain rates of loading on specimens of beef bone, cut and tested in different directions, has recently been investigated by Bird et al. Embalming also affects the mechanical properties of bone, at least those of compact bone. Thus, the mean ultimate tensile strength in the long axis of the specimen and of the intact bone is greater at the 0. Furthermore, embalmed, wet-tested tibial specimens have a higher mean tensile strain, a greater mean single shearing strength perpendicular to the long axis of the specimen and are harder Rockwell No. However, the latter type of specimens has a higher mean modulus of elasticity. An analysis of variance showed that the increase in the hardness of the embalmed specimens was significant at the 0. As far as I am aware, there are no similar studies concerning the effect of embalming on the mechanical properties of spongy bone. Two types or forms of bones are found in the foot-irregularly shaped bones the tarsals and miniature long bones the metatarsals and the phalanges. The tarsal bones are essentially shells of compact bones filled with spongy bone, fat, marrow substance, blood, etc. The actual amount of osseous material in bones, such as the tarsals and the bodies of vertebrae, is not very great. According to Policard and Roche the talus and the calcaneus are about 80 per cent nonosseous tissue. The percentage of bone in the bodies of 92 human lumbar vertebrae studied by Bromley et al. As far as I am aware, there are no studies on the mechanical properties of spongy bone from the foot. Therefore, examination of such properties will be based on data obtained from the human femur. Two types of specimens were used-a rectangular bar the standard specimen 0. The specimens were obtained from the head, neck, greater trochanter, and condyles of the femur with the long axis of the standard specimens oriented in different directions. The specimens were tested under direct compression in a Riehle lb. The low range scale of the machine lbs. The specimens were loaded at a speed of 0. All specimens were tested wet to more nearly approximate the condition in the living foot. Drying of compact bone increases its ultimate tensile strength in the long axis of the specimen , its modulus of elasticity, and its hardness Rockwell No. Similar studies have not, to my knowledge, been made on spongy bone. The ultimate compressive stress strength and strain, the modulus of elasticity, and the energy absorbed to failure were computed from stress-strain curves for wet-tested specimens. The density of air-dried specimens was determined with a strontium 90 densitometer developed by Evans, Coolbaugh, and Lebow. Dry specimens were used to avoid the effects of moisture that might be trapped within the interstices of the specimens. A total of 69 rectangular standard specimens and of 15 cubic specimens from 1 adult, white female, 3 adult, Negro males, and 6 adult, white males were tested. All specimens were kept in saline solution until tested. A minimum of 20 load-deformation readings were taken for each specimen during the test period. The results of the study showed that the mean compressive stress strength of the cubic specimens was greater than that of the rectangular standard specimens from the same region Fig. This phenomenon is characteristic of practically all materials. In cubic specimens high frictional forces developed between the ends of the specimen and the testing machine to resist the tendency of the specimen to be squeezed out of the machine. Furthermore, the upper part of the cube tends to be impacted into the lower part. Both of these factors contribute to higher values for compressive stress and modulus of elasticity in cubic than in specimens which are longer than wide. Because of these factors, it is felt that the values obtained from the rectangular standard specimens more accurately represent the true mechanical properties of spongy bone. In the living body, most of the bones are subjected to bending action as a result of gravity, muscular activity during movement, and blows. Consequently, the bones are subjected to a combination of tension, compression, and shearing rather than to a single pure force. The question then arises as to why the strength of bone is usually determined by testing the specimens under a pure force. The answer to this question, on mechanical grounds, has already been given. There are, however, other valid reasons for testing the strength of bone under pure tension or compression. Experimental studies with strain sensitive lacquers on bones within the living body as well as outside of it demonstrate that certain types of linear fractures of the skull, the pelvis, and the long bones all arise from failure of the bone from tensile stresses and strains produced in it by bending. The determination of the tensile strength of bone under pure tension thus has direct application to the mechanics of fractures of those types. Clinical experience also indicates that tensile forces are important in the production of many types of fractures. Compression fractures are quite common in the bodies of the vertebrae, especially those in the lumbar region, and in the calcaneus, the most frequently fractured of the tarsal bones. Compression fractures of the talus also occur. There is, consequently, a sound practical reason for investigating the compressive strength of the tarsal bones, especially the calcaneus and the talus although, to my knowledge, it has not been done. The rationale for determining the strength of spongy bone from the femoral head and condyles under direct compression is that these regions of the bone are normally subjected to compression forces in the erect posture. Specimens from other regions were similarly tested for comparative purposes. When the results of the tests were compared according to the region of the bone from which the specimens were obtained, without regard to the direction of loading, several differences were found. The rectangular standard specimens from the neck had the highest and those from the greater trochanter the lowest mean compressive stress. Among the cubic specimens the highest and the lowest mean compressive stresses were found in specimens from the head and the medial condyle, respectively. Regional variation was also found in the modulus of elasticity stiffness of the specimens Fig. The mean stiffness of the rectangular specimens exceeded that of the cubic specimens from the same region except for the specimens from the head. The rectangular specimens from the neck and the medial condyle, respectively, had the highest and the lowest mean modulus. The maximum and the minimum stiffness means of the cubic specimens were found in those from the head and the medial condyle, respectively. Comparison of the mean compressive strain, mean energy absorbed to failure, and mean density of the rectangular and cubic specimens from different parts of the femur also reveals interesting differences Fig. The cubic specimens showed somewhat more variation in the mean compressive strain than did the rectangular ones, the strain being greatest in the specimens from the head and least in those from the medial condyle. Little difference was found in the mean compressive strain of the rectangular specimens, those from the head having a slightly greater strain than those from the condyles. The cubic and the rectangular specimens from the head had the highest while those from the medial condyle had the lowest mean energy absorbed to failure. However, the former specimens showed more regional difference than did the latter. The mean density for both types of specimens was greatest in those from the head and least in the ones from the lateral condyle. A statistical analysis of the above data from the rectangular standard specimens revealed the following significant differences between the means. The mean compressive stress of the strongest specimens from the neck was greater, at the 0.

DOWNLOAD PDF THE BIOMECHANICAL METHODS USED IN DETERMINING BONE QUALITY ELASTICITY AND STRENGTH

Chapter 6 : Biomechanics of Bone | Team Bone

Abstract: The aim of the article is to explain in more detail the biomechanical methods used in determining bone quality as well as to describe basic characteristic bone qualities resulting from.

 Abstract Objectives The complexity and heterogeneity of human bone, as well as ethical issues, most always hinder the performance of clinical trials. Thus, in vitro studies become an important source of information for the understanding of biomechanical events on implantsupported prostheses, although study results cannot be considered reliable unless validation studies are conducted. The purpose of this work was to validate an artificial experimental model based on its modulus of elasticity, to simulate the performance of human bone in vivo in biomechanical studies of implant-supported prostheses. Material and Methods In this study, fast-curing polyurethane F16 polyurethane, Axson was used to build 40 specimens that were divided into five groups. A universal testing machine Kratos model K â€" MP was used to measure modulus of elasticity values by compression. Results Mean modulus of elasticity values were: Group A â€" Despite the high success rates reported, failures are likely to occur. It is well established in the literature that late implant failures are related to biomechanical complications, and that limited understanding on implant biomechanics is the primary cause of these failures. Controlling the forces acting on implants is essential for long-term success, and the adequate qualification and quantification of these forces are crucial for treatment outcome. Measuring and assessing these forces are a complex problem and a challenge to be solved 3. In humans, bone is not homogenous. Its physical properties vary greatly according to species, age, gender, type e. This heterogeneity hinders efforts to model bone in finite element analysis and photoelastic studies 7. Dental implant stability and functional longevity are largely dependent on the supporting bone 1. Implant failure has been reported to be greater in poor quality bone. Given that bone implants are often placed in contact with trabecular bone, knowledge of the mechanical properties of the trabecular bone in different areas of the human mandible and maxilla may provide the understanding of the cause of higher failure rates in poor quality bone 6. The modulus of elasticity is a material property of bone that may be affected by the processes of apposition and alveolar resorption that occur following tooth loss. The modulus of elasticity is a measure of the material rigidity and varies as a function of both the density and microstructure of the bone. Same result was reported by Misch, Qu and Bidez 6 who tested compression in bone specimens and observed that the modulus of elasticity ranged from In order to obtain reliable data in experiments assessing the forces that are applied on implants and transferred to the supporting bone, the use of strain gauges has been recommended. However, in vivo strain gauge studies cannot be easily conducted due to the difficulty in attaching the sensors to the oral cavity. Ideally, the material used in this type of experiment, should have isotropic elastic characteristics as well as physical and mechanical characteristics similar to those found in the target bone region. Furthermore, it should be suitable for use in in vitro studies of the distribution of the forces generated by implant-supported prostheses. Based on these grounds, it seems necessary to validate a homogeneous, artificial experimental model with isotropic elastic properties, and modulus of elasticity and density, similar to those found in the human medullar bone that could simulate human bone performance in biomechanical studies of implant-supported prostheses. For such, five groups of polyurethane specimens, differing in their composition by the reagents content, were formed to test the null hypothesis that none of them can present a modulus of elasticity compatible to bone to be used as bone model in biomechanical bench tests. Its major characteristics include quick demolding, good temperature resistance after cure and low viscosity. It is formed by two reagents: Polyol part A and Isocyanate part B , and reaches 1. This mold allowed the shaping of 10 specimens measuring 9.