DEDICATION

We dedicated this project to our dearest parents & Teachers, Who prayed for our success. and to all our love ones whom we love from the core of heart.

ACKNOWLEDGMENT

Several people played an important role in the accomplished of this research. And we would like to acknowledge them here. First, we would like to thank Dr. IkhlasAbdulaziz, research supervisor for the assistance and encouragement to pursue to this study we also wish to thank our friend, SohaibAlromy for the advices and assistance. To our family, for the support in financial aspect as well for the advice and assistance, and for the generous support and for inspiration. Thank you also for the unconditional love and fidelity. Last but not the least, we thank Almighty God for reasons too numerous to mention. "How numerous you have made your wondrous deeds o Lord, our God and in your plans for us there is none to equal you, should I wish to declare or tell them? They would be too many to recount.

Abstract

Measurement of bone density is one of important method that use international to decrease the problem of the bone which effect in life activity ,and the common method that use is DEXA which is best one that discover after many stages of development from radiological absorptiometry (RA) then single energy photon absorptiometry (SPA) then single energy X-ray absorptiometry (SXA).

This study is attempt to measure the bone dense which a lot of us neglected it and never take care to it till after the complaint or effect by problem in it ,therefore we tried to give reference guidance to take care in early stage to avoid any complication that can occur in future.

This study performed in Antalia medical center of computer tomography in Khartoum state on 40 patients with different ages and variable range from (22-95) years old, sex (20 males and other 20 are females) and complains but all of them under went abdomen investigation. And study concentrate on measure the average of bone dense of the L2-L3 by using CT number. And we measure on this because this area give accurate estimation to any change in bone in addition to it is one of world method to detect bone dense.

The study show increase in bone dense on male rather than female and that appear clearly in increase the average of compact and spongy bony as is (387.30- 149.75) this reading for compact and spongy respectively but female bone dense average is (337.11-140.72) this reading for average of compact and spongy respectively, with (-or+) 82.996 for male and (-or+) 69.513 for female and these return to sexual hormone effect.

The relation of average of compact and spongy with sex and age range is weak and opposite propagation.

The relation of average of compact and spongy bone generally not strong but there are positive propagation and that refer to union body nutrition.

الخلاصة

قياس كثافة العظام هي احدى الوسائل العالمية التي تستخدم لتقليل مشاكل كثافه العظام التي تؤثر على نشاط الحياة ، واكثر الوسائل انتشارا هو جهاز قياس امتصاص طاقة الاشعه المزدوج المعروف بدكسا الذي يعتبر من افضل الأجهزة لقياس كثافة العظام والذي مر بعدة مراحل في تطوره من جهاز قياس الإمتصاص الاشعاعي من ثم جهاز قياس إمتصاص طاقة الفوتون المفرد ثم جهاز قياس امتصاص طاقة الاشعة السينة المفردة.

هذه الدراسة محاولة لقياس كثافة العظام التي يجهلها الكثيرون ولا يعطونها ادنى اهتمام لحين ظهور مشاكل صحية فيه لذا قامت هذه الدراسة كمحاولة لوضع مرجعية لكثافة عظام السودانين لأخذ الحذر والاحتياطات في المراحل المبكرة لزيادة امكانية العلاج بواسطة العقاقير والأدوية لتفادي الحوادث التي تحدث في المستقبل.

اجريت هذه الدراسة في مركز انطاليا الطبي في ولاية الخرطوم على مرضى عددهم 40 مريضا جميعهم مختلفوا الاعمار والتي تتزاوح من (22-95) سنة والنوع (20منهم ذكور و 20 منهم اناث) والشكاوي والاعراض وكلهم اجريت لهم أشعة مقطعية قطنية ؛ وركزت الدراسة على قياس كثافة العظام عن طريق قياس متوسط الفقرات القطنية الثانية والثالثة عن طريق الرقم الذري للاشعة المقطعية واختيرت هذه الفقرات لأنهما تعطيان قراءات دقيقة لأى تغيير يحدث في الكثافة كما انها احدى الطرق العالمية لقياس كثافة العظام.

اكدت هذه الدراسة بزيادة كثافة العظام لدى الذكور اكثر من الاناث ويظهر هذا جليا في متوسط كثافة العظم الرخو والصلب (149.75-387.30) على التوالي اما في الاناث (140.72-337.11) على التوالي +او- (82.996) للذكور و +او-(69.513) للإناث لذا علاقة كثافة العظام بالنسبة للنوع والعمر علاقة ضعيفة وعكسية وهذا يرجع لتاثير الهرمونات الجنسية.

كما ان علاقة العظم الصلب والرخو فيما بينهم ليست قوية ولكنها طردية وهذا يرجع لنوع الغذاء الموحد للجسم.

Glossary of abbreviation

CA	Calcium
SD	Stander deviation
PH	Phosphor
BMC	Bone Mineral Content
BMD	Bone Mineral Density
DEXA	Double Energy X-ray Absorptiometry
CT	Computerized Tomography
QUS	Qualitative Ultra Sound
QCT	Quantitative Computed Tomography
RT	Right
LT	Left
GE	General Electric
Pt	Patient
CV	Co-efficient Variation
SPSS	Static Package of social studies

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Chapter one

1.1. Introduction:

X-ray computed tomography (X-ray CT), also called CT scan or computerized axial tomography scan (CAT scan), makes use of computer-processed combinations of many X-ray images taken from different angles to produce cross-sectional (tomographic) images (virtual 'slices') of specific areas of a scanned object, allowing the user to see inside the object without cutting. Digital is used to generate a three-dimensional image of the inside of the object from a large series of two-dimensional radiographic images taken around a single axis of rotation. Medical imaging is the most common application of X-ray CT. Its cross-sectional images are used for diagnostic and therapeutic purposes in various medical disciplines. The rest of this article discusses medical-imaging X-ray CT; industrial applications of X-ray CT are discussed at industrial computed tomography scanning. (Hiba Osman et.al 2015)

As X-ray CT is the most common form of CT in medicine and various other contexts, the term computed tomography alone (or CT) is often used to refer to X-ray CT, although other types exist (such as positron emission tomography [PET] and single-photon emission computed tomography [SPECT]). Older and less preferred terms that also refer to X-ray CT are computed axial tomography (CAT scan) and computer-aided/assisted tomography. X-ray CT is a form of radiography, although the

word "radiography" used alone usually refers, by wide convention, to non-tomographic radiography. CT produces a volume of data that can be manipulated in order to demonstrate various bodily structures based on their ability to block the X-ray beam. Although, historically, the images generated were in the axial or transverse plane, perpendicular to the long axis of the body, modern scanners allow this volume of data to be reformatted in various planes or even as volumetric (3D) representations of structures. Although most common in medicine, CT is also used in other fields, such as nondestructive materials testing. Another example is archaeological uses such as imaging the contents of sarcophagi. Individuals responsible for performing CT exams are called radiographers or radiologic technologists and are required to be licensed in most states of the USA.

Usage of CT has increased dramatically over the last two decades in many countries. An estimated 72 million scans were performed in the United States in 2007. One study estimated that as many as 0.4% of current cancers in the United States are due to CTs performed in the past and that this may increase to as high as 1.5 to 2% with 2007 rates of CT usage; however, this estimate is disputed, as there is not a scientific consensus about the existence of damage from low levels of radiation. Kidney problems following intravenous contrast agents may also be a concern in some types of studies.

"https://en.wikipedia.org/wiki/CT_scan"

*A bone is a rigid organ that constitutes part of the vertebral skeleton. Bones support and protect the various organs of the body, produce red and white blood cells, store minerals and also enable mobility. Bone tissue is a type of dense connective tissue. Bones come in a variety of shapes and sizes and have a complex internal and external structure. They are lightweight yet

strong and hard, and serve multiple functions. Mineralized osseous tissue or bone tissue, is of two types – cortical and cancellous and gives it rigidity and a coral-like three-dimensional internal structure. Other types of tissue found in bones include marrow, endosteum, periosteum,nerves, blood vessels and cartilage.Bone is an active tissue composed of different cells. Osteoblasts are involved in the creation and mineralization of bone; osteocytesand osteoclasts are involved in the reabsorption of bone tissue. The mineralized matrix of bone tissue has an organic component mainly of collagen and an inorganic component of bone mineral made up of various salts. In the human body at birth, there are over 270 bones, but many of these fuse together during development, leaving a total of 206 separate bones in the adult, not counting numerous small sesamoid bones. The largest bone in the body is the thigh-bone (femur) and the smallest is the stapes in the middle ear.Bone is not a uniformly solid material, but is mostly a matrix. The primary tissue of bone, osseous tissue, is relatively hard and lightweight. Its matrix is mostly made up of a composite material incorporating the inorganic mineral calcium phosphate in the chemical arrangement termed calcium hydroxylapatite (this is the osseous tissue that gives bones their rigidity) and organic collagen, an elastic protein which improves fracture resistance. Bone is formed by the hardening of this matrix around entrapped cells. When these cells become entrapped from osteoblasts they become osteocytes. "https://en.wikipedia.org/wiki/Bone"

*Bone disease is a condition that damages the skeleton and makes bones weak and prone to fractures. Weak bones are not a natural part of aging. While strong bones begin in childhood, people of all ages can improve their bone health.

The most common bone disease is osteoporosis, which is characterized by low bone mass and deterioration of bone structure. Osteoporosis can be prevented, as well as diagnosed and treated. Low bone mass is when bones lose minerals, like calcium, that make them strong, and as a result, bones become weak and fracture easily. Fractures to weak bones typically occur from falling or other common accidents. Other bone diseases include Paget's disease and osteogenesis imperfecta. Paget's disease affects older men and women, and causes skeletal deformities and fractures.

Osteogenesis imperfecta is an inherited disorder that causes brittle bones and frequent fractures in children.

A healthy skeletal system with strong bones is essential to overall health and quality of life. Strong bones support our body; protect our heart; lungs and brain from injury; and are the framework for muscles that allows us to move. Bones are also a storehouse for life-supporting minerals.

Osteoporosis and other bone diseases, such as Paget's disease and osteogenesis imperfecta, can lead to a downward spiral in physical health and quality of life including losing the ability to walk, stand, and dress. It can even lead to premature death. Weak bones can result in painful and debilitating fractures. Each year, 1.5 million Americans suffer a fracture because of weak bones. The most common breaks are of the wrist, spine and hip.

Hip fractures are by far the most devastating type of broken bone and account for almost 300,000 hospitalizations each year. Of hip-fracture patients: 20 percent die within a year of the fracture, and 20 percent end up

in a nursing home within a year. Many become isolated, depressed or afraid to leave home because they fear falling.

Bone disease is costly for society and individuals with the disease. In the United States, care for bone fractures from osteoporosis costs nearly $18 billion each year. The cost from a hip fracture for one individual can be more than $81,000 during their lifetime.

Many Americans do not know that their bone health is in jeopardy. Osteoporosis is a silent disease until fractures occur. Four times as many men and nearly three times as many women have osteoporosis than report having the disease. The number of hip fractures in the United States could double or even triple by 2040. Bone disease affects women and men of all ethnicities, although the risk of bone disease is highest among women. Bone disease is a real risk for any man or woman at any age.

"http://www.news-medical.net/health/Bone-Disease.aspx"

1.2. Problem of the study:

Bone density is considered as a factor used to assess the many disease of the bone but due to shortness of studies in Sudan for bone density we measured normal bone density in order to give a references standardized value for Sudanese population to help in evaluation of bone diseases and early detection of disease related to the bone density.

1.3. Objectives

1-3-1 General Objective:

The general aims of this study was to measurement of normal bone density for Sudanese patients using computed tomography in order to give a reference value for Sudanese populations.

1-3-2 Specific objective:

- To assess the degree of bone density in the Sudanese people using CT
- To be references for Sudanese bone density and predicted the future risks
- To emphasize the need for bone investigations in early densitometry status to avoid risk of common fracture and many diseases that can attack the body.

1.4. Significance of the study:

Lack of studies in Sudanese people. And importance of the study in reducing the problems of the bone.

Chapter two

2.1. Theoretical background:

2.1.1. Anatomy and physiology of the bone:

A bone is a rigid organ that constitutes part of the vertebral skeleton. Bones support and protect the various organs of the body, produce red and white blood cells, store minerals and also enable mobility. Bone tissue is a type of dense connective tissue. Bones come in a variety of shapes and sizes and have a complex internal and external structure. They are lightweight yet strong and hard, and serve multiple functions. Mineralized osseous tissue or bone tissue, is of two types – cortical and cancellous and gives it rigidity and a coral-like three-dimensional internal structure. Other types of tissue found in bones include marrow, endosteum, periosteum, nerves, blood vessels and cartilage. Bone is an active tissue composed of different cells. Osteoblasts are involved in the creation and mineralization of bone; osteocytes and osteoclasts are involved in the reabsorption of bone tissue. The mineralized matrix of bone tissue has an organic component mainly of collagen and an inorganic component of bone mineral made up of various salts. In the human body at birth, there are over 270 bones, but many of these fuse together during development, leaving a total of 206 separate bones in the adult, not counting numerous small sesamoid bones. The largest bone in the body is the thigh-bone (femur) and the smallest is the stapes in the middle ear.

2.1.1.1.Structure:
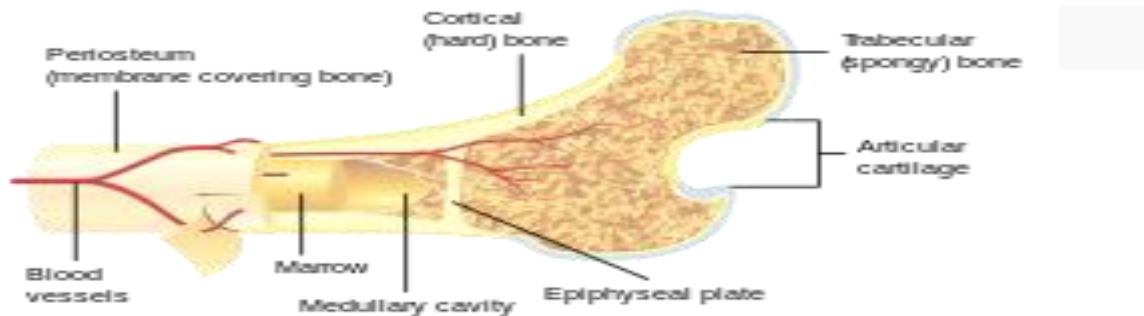
Figure (2.1) Cross-section of bone

Bone is not a uniformly solid material, but is mostly a matrix. The primary tissue of bone, osseous tissue, is relatively hard and lightweight. Its matrix is mostly made up of a composite material incorporating the inorganic mineral calcium phosphate in the chemical arrangement termed calcium hydroxylapatite (this is the osseous tissue that gives bones their rigidity) and organiccollagen, an elastic protein which improves fracture resistance. Bone is formed by the hardening of this matrix around entrapped cells. When these cells become entrapped from osteoblasts they become osteocytes.

Layered structure

Cortical bone
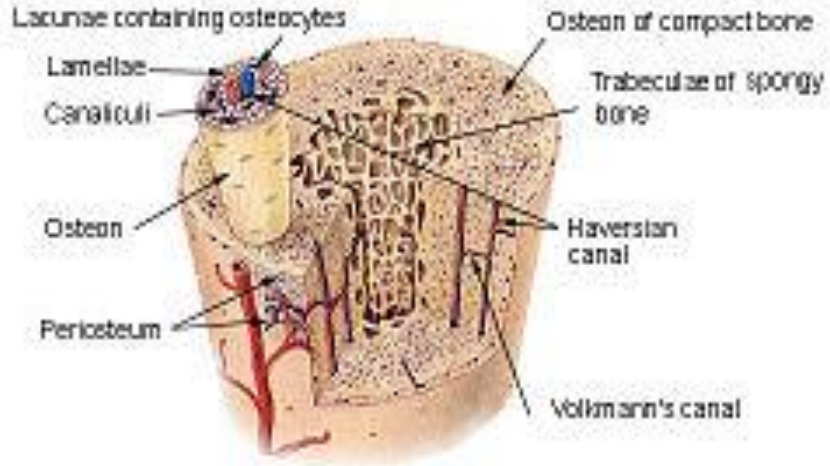
Figure (2-2) Cross-section details of a long bone

The hard outer layer of bones is composed of cortical bone also called compact bone. Cortical referring to the outer (cortex) layer. The hard outer layer gives bone its smooth, white, and solid appearance, and accounts for 80% of the total bone mass of an adult skeleton.

Cortical bone consists of multiple microscopic columns, each called an osteon. Each column is multiple layers of osteoblasts and osteocytes around a central canal called the Haversian canal. Volkmann's canals at right angles connect the osteons together. The columns are metabolically active, and as bone is reabsorbed and created the nature and location of the cells within the osteon will change. Cortical bone is covered by a periosteum on its outer surface, and an endosteum on its inner surface. The endosteum is the boundary between the cortical bone and the cancellous bone.

Cancellous bone:
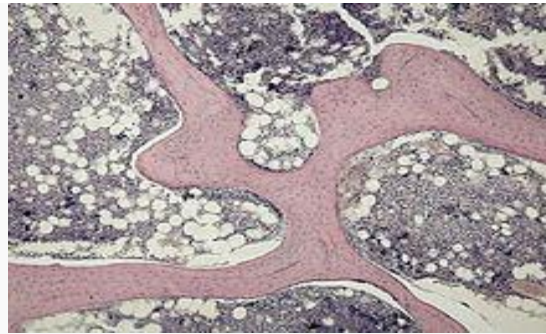
Figure (2-3) Micrograph of cancellous bone

Filling the interior of the bone is the cancellous bone also known as trabecular or spongy bone tissue. It is an open cell porous network. Thin formations of osteoblasts covered in endosteum create an irregular network of spaces. Within these spaces are bone marrow and hematopoietic stem cells that give rise to platelets, red blood cells and white blood cells. Trabecular marrow is composed of a network of rod- and plate-like elements that make the overall organ lighter and allow room for blood vessels and marrow. Trabecular bone accounts for the remaining 20% of total bone mass but has nearly ten times the surface area of compact bone.

2.1.1.2.Bone marrow:
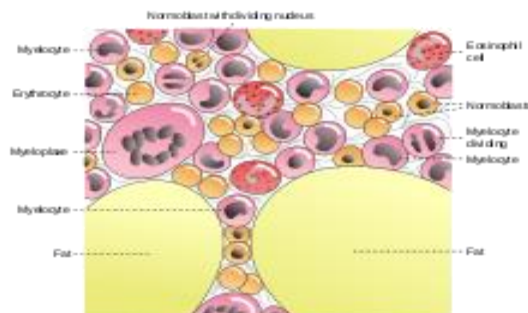
Figure (2-4) a simplified illustration of cells in bone marrow

Bone marrow, also known as myeloid tissue, can be found in almost any bone that holds cancellous tissue. In newborns, all such bones are filled exclusively with red marrow, but as the child ages it is mostly replaced by yellow, or fatty marrow. In adults, red marrow is mostly found in the bone marrow of the femur, the ribs, the vertebrae and pelvic bones.

2.1.1.4.Types:

Classification of Bones by Shape
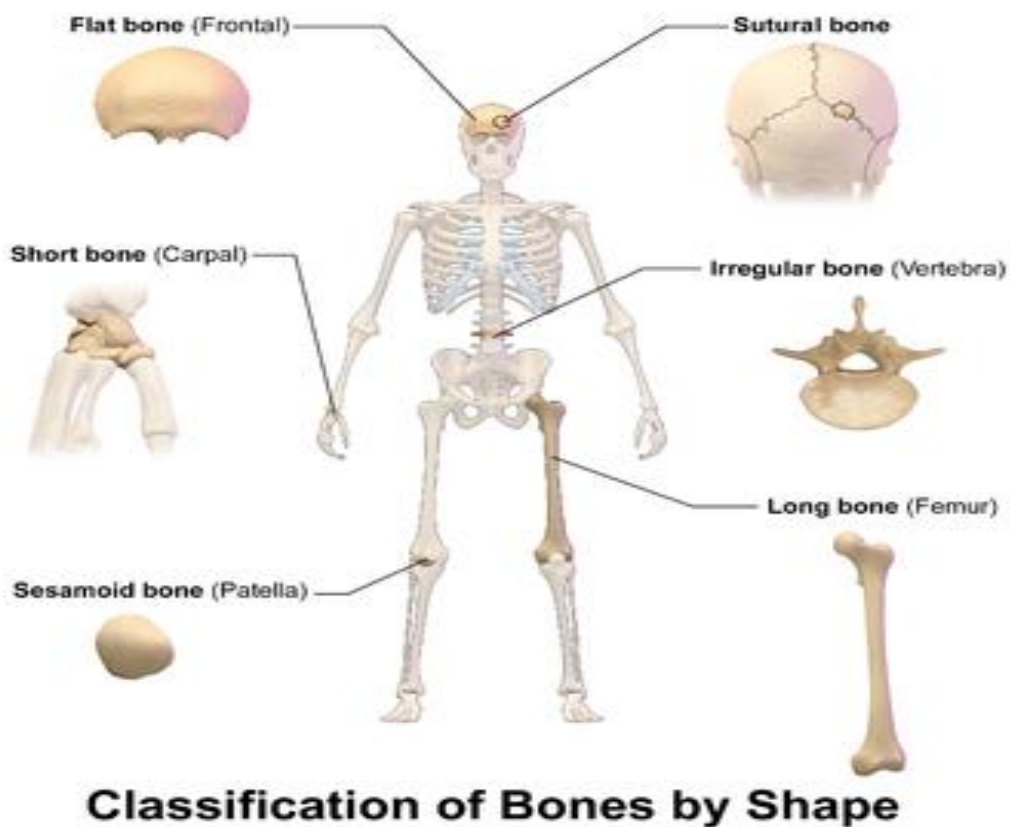
Figure (2-5)

There are five types of bones in the human body: long, short, flat, irregular, and sesamoid.

Long bones are characterized by a shaft, the diaphysis which is much longer than its width; and by an epiphysis, a rounded head at each end of the shaft.

They are made up mostly of compact bone, with lesser amounts of marrow, located within the medullary cavity, and spongy, cancellous bone. Most bones of the limbs, including those of the fingers and toes, are long bones. The exceptions are those of the wrist, ankle and kneecap. And Short bones are roughly cube-shaped, and have only a thin layer of compact bone surrounding a spongy interior. The bones of the wrist and ankle are short bones, as are the sesamoid bones. Flat bones are thin and generally curved, with two parallel layers of compact bones sandwiching a layer of spongy bone. Most of the bones of the skull are flat bones, as is the sternum. Sesamoid bones are bones embedded in tendons. Since they act to hold the tendon further away from the joint, the angle of the tendon is increased and thus the leverage of the muscle is increased. Examples of sesamoid bones are the patella and the pisiform. Irregular bones do not fit into the above categories. They consist of thin layers of compact bone surrounding a spongy interior. As implied by the name, their shapes are irregular and complicated. Often this irregular shape is due to their many centers of ossification or because they contain bony sinuses. The bones of the spine, pelvis, and some bones of the skull are irregular bones. Examples include the ethmoid and sphenoid bones.

2-1-1-5 Development

The formation of bone is called "ossification". During the fetal stage of development this occurs by two processes, Intramembranous ossification and endochondral ossification , Intramembranous ossification involves the creation of bone from connective tissue, whereas in the process of endochondral ossification bone is created from cartilage.

***Intramembranous ossification*:** Intramembranous ossification mainly occurs during formation of the flat bones of the skull but also the mandible, maxilla, and clavicles; the bone is formed from connective tissue such as mesenchyme tissue rather than from cartilage. The steps in intramembranous ossification are:
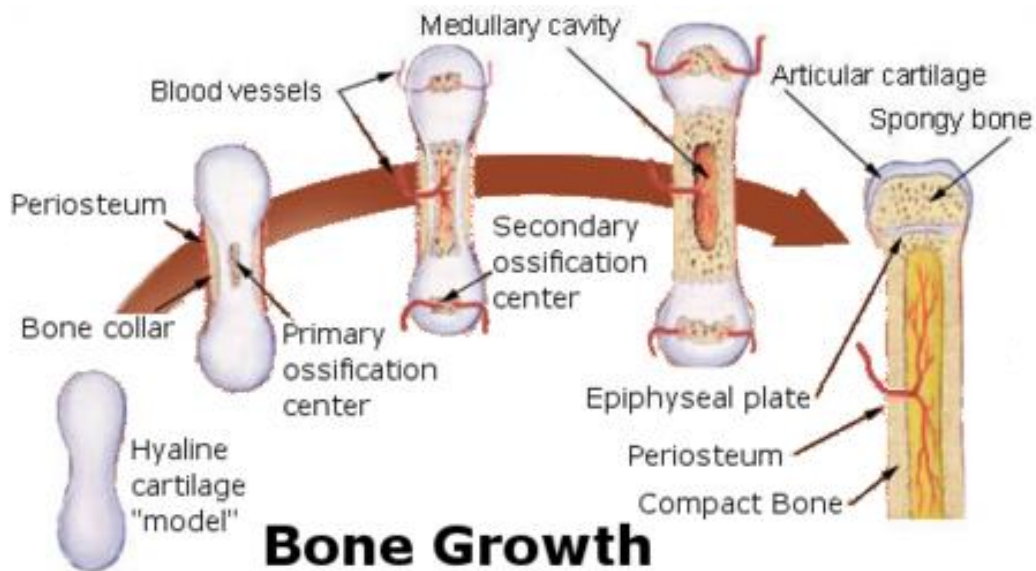
Figure (2-6) Development of ossification center

Calcification, Formation of trabeculae and Development of periosteum

***Endochondral ossification*:** Endochondral ossification, on the other hand, occurs in long bones and most of the rest of the bones in the body; it involves an initial hyaline cartilage that continues to grow. The steps in endochondral ossification are: Development of cartilage mode, Growth of cartilage model, Development of the primary ossification center,

Development of the secondary ossification center and Formation of articular cartilage and epiphyseal plate:

Endochondral ossification begins with points in the cartilage called "primary ossification centers." They mostly appear during fetal development, though a few short bones begin their primary ossification after birth. They are responsible for the formation of the diaphysis of long bones, short bones and certain parts of irregular bones. Secondary ossification occurs after birth, and forms the epiphyses of long bones and the extremities of irregular and flat bones. The diaphysis and both epiphyses of a long bone are separated by a growing zone of cartilage (the epiphyseal plate). When the child reaches skeletal maturity (18 to 25 years of age), all of the cartilage is replaced by bone, fusing the diaphysis and both epiphyses together (epiphyseal closure).[citation needed] In the upper limbs, only the diaphysis of the long bones and scapula are ossified. The epiphyses, carpal bones, coracoid process, medial border of the scapula, and acromion are still cartilaginous.

The following steps are followed in the conversion of cartilage to bone:

Firstly Zone of reserve cartilage. This region, farthest from the marrow cavity, consists of typical hyaline cartilage that as yet shows no sign of transforming into bone.

Zone of cell proliferation. A little closer to the marrow cavity, chondrocytes multiply and arrange themselves into longitudinal columns of flattened lacunae.

Zone of cell hypertrophy. Next, the chondrocytes cease to divide and begin to hypertrophy (enlarge), much like they do in the primary ossification

center of the fetus. The walls of the matrix between lacunae become very thin.

Zone of calcification. Minerals are deposited in the matrix between the columns of lacunae and calcify the cartilage. These are not the permanent mineral deposits of bone, but only a temporary support for the cartilage that would otherwise soon be weakened by the breakdown of the enlarged lacunae.

Zone of bone deposition. Within each column, the walls between the lacunae break down and the chondrocytes die. This converts each column into a longitudinal channel, which is immediately invaded by blood vessels and marrow from the marrow cavity. Osteoblasts line up along the walls of these channels and begin depositing concentric lamellae of matrix, while osteoclasts dissolve the temporarily calcified cartilage.

2.1.1.6.Function:

Bones have a variety of functions:

Mechanical: See also: Skeleton, Human skeleton and List of bones of the human skeleton

Bones serve a variety of mechanical functions. Together the bones in the body form the skeleton. They provide a frame to keep the body supported, and an attachment point for skeletal muscles, tendons, ligaments and joints, which function together to generate and transfer forces so that individual body parts or the whole body can be manipulated in three-dimensional space (The interaction between bone and muscle is studied in biomechanics).

Bones protect internal organs, such as the skull protecting the brain or the ribs protecting the heart and lungs. Because of the way that bone is formed, bone has a high compressive strength of about 170 MPa (1800 kgf/cm²), poor tensile strength of 104–121MPa, and a very low shear stress strength (51.6 MPa). This means that bone resists pushing(compressional) stress well, resist pulling(tensional) stress less well, but only poorly resists shear stress (such as due to torsional loads). While bone is essentially brittle, bone does have a significant degree of elasticity, contributed chiefly by collagen.

Mechanically, bones also have a special role in hearing. The ossicles are three small bones in the middle ear which are involved in sound transduction.

Synthetic: Cancellous bones contain bone marrow. Bone marrow produces blood cells in a process called hematopoiesis. Blood cells that are created in bone marrow include red blood cells, platelets and white blood cells. Progenitor cells such as the hematopoietic stem cell divide in a process called mitosis to produce precursor cells. These include precursors which eventually give rise to white blood cells, and erythroblasts which give rise to red blood cells. Unlike red and white blood cells, created by mitosis, platelets are shed from very large cells called megakaryocytes. This process of progressive differentiation occurs within the bone marrow. After the cells are matured, they enter the circulation. Every day, over 2.5 billion red blood cells and platelets, and 50-100 billion granulocytes are produced in this way.

As well as creating cells, bone marrow is also one of the major sites where defective or aged red blood cells are destroyed.

Metabolic: Mineral storage — bones act as reserves of minerals important for the body, most notably calcium and phosphorus. And Growth factor storage — mineralized bone matrix stores important growth factors such as insulin-like growth factors, transforming growth factor, bone morphogenetic proteins and others. And Fat storage — the yellow bone marrow acts as a storage reserve of fatty acids. And Acid-base balance — bone buffers the blood against excessive pH changes by absorbing or releasing alkaline salts. Also Detoxification — bone tissues can also store heavy metals and other foreign elements, removing them from the blood and reducing their effects on other tissues. These can later be gradually released for excretion. Endocrine organ — bone controls phosphate metabolism by releasing fibroblast growth factor – 23 (FGF-23), which acts on kidneys to reduce phosphate reabsorption. Bone cells also release a hormone called osteocalcin, which contributes to the regulation of blood sugar (glucose) and fat deposition. Osteocalcin increases both the insulin secretion and sensitivity, in addition to boosting the number of insulin-producing cells and reducing stores of fat and Calcium balance the process of bone resorption by the osteoclasts releases stored calcium into the systemic circulation and is an important process in regulating calcium balance. As bone formation actively fixes circulating calcium in its mineral form, removing it from the bloodstream, resorption

actively unfixes it thereby increasing circulating calcium levels. These processes occur in tandem at site-specific locations.

***Remodeling*:** Bone is constantly being created and replaced in a process known as remodeling. This ongoing turnover of bone is a process of resorption followed by replacement of bone with little change in shape. This is accomplished through osteoblasts and osteoclasts. Cells are stimulated by a variety of signals, and together referred to as a remodeling unit. Approximately 10% of the skeletal mass of an adult is remodeled each year. The purpose of remodeling is to regulate calcium homeostasis, repair micro damaged bones from everyday stress, and also to shape and sculpt the skeleton during growth. Repeated stress, such as weight-bearing exercise or bone healing, results in the bone thickening at the points of maximum stress (Wolff's law). It has been hypothesized that this is a result of bone's piezoelectric properties, which cause bone to generate small electrical potentials under stress.

The action of osteoblasts and osteoclasts are controlled by a number of chemical enzymes that either promote or inhibit the activity of the bone remodeling cells, controlling the rate at which bone is made, destroyed, or changed in shape. The cells also use paracrine signaling to control the activity of each other. For example, the rate at which osteoclasts resorb bone is inhibited by calcitonin and osteoprotegerin. Calcitonin is produced by parafollicular cells in the thyroid gland, and can bind to receptors on osteoclasts to directly inhibit osteoclast activity. Osteoprotegerin is secreted by osteoblasts and is able to bind RANK-L, inhibiting osteoclast stimulation.

Osteoblasts can also be stimulated to increase bone mass through increased secretion of osteoid and by inhibiting the ability of osteoclasts to break down osseous tissue.[citation needed] Increased secretion of osteoid is stimulated by the secretion of growth hormone by the pituitary, thyroid

hormone and the sex hormones (estrogens andandrogens). These hormones also promote increased secretion of osteoprotegerin. Osteoblasts can also be induced to secrete a number of cytokines that promote reabsorbtion of bone by stimulating osteoclast activity and differentiation from progenitor cells. Vitamin D, parathyroid hormone and stimulation from osteocytes induce osteoblasts to increase secretion of RANK-ligand and interleukin 6, which cytokines then stimulate increased reabsorption of bone by osteoclasts. These same compounds also increase secretion of macrophage colony-stimulating factor by osteoblasts, which promotes the differentiation of progenitor cells into osteoclasts, and decrease secretion ofosteoprotegerin.

2-1-1-7 Bone volume:

Bone volume is determined by the rates of bone formation and bone resorption. Recent research has suggested that certain growth factors may work to locally alter bone formation by increasing osteoblast activity. Numerous bone-derived growth factors have been isolated and classified via bone cultures. These factors include insulin-like growth factors I and II, transforming growth factor-beta, fibroblast growth factor, platelet-derived growth factor, and bone morphogenetic proteins. Evidence suggests that bone cells produce growth factors for extracellular storage in the bone matrix. The release of these growth factors from the bone matrix could cause the proliferation of osteoblast precursors. Essentially, bone growth factors may act as potential determinants of local bone formation. Research has suggested that trabecular bone volume in postmenopausal osteoporosis may be determined by the relationship between the total bone forming surface and the percent of surface resorption.

2.1.2. Bone disorders:

***Osteoporosis*:** is a disease of bone where there is reduced bone mineral density, increasing the likelihood of fractures. Osteoporosis is defined by the World Health Organization in women as a bone mineral density 2.5 standard deviations below peak bone mass, relative to the age and sex-matched average, as measured by Dual energy X-ray absorptiometry, with the term "established osteoporosis" including the presence of a fragility fracture. Osteoporosis is most common in women after menopause, when it is called "postmenopausal osteoporosis", but may develop in men and premenopausal women in the presence of particular hormonal disorders and other chronicdiseases or as a result of smoking and medications, specifically glucocorticoids. Osteoporosis usually has no symptoms until a fracture occurs. For this reason, DEXA scans are often done in people with one or more risk factors, who have developed osteoporosis and be at risk of fracture.

Osteoporosis treatment includes advice to stop smoking, decrease alcohol consumption, exercise regularly, and have a healthy diet. Calcium supplements may also be advised, as may Vitamin D. When medication is used, it may include bisphosphonates, Strontium ranelate, and osteoporosis may be one factor considered when commencing Hormone replacement therapy In planar projected images of the patient, important details may be hidden by Over-laying tissues. By using slice-imaging techniques (tomography), selective Demonstration of morphologic properties, layer by layer, may be performed.

Computerized tomography, CT, is an ideal form of tomography yielding sequence images of thin consecutive slices of the patient and providing the opportunity to localize in three dimensions. Unlike conventional, classical tomography, computerized tomography does not suffer from interference

from structures in the patient outside the slice being imaged. This is achieved by irradiating only thin slices of the patient with a fan-shaped beam. Trans axial images (tomograms) of the patient's anatomy can give more selective information than conventional planar projection radiographs. Compared to planar radiography, CT images have superior contrast resolution, i.e., they are capable of distinguishing very small differences in tissue-attenuation (contrasts), but have inferior spatial resolution. An attenuation difference of 0.4% can be visualized but the smallest details in the image that can be resolved must be separated at least 0.5 mm. In conventional planar radiography, the lowest detectable contrast is larger but details of smaller size can be separated.

Osteopetrosis: Is a rare bone disorder where the bones literally become petrified and are literally dissolve and break.

Paget's disease: Leads to the bones to break down faster than they rebuild. Normally this process is kept in balance, but the accelerated breakdown occurring in Paget's results in fragile bones with an increased risk of fracture.

Rickets/ Osteomalacia: Rickets is caused from a severe deficiency of calcium, vitamin D and phosphate. Bones soften and become weak losing their normal shape. Bone pain, muscle cramps and skeletal deformities occur.

***Bone Cancer*:** Tumors can arise in bones in a similar fashion as other solid organ cancers. Bone cancer can occur as a primary type of cancer or can be a sign of an advanced cancer located elsewhere in the body that has spread (metastasized) to the bones. Primary bone cancers include osteosarcoma and Ewing's. Metastatic cancer examples include lung, breast and prostate.

Tumors: There are several types of tumor that can affect bone; examples of benign bone
tumors include osteoma, osteoidosteoma,osteochondroma, osteoblastoma, en chondroma, giant cell tumor of bone, aneurismal bone cyst, and fibrous dysplasia of bone.

2.1.3. Computed tomography:

In planar projected images of the patient, important details may be hidden by Over-laying tissues. By using slice-imaging techniques (tomography), selective Demonstration of morphologic properties, layer by layer, may be performed.

Computerized tomography, CT, is an ideal form of tomography yielding sequence images of thin consecutive slices of the patient and providing the opportunity to localize in three dimensions. Unlike conventional, classical tomography, computerized tomography does not suffer from interference from structures in the patient outside the slice being imaged. This is achieved by irradiating only thin slices of the patient with a fan-shaped beam. Trans axial images (tomograms) of the patient's anatomy can give more selective information than conventional planar projection radiographs. Compared to planar radiography, CT images have superior contrast resolution, i.e., they are capable of distinguishing very small differences

In tissue-attenuation (contrasts), but have inferior spatial resolution. An attenuation difference of 0.4% can be visualized but the smallest details in the image that can be resolved must be separated at least 0.5 mm. In conventional planar radiography, the lowest detectable contrast is larger but details of smaller size can be separated. Two steps are necessary to derive a CT image. Firstly physical measurements of the attenuation of x-rays traversing the patient in different directions and secondly mathematical calculations of the linear attenuation coefficients, allover the slice. The procedure is as follows. The patient remains stationary on the examination table while the X-ray tube rotates in a circular orbit around the patient in a plane perpendicular to the length-axis of the patient (figure2-7)A fan-shaped

beam of variable thickness (1-10 mm), wide enough to pass on both sides of the patient is used. The X-ray tube is similar to but more powerful than those used in planar radiography. The image receptor is an array of several hundred small separate receptors. Readings from the receptors are fed in to a computer which, after numerous calculations, produces a tomogram of the patient, i.e., a map of linear attenuation coefficients.
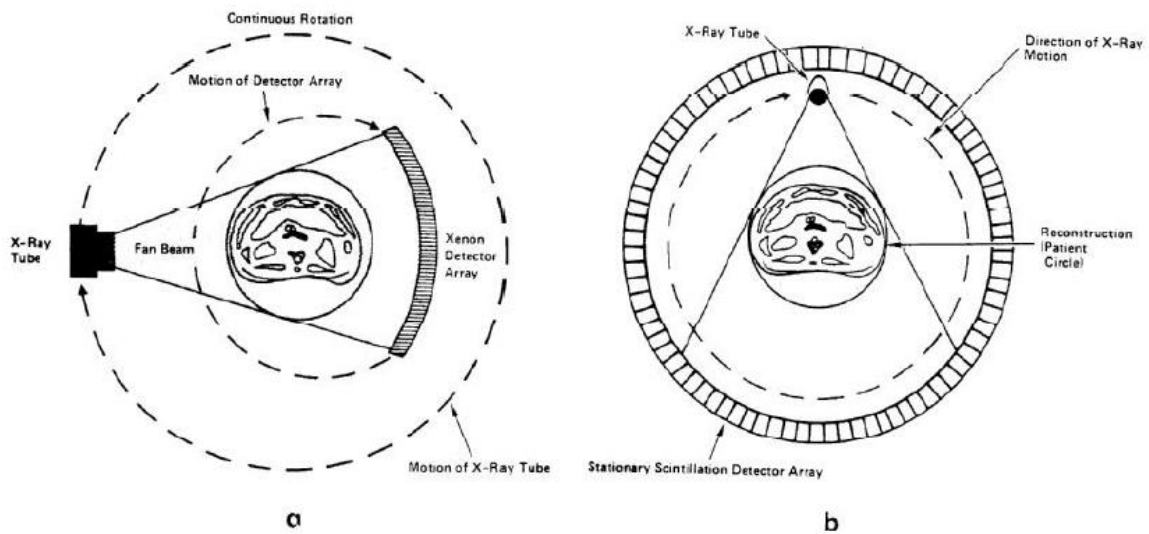
Figure (2-7). (a) Third-generation CT scanner. The X-ray tube and the receptor array are located on opposite sides of the patient and both rotate around the patient during data acquisition. In this particular situation the receptor array consists of about 700 pressurized Xenon detectors. (b) Fourth-generation CT scanner. Here, only the X-ray tube rotates around the patient; the receptor array which is situated in the outside of the scanning frame remains stationary. The receptors are made from solid-state material and can be as many as 4000.Both scanners use fan-beams and about 1000 projections. The data acquisition time is a few seconds and a 512x512 image matrix can be viewed just a few seconds after the data acquisition is completed. Reprinted with permission from. The arrangement of the X-ray

tube and the receptors have changed during the years, the different technical solutions being named 'generations'. CT scanners used today are third- or fourth-generation (see figure **2-7**). An arrangement whereby the X-ray tube and the receptor array rotate together is typical of the third generation of CT scanners, whereas the fourth generation has a complete ring of receptors that remains stationary and only the X-ray tube rotates. CT scanners are now available in which the X-ray tube circles the patient while the examination table move continuously, so that the X-ray tube moves in a spiral orbit around the patient. These are called spiral CT scanners.

2.1.3.1.CT scanner (evolution):

CT scanners were first introduced in 1971 with a single detector for brain study under the leadership of Godfrey Hounsfield, an electrical engineer at EMI (Electric and Musical Industries, ltd). Thereafter, it has undergone several changes with increase in number of detectors and decrease in the scan time.

First generation

- detectors: one
- type of beam: pencil-like X-ray beam
- tube-detector movements: translate-rotate
- duration of scan (average): 25-30 mins

Second generation

- detectors: multiple (up to 30)
- type of beam: fan shaped x-ray beam
- tube-detector movements: translate-rotate

- duration of scan (average): less than 90 sec

Third generation

- detectors: multiple, originally 288; newer ones use over 700 arranged in an arc

- type of beam: fan shaped x-ray beam

- tube-detector movements: rotate-rotate

- duration of scan (average): approximately 5 sec

Fourth generation

- detectors: multiple (more than 2000) arranged in an outer ring which is fixed

- type of beam: fan shaped x-ray beam

- tube-detector movements: rotate-fixed

- duration of scan (average): few seconds

2.1.3.2.CT numbers:

A normalized value of the calculated x-ray absorption coefficient of a pixel (picture element) in a computed tomogram, expressed in Hounsfield units, where the CT number of air is −1000 and that of water is 0.

2.1.3.3 Hounsfield unit:

The Hounsfield unit (HU) scale is a linear transformation of the original linear attenuation coefficient measurement in one in which the radio density of distilled water at standard pressure and temperature (STP) is defined as zero, while the radio density of air at STP is defined as -1000 HU. Hounsfield unit are used in medical imaging to describe the amount of x-ray attenuation of each "voxel" in the 3D image. Voxels are normally

represented as 12-bitbinary numbers and therefore have 212 = 4096 possible values. These values are arranged one scale from -1024 HU to +3071 HU, calibrated so that -1024 HU is the attenuation produced by air and 0 HU is the attenuation produced by water.

For a material X with linear attenuation coefficient μ X, the corresponding HU value is therefore given by

$$HU = \frac{\mu_x - \mu_{water}}{\mu_{water} - \mu_{air}} \times 1000$$

Where μ water, μ air are the linear attenuation coefficients of water and air, respectively.

Thus, a change of one Hounsfield unit (HU) represents a change of 0.1% of the attenuation coefficient of water since the attenuation coefficient of air is nearly zero. CT scanners are calibrated with reference to water (Brooks &Chiro 1976). The CT number is directly related to the linear attenuation coefficient for the x-ray and is usually calibrated to 0 for water and to −1000 for air, -120 for fat, +40 for muscle, and +400 or more for bone.

The Hounsfield number of a tissue varies according to the density of the tissue; the higher the number, the denser the tissue. Consequently, the mean Hounsfield number is a ratio in proportion to the atomic weights of the whole particles and particle numbers within the evaluation site. It has been discovered that when there is an increase in the fat amount of ROI volume, there is a corresponding decrease in the amount of minerals and in the Hounsfield number. The reverse has also been observed. The mean

Hounsfield number decreases when the amount of fat increases or the amount of mineral decreases. The Hounsfield number can be used directly to determine bone quality alterations.

CT is another extension of photon absorptiometry, but for a much more general purpose.

Rather than a simple measurement of the photon attenuation along a fixed line through an object, as in SPA, a series of measurements are made at any point along that line by (in effect) rotating the source and detector about that point. Thus, a point on the line is" viewed" from up to a thousand different directions. Through the mathematical process known as projection reconstruction, these points along the line are separated from one another, as are points along other lines that make up the two-dimensional axial image plane.

This process of reconstructing the CT image produces a map of the x-ray attenuation coefficients in a cross-sectional "slice" of the body, and these coefficients can be used to determine tissue density at any point in the image. The size and number of points along a line in current CT scanners is variable depending on the object being scanned, but ranges from points 0.25 mm up to 1.5 mm in size, and typically 256–512 elements lie along the line. Each "slice" of a patient scanned can also have variable thickness (the portion exposed to the x-ray beam), ranging from 1 mm up to 10 mm thick. Each point, or element, in a given reconstructed image is the same size, but this size can vary from 0.25 x 0.25 x 1 mm (0.0625mm3) to 1.5 x 1.5 x 10 mm (22.5 mm3). When viewed on a display monitor, these points are called picture elements or "pixels"; when stored in the computer and used for quantitative purposes, they represent volume elements because of the finite

slice thickness and are termed ''voxels'' .(Christopher et al 1989, .Cann&Genant 1980).

2.1.2.4.Image display:

To maximize the perception of medically important features, images can be Digitally processed to meet a variety of clinical requirements. Assignments of grey values on a display-monitor to the CT numbers in the computer memory can be adjusted to suit special application requirements. A look-up table lists the relationship between stored CT numbers and their corresponding grey scale values. Examples are given in figure 5. A linear look-up table produces the simplest possible relationship between input and output values. Contrast can be enhanced by assigning just a narrow interval of the CT numbers to the entire grey scale on the display-monitor. This is called 'window technique', the range of CT numbers displayed on the whole grey scale being called the 'window width' and the average value the 'window level'. Changes in window width alter contrast and changes in window level select the structures in the image displayed on the grey scale, i.e., from black to white. Examples of different window widths and levels are shown in figure 5. As the window width is made narrower, part of the image is displayed over the whole grey scale but only over the window width centered around the window level. These structures benefit from the higher contrast, whereas structures on the lower and higher sides of the window width (low and high CT numbers) are either completely black or white. As the window width is made even narrower, the contrast of the structures displayed increases. Combinations of these techniques enable small differences in tissue attenuations and composition to be visualized provided the precision in the measured CT numbers is high enough, i.e., if

the   image   quality   is   sufficient.

a   b   c
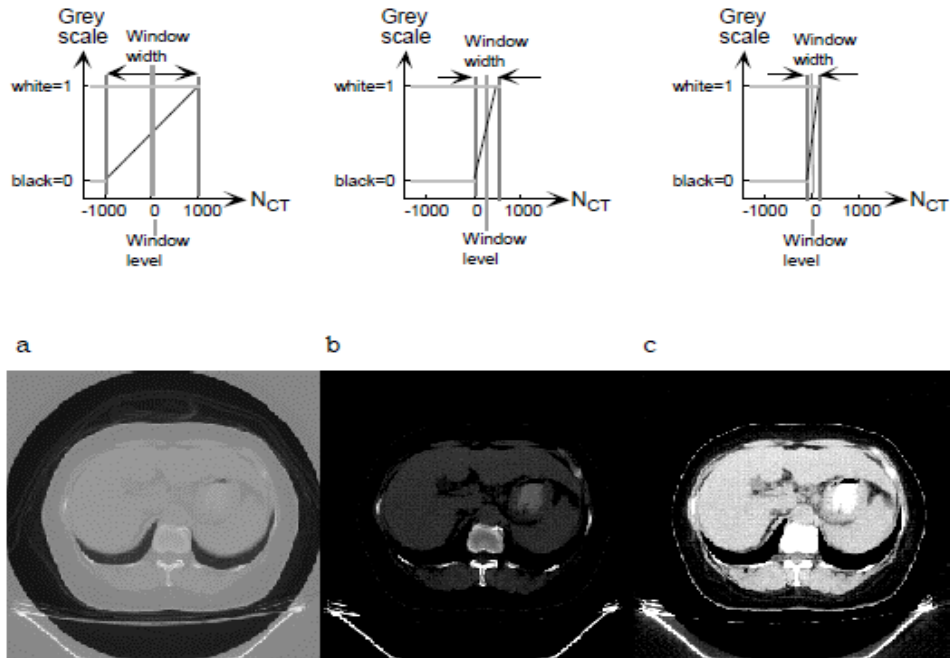
Figure (2-8) .A tomogram of the thorax. The images show the effect from changes in window width and window level. Figure (a) show a wide range of CT numbers between -1000=NCT=1000, and the contrast is low; (b) show CT numbers between 0=NCT=500 which displays some soft tissue and bone; (c) show a narrow range of CT numbers between -100=NCT=100, which displays soft and adipose tissue and the skin with higher contrast. As the window width decreases, the contrast of tissues centred around the window level increases. Structures outside the window width are displayed either completely black or white (see schematic diagrams of look-up tables above).

2.1.2.5. Image quality:

In a digital imaging system image quality and absorbed dose in the patient areinterrelated. Image quality can be expressed in terms of quantum noise, contrast and resolution. Contrast, which is primarily determined by

differences in CT numbers, can be manipulated as discussed in the previous section. Since only a thin slice of the body is irradiated at a time, scattered photons are not such a large problem as in planar radiography.

Precision in the measurement of CT numbers is limited by quantum noise.

The stochastic nature of quantum noise can be shown by inspecting a tomogram of a homogeneous object. All pixels do not have the same CT number but a random spread in CT numbers is found. This is because attenuation and absorption of X-ray photons are stochastic processes and only limited numbers of X-ray photons are detected and used to construct the image. The larger the number of X-ray photons absorbed in the receptors, the larger the precision and the lower the quantum noise. Figure 6a-c show tomograms of a cylinder-shaped Plexiglas container containing water and disk-shaped details of varying contrasts and diameters. The numbers of photons used in the reconstruction of the image decreases 10 times going from figure 6a to 6b and from 6b to 6c. The detect ability of the small low contrast details is significantly reduced when fewer X-ray photons are used since this increases quantum noise. The number of X-ray photons absorbed in the receptors depends on the X-ray tube charge (the product of X-ray tube current (mA) and exposure time (s)), the energy spectrum of the photons and the thickness of the patient (largernumbers for high tube potential and thin patients), the efficiency of the receptor (larger for thicker receptors) and the receptor area (larger for large receptor areas).
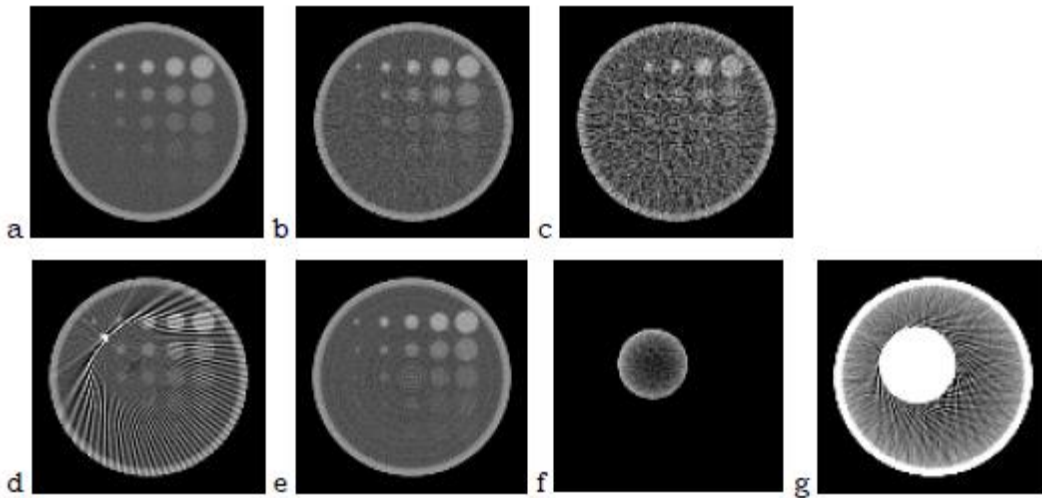
Figure (2-9). Tomogram of a cylinder-shaped Plexiglas container (1 cm thick wall)containing 20 cm water and low contrast details of increasing contrast (1, 2, 4,8, 16% higher) and diameter (0.5, 1.0, 1.5, 2.0, 2.5 cm). In (a)-(c), the numbers of X-ray photons used in the reconstruction of the image is decreases by a factor of 10 between each tomogram which significantly reduces the detect ability of small, low-contrast details (at the lower left in the images). The percentages of quantum noise in the projection data in (a), (b) and (c) are 0.1%, 0.316%, and 1%, respectively. Examples of artifacts are shown in (d)-(g); d: partial volume effect (a 3 mm diameter steel pin in the upper left corner), e: ring artifacts (due to poorly calibrated receptors), and f: the beam hardening effect in an 8 cm disk of bone (darkening towards the disk center). With a lower window level (g), the beam hardening effect in the surrounding water is also visualized. Note also the partial volume effect in water in the vicinity of the water-bone boundary. The receptor area is proportional to the slice thickness and voxel size (=pixel size) and is therefore related to the image resolution. If the resolution in the images is doubled (pixel size halved), the number X-ray quanta required to retain the

same noise level as with the larger voxels is increased by 24=16 times. This means that in order to make use of the increased spatial resolution, one needs to increase the dose to the patient sixteen times. For a 25 cm thick patient, the pixel side for a 256x256 matrix would be just below 1.0 mm and for 512x512 matrix 0.5 mm. A less noisy image can be achieved by changing from a 512x512 to a 256x256 matrix, at the expense of a loss in spatial resolution.

2-1-2-6Artifacts

Although images produced by CT are generally faithful representations of the scanned volume, the technique is susceptible to a number of artifacts, such as the following:

***Streak artifact*:** Streaks are often seen around materials that block most X-rays, such as metal or bone. Numerous factors contribute to these streaks: under sampling, photon starvation, motion, beam hardening, and Compton scatter. This type of artifact commonly occurs in the posterior fossa of the brain, or if there are metal implants. The streaks can be reduced using newer reconstruction techniques or approaches such as metal artifact reduction (MAR). MAR techniques include spectral imaging, where CT images are taken with photons of different energy levels, and then synthesized into monochromatic images with special software such as GSI (Gemstone Spectral Imaging).

***Partial volume effect*:** This appears as "blurring" of edges. It is due to the scanner being unable to differentiate between a small amount of high-density material (e.g., bone) and a larger amount of lower density (e.g., cartilage). The reconstruction assumes that the X-ray attenuation within each

voxel is homogenous; this may not be the case at sharp edges. This is most commonly seen in the z-direction, due to the conventional use of highly anisotropic voxels, which have a much lower out-of-plane resolution, than in-plane resolution. This can be partially overcome by scanning using thinner slices, or an isotropic acquisition on a modern scanner.

Ring artifact: Probably the most common mechanical artifact, the image of one or many "rings" appears within an image. They are usually caused by the variations in the response from individual elements in a two dimensional X-ray detector due to defect or miscalibration. "Rings" are suppressed by a transformation to polar space, where they become linear stripes.

Noise: This appears as grain on the image and is caused by a low signal to noise ratio. This occurs more commonly when a thin slice thickness is used. It can also occur when the power supplied to the X-ray tube is insufficient to penetrate the anatomy.

Motion artifact: This is seen as blurring and/or streaking, which is caused by movement of the object being imaged. Motion blurring might be reduced using a new technique called IFT (incompressible flow tomography).

Windmill: Streaking appearances can occur when the detectors intersect the reconstruction plane. This can be reduced with filters or a reduction in pitch.

Beam hardening: This can give a "cupped appearance". It occurs when there is more attenuation along a path passing through the center of an object, than a path that grazes the edge. This is easily corrected by filtration and software

2.1.4. Reasons of measuring bone density:

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

2.1.5. Types of bone mineral density tests:

- Ultrasound

- DEXA (Dual Energy X-ray Absorptiometry)

- SXA (single Energy X-ray Absorptiometry)

- PDXA (Peripheral Dual Energy X-ray Absorptiometry)

- RA (Radiographic Absorptiometry)

- DPA (Dual Photon Absorptiometry)

- SPA (Single Photon Absorptiometry)

- MRI (Magnetic Resonance Imaging)

- QCT (Quantitative Computed Tomography)

- Laboratory tests

2.1.5.1 Ultrasound:

Measuring area is the heel. New methods of measuring osteoporosis using ultrasound have also been developed. One such ultrasound system measures BMD at the patient's heel and takes about a minute. Non absorptiometric

methods such as ultrasound of bone do not directly measure bone density, but give alternative information about properties of bone, such as the speed of sound, that are related to bone density and structure. The ultrasound systems for testing osteoporosis are smaller and less expensive than traditional methods.

Further, density changes in the heel occur much slower than in the hip or spine. Therefore, ultrasound densitometry should not be used to monitor a patient's response to the therapy (Njeh et al., 1997 & Rang et al., 1998).

Ultrasound densitometry may not be as sensitive as other techniques, such as DEXA or QCT, that measure the spine or hip, since the heel may be normal in bone density even when central sites such as the hip or spine are already significantly abnormal.

However, the new ultrasound densitometry systems will allow many more people access to bone densitometry and potentially diagnose osteoporosis before a traumatic fracture occurs (Njeh et al., 1997 &Rang&Speller., 1998).

2.1.5.2 DEXA (dual energy X-ray absorptiometry)

The measuring area is spine, hip, or total body. DEXA (dual energy X-ray absorptiometry) is the most widely available method of bone densitometry, and most insurance plans will cover the cost for the test, given that certain medical indicators are present. Bone mineral density measurement with DEXA is painless and requires no injections, invasive procedures, sedation, special diet, or any other advance preparation. During a DEXA exam, the patient lies fully clothed on a padded table while the system scans one or more areas of bone (usually the lower spine or hip). The entire exam typically takes just a few minutes to complete. Dual energy x-ray absorptiometry (DXA) measures the bone by computing the difference in absorption of low-energy photons and high energy photons by the mixture of

soft tissue and bone in the path of the beam and can generate a 2 dimensional image for localization of the bone.

While DEXA uses x-rays, the radiation dose is less than during a chest x-ray. Each patient's bone density is plotted against the "norm" for a healthy young adult or against age-matched control data. A radiologist or other physician then interprets the data and creates a concise report on the status of the patient's bone density.

DEXA systems have recently received US Food and Drug Administration (FDA) clearance.

The accuracy of bone mineral density testing is high, ranging from 85% to 99%. DEXA is the most accurate and widely available BMD test (Mazess et al., 1992).

The interpretation of individual DXA studies is not difficult. However, the responsibility of a physician overseeing a densitometry service lies more in familiarity with the conceptual context as it relates to the role of densitometry in and the management of osteoporosis (Lentle&Prior, 2003).

2.1.5.3 SXA (single energy X-ray absorptiometry)

Measuring area is the wrist or heel. This is a method of assessing bone mineral density using a single energy X-ray beam. Single energy x-ray absorptiometry (SXA) computes bone mineral from the increased absorption of the beam as it passes from a constant thickness of soft tissue or water bag into the bone. Localization for SXA is normally done using external landmarks without an image. It is now widely considered inferior to dual-energy X-ray absorptiometry, which uses a second energy beam to correct for absorption of X-ray energy by non-calcium containing tissues (Adams, 1997).

2.1.5.4 PDXA (peripheral dual energy X-ray absorptiometry)

Measuring area is the wrist, heel, or finger. The acronym PDXA (peripheral dual-energy X-ray absorptiometry) is used to describe dedicated devices that are specifically designed to measure the BMD of peripheral skeletal sites using DXA. There is no fundamental difference in technology between peripheral and central DXA. PDXA (Hans et al., 2008),

2.1.5.5 RA (radiographic absorptiometry)

The measuring area is the hand. RA, or radiographic absorptiometry, uses an X-ray of the hand and a small metal wedge to calculate bone density in the middle phalanges.

Radiographic absorptiometry (RA) measures bone density in the fingers relative to an aluminum calibration wedge on the film. RA is one of the most preferred bone mass measurements because it can calculate bone loss quickly and it is a relatively inexpensive option for any medical specialist and medical office (Yang et al., 1994),

2.1.5.6 DPA (dual photon absorptiometry)

The measuring area is the spine, hip, or total body. Measurement of the BMC of spine and proximal femur (or any part or the entire skeleton) requires measurement of the relative attenuation of two differing photon energies to permit a correction for soft-tissue attenuation. This allows an assay of the calcium content in deeper structures, although the technique only provides a real density of calcium (in grams per square centimeter) not true volumetric density such as may be achieved with quantitative CT (Blake &Fogelman 1997, Genant& Boyd 1977).

2.1.5.7 SPA (single photon absorptiometry)

The measuring area is the wrist. The method overcame the problems for radiographic photo densitometric techniques, caused by polychromatic X-rays and non-uniformity of film sensitivity and development, by using a single energy g-ray source (125I, photon energy27.3 Kev) and a scintillation detector to measure transmitted photons (Adams 1997). SPA was used to advance bone measurement from the early days of measurement of bone size On radiographs of the hand or crude determinations of optical density from similar images.

It is an effective technique for measurements of bone in the distal radius and ulna (Duppeetal. 1997).

2.1.5.8 MRI (magnetic resonance imaging)

The measuring area is the spine, hip, or total body. MRI might be used effectively, as it is noninvasive and radiation-free, and it is a reliable in vivo method for assessing features of the trabecular bone structure (Wehrli et al. 2000; Majumdar 2002;Strolka et al 2005,Celenk&Celenk 2010). Trabecular bone is highly responsive to metabolic stimuli and has a turnover rate approximately three to 10 times higher than cortical bone, and so it is a prime site for detecting early bone loss and monitoring response to therapeutic intervention.

2.1.5.9 Laboratory tests

Laboratory tests that measure the amount of collagen in urine samples can indicate bone loss. Lab tests may also be used in conjunction with DEXA or other methods of bone densitometry to diagnose osteoporosis.

2.1.5.10 QCT (quantitative computed tomography) and osteoporosis

2.15.10.1 The foundations of the CT density

Measuring area is the entire body

QCT refers to a class of techniques in which the CT numbers, or x-ray attenuation, of a tissues properly referenced to a calibration standard and then used to quantify some property of the tissue. Techniques were developed and published from 1978 to 1982 for bone density, lung nodule calcification, liver and brain tumor volumes, body fat measurement, muscle mass, liver iron measurement, kidney stone composition, and tissue blood flow. Of these, bone mineral density, lung nodule calcification, and tissue blood flow have been commercialized.

2.15.10.2 Reasons of quantitative computed tomography:

CT numbers (i.e., Hounsfield units, HU) are strongly related to biological tissues density (Ciarelli et al., 1991; McB- room et al., 1985). The directly measured Hounsfield number for bone density may be used to examine bone quality. This method is recommended by some authors (Nilsson et al 1988, Shapurian et al 2006, Norton et al 2001). The mean number of HU within each ROI measures and uses the BD as the marker of metabolic alterations within the trabecular field.

QCT was one of the earliest ways of measuring bone density its use has largely been superseded by the use of dual energy x-ray absorptiometry (DXA) (Adams et al. 1997). QCT has several advantages over DXA, providing true volumetric density (so being size independent) separately in trabecular and cortical bone and being free of the inaccuracies caused by spinal DXA by extra-osseous calcification and hyperostosis. Quantitative CT and simple trabecular ROI attenuation approaches bone density measurement simply and accurately. QCT also shows promise as effective

tools in measuring BD. However, QCT is not widely available and delivers more radiation to the patient than DEXA.

DEXA T-scores are the standard used by "all the major national and international societies, including the World Health Organization. "Gugliemi et al (1994) said we believe that considerations should be given to the use of QCT as the gold standard against which other measurements of spinal BD are judged.

Development in QCT technology (spiral acquisition) and software has enabled rapid acquisition of 3D volume images and application to other relevant sites. We have therefore reassessed QCT in the assessment of patients with osteoporosis. The analysis showed similar results across the board—with no significant differences for any of the measurements versus DEXA.

Given the poor agreement between the two methods for the diagnosis of osteoporosis and the much better fracture discrimination with QCT, we believe that consideration should be given to the use of QCT as the "gold standard" against which other measurements of spinal BMD are judged.

Investigators often diagnose osteoporosis by measuring a patient's bone mineral density (BMD). Bone mineral density measures the amount of calcium in regions of the bones. Bone density is a good measurement for bone quality but it is not sufficient in itself. However, BD might be used to imply bone quality when the density alterations represent changes in trabecular structure (Celenk&Celenk, 2008).

Most methods for measuring BD (also called bone densitometry) are fast, non-invasive, painless, and available on an outpatient basis. Bone densitometry can also be used to estimate a patient's risk of fracture. These methods compare the numerical density of the bone (calculated from the

image), with empirical (historical) databases of bone density to determine whether a patient has osteoporosis, and often, to what degree.

The accuracy of the results remained high whether BD was measured by using QCT or by means of a simple region of interest (ROI) CT density assessment. The "simple ROI" technique can perform without angulations or precise measurements.

This information at CT is currently being wasted. ROI measurement of vertebral body trabecular attenuation takes a matter of seconds" and adds value to any routine BD measurement that can be performed with the same CT data. This means that any CT examination that covers any bone alone can effectively rule out osteoporosis and osteopenia without need of a second test.

Reinbold et al. (1986) said that trabecular bone is approximately eight times more metabolically active than cortical bone. Quantitative computed tomography (QCT), which measures trabecular bone density, is therefore highly sensitive to changes in skeletal density.

We can use QCT as the reference standard and any CT examination covers vertebra. The investigators are also looking to detect suspected lumbar compression factors with QCT, which DEXA can miss this condition.

QCT is the only commercially available 3-dimensional technique, meaning it can be used to measure 100% isolated trabecular bone. All other techniques measure the mixture of trabecular bone and the overlying compact bone. In the spine, trabecular bone is 30-35% of the total, in the distal radius it is 35-50%, and 60-75% in the calcaneus.

Trabecular bone is important to measure because it is more metabolically active than compact bone and is the first to change in response to a stimulus such as estrogen deficiency. Trabecular bone in the spine is a more reliable

indicator of overall skeletal response than the heavily weight-bearing bone in the calcaneus. However, it is also important to consider that any measurement must be done precisely; otherwise, the measurement will be insensitive.

DEXA can produce false-negative results for osteoporosis in the setting of unsuspected lumbar compression fractures that CT can potentially detect. While DEXA uses x-rays, theradiation dose is less than during a chest x-ray.

Baran et al. (1997) said that the QCT examination, when performed correctly, givesrelatively low radiation exposure compared with conventional radiographs or standard CTstudies, typically equivalent to a transcontinental airline trip.

Summers et al. (2001) said that ''we can record the actual bone mineral density value In grams per cubic centimeter instead of using the T-scores or Z-scores produced by the DEXA phantom less QCT software "because they don't really have a reference standard that 'accepted".

Both lumbar QCT and simple ROI measurements are effective at assessing bone mineral density relative to DEXA, which is a reference standard we have to use. We can set a certain level and be at 100% sensitivity for osteoporosis and also exclude osteoporosis in a large fraction of people—over half of people depending on the level—and actually preclude the possible need for DEXA in those cases (Summers et al., 2001).

For the same precision, QCT is 2-3 times more sensitive than DXA and 5 times more than SXA for detecting a change in bone mineral density in early postmenopausal women (Reinbold et al 1988).

2-2 previous studies:

2-2-1 Bone growth and development in prehistoric populations from Sudanese Nubia:

The analysis of a large sample of skeletons from a number of Sudanese Nubian cemeteries demonstrates the usefulness of this material in the study of bone growth and development. A skeletal series and the Meroitic (B.C. 350-A.D 350), x-group (A.D. 350-550), and Christian (A.D. 550-1400) period were utilized in determining the rate of bone development and age related changes in the internal structure of the femur Specifically, we have been able to demonstrate the following: 1. (i) the growth velocity determined from the long bone of the Nubian samples was similar but somehow more irregular than the growth velocity of long bone in American boys 2- growth symmetry of long bone determined by the ratio of lengths shows a greater stability than that which occurs in boys. 3- Decrease in femoral cortical thickness with age was significant in Nubian females 4- the density of femoral head trabecular bone organ volume decreases with age at similar rates in both males and females, but the females lose a larger percentage of density since they enter the age period (17 years) with a lower density. 5. 5- The average thickness of femoral head trabeculae decrease with age in males, while in females there is an increase in thickness. It appears that as cross-members decrease in thickness with age, struts increase in thickness. 6-Microradiographic analysis of archeological material may provide an additional dimension to the study of bone turnover rate.

2-2-2 Hiba Osman 2010 (measurement of normal bone density using computed tomography)

This study show increase of bone dense on male rather than female and that appear clearly in increase of average compact and spongy bone as is (301.571- 187.55) this reading for compact and spongy respectively but female bone dense average is (267-173.42) this reading for average of compact and spongy respectively, with (+or-) 68.77 for male and (+or-) 49.31 for female and that return to the sexual hormone effect.

The relation of average of spongy and compact with sex and age range is weak and opposite propagation.

The relation between average of compact and spongy bone generally not strong but there are positive propagation and that refer to union body nutrition.

The relationship between the average of spongy and compact with patient have problem means pt. with disease is negative propagation when increase the severity of disease the average of bone dense decrease.

Chapter three

Materials and methods

3.1Materials:

3.1.1 Sampling and sample size :

There was 40 patients had been selected by the technique of noun probability sample as follow   male and   female with different ages , all of them have underwent CT abdomen exam for different clinical reasons (liver mass , renal stone , ……. Etc.) .

.3.1,2CT machine used in bone densometery :

GE LightSpeed Ultra Advantage specifications	
Scanner gantry	
Generation	3rd generation
Aperture (cm)	70
Scan fields of view (cm)	25 and 50
Nominal slice widths for axial scans (mm)	0.625, 1.25, 2.5, 3.75, 5, 7.5, 10
Tilt range (degrees)	± 30
Type of positioning lights	Laser

Patient Couch

Material	Carbon fibre
Length x width (cm)	239 x 62 (or 42 just for cradle)
Horizontal movement range (cm)	170
Vertical movement range out of	51 – 99

gantry (cm)	
Vertical movement range in gantry (cm)	88 – 99
Maximum weight allowed on couch (kg)	205

X-ray generator

Type	High frequency
Location	rotation assembly
Power rating (kW)	53.2
kV settings available	*80, 100, 120, 140*
mA Range and Step size	10 - 440 (10mA steps)
Max. mA allowed for each kV	80kV: 400mA, 100kV: 420mA, 120kV: 440mA

X-ray tube

Focal spot size(s) (mm), quoted to IEC 336/93 standard	0.6 x 0.7, 0.9 x 0.9
Total filtration (inherent + beam shaping filter) at central axis (mm Al equivalent)	4.75 (70kV, head) 5.65 (70kV, body)
Anode heat capacity (MHU)	6.3
Method of cooling	Oil to air

3.2 Methods

3.2.1 CT technique used in bone density:

In this study we performed the technique of abdomen, the patient scan from the area of diaphragm till pelvic area as clinical inductions needed and took slice, sometimes patient given contrast media and other time had not investigation demand.

3.2.2 CT measure used in bone density:

In this study we measured the L2-13 vertebrae as reference point in all cases and in one vertebrae we took different reading in body of it (compact) from edge of outside till inner it reached to seven reading as of follow (upper and lower edge RT and LT pedicels area, RT and LT transvers processes and spinous processes) and then we measured to inner (spongy) of bone three reading randomly regions and then made the average reading to both readings for both vertebra to spongy of each one as individual, and then made one average to compact and spongy by done the average to two vertebrae (L2-L3) to gain the average of bone dense to the whole body of the patient, and in all measured the circle of CT number measure not increase than 5 in width of.

3.2.3 Type of study :

This study is Cross sectional study (Experimental study)

3.2.4 Area f the study :

This study done in Antalia Medical Center

3.2.5 Duration of the study :

This study took three months from July till September 2015.

3.2.6 Variables of study :

Sex , age , range , spongy bone , compact bone and disease .

3.2.7 Data collection :

Used data collection sheet .

3.2.8 :Inclusion criteria :

All patients whom have not forbidden reason which can effect bone dense.

3.2.9 Exclusion criteria:

Patients with asthmatic, diabetic mellitus and any one use medication which entrance in the steroid compounds

3.2.10 Data analysis:

Used SPSS program.

3.2.11 Data presentation:

Present on tables and figures.

3.2.12 Ethical considerations:

This study performed on patients whom come to CT center to done an exam without any mandatory force.

Chapter four

Results

The study included 40 patients male and female with different abdomen examination indications and the following tables and graphs show summary of the result with vary of gender , age , and average of bone dense include average of compact and spongy bone , and correlation between them as follow:

Table (4.1): explains the number of patents and the minimum,maximum,mean,std.deviation and variance of age, cortical bone and spongy bone:

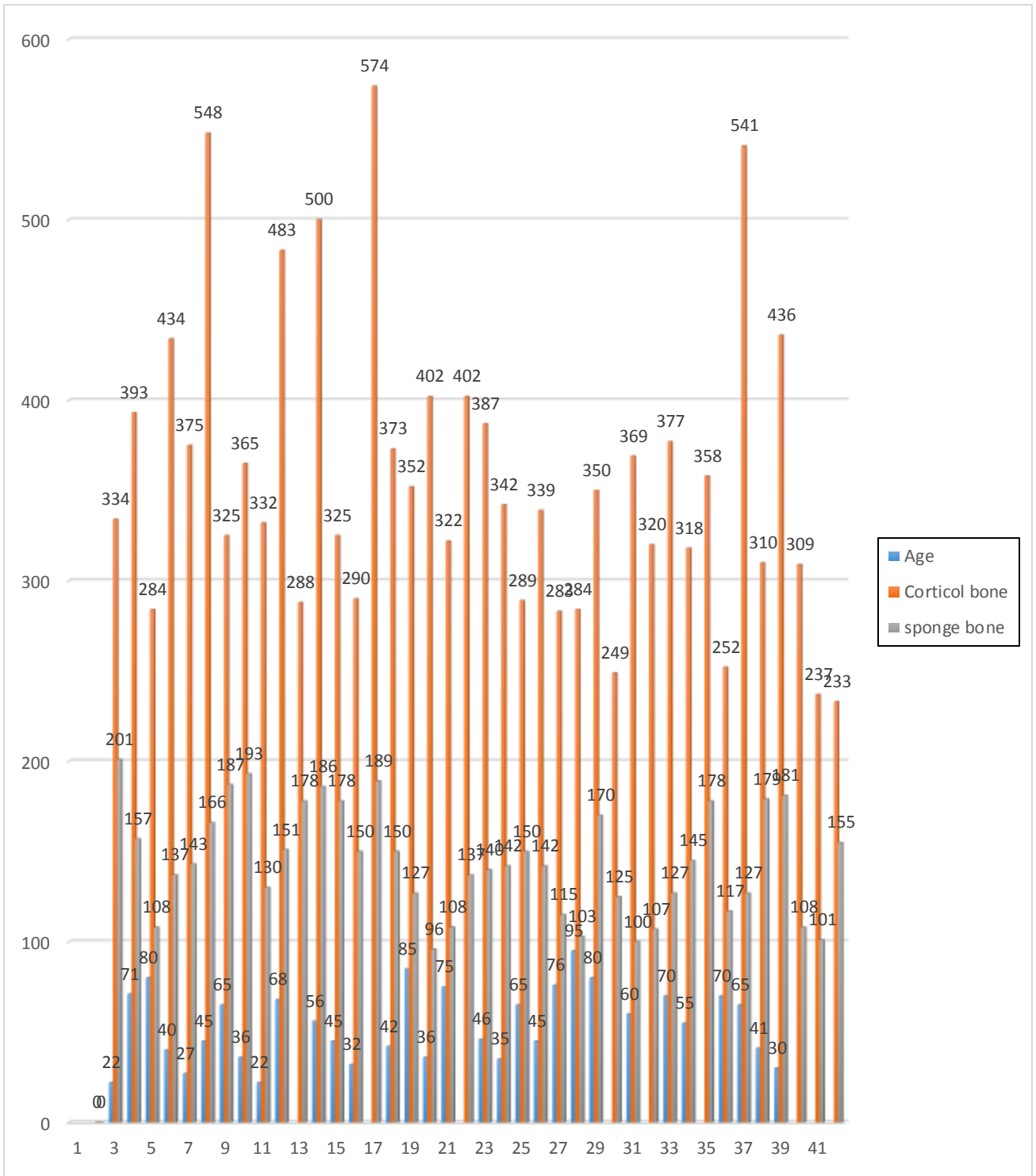|	Number	Minimum	Maximum	Mean	Std. Deviation	Variance
Age	40	22	95	54.19	19.984	399.361
Corticalbone	40	233	574	357.10	82.940	6879.015
Spongy bone	40	96	201	144.60	29.995	899.682

Figure (4.1): shows the range of the age, cortical bone and spongy bone
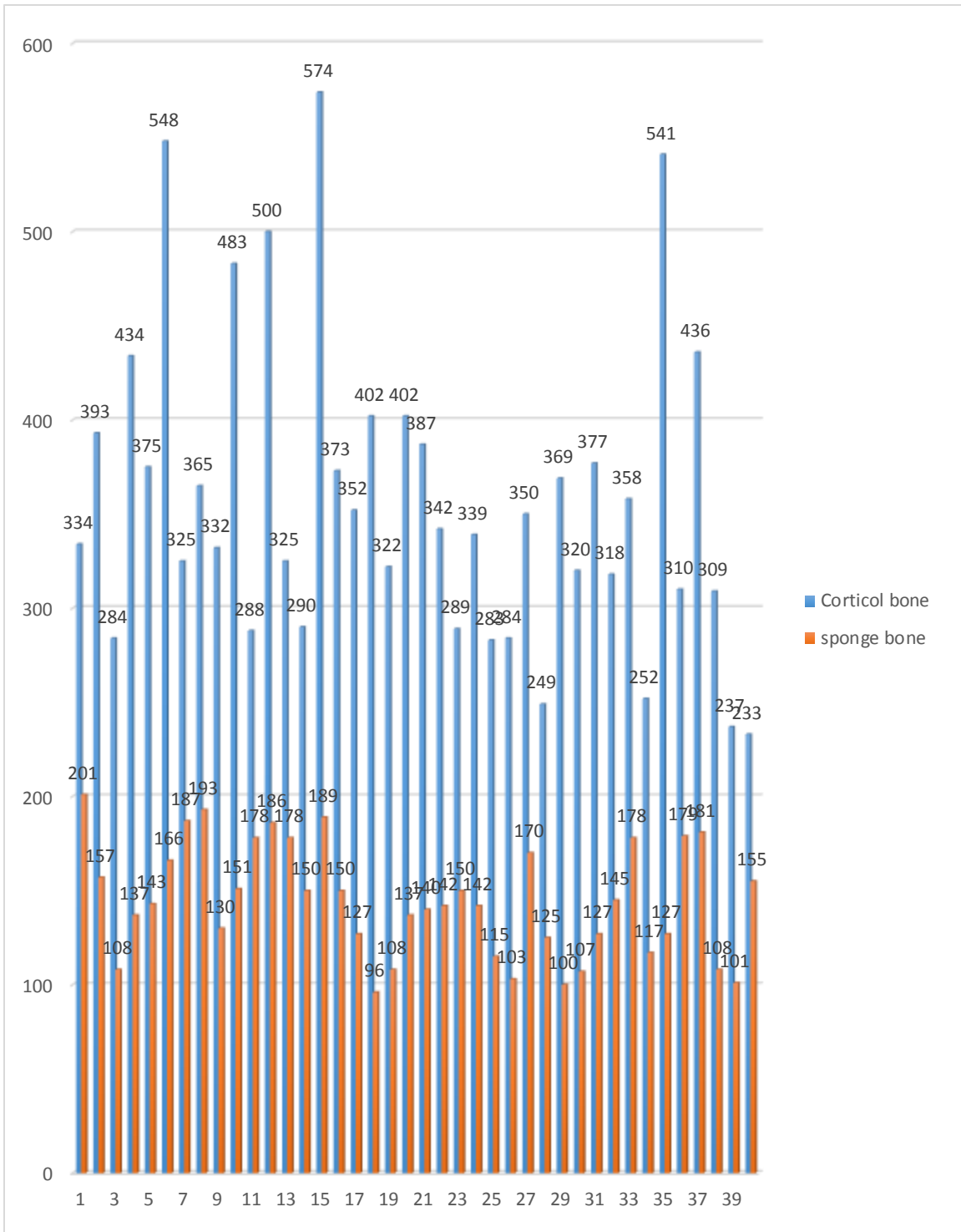
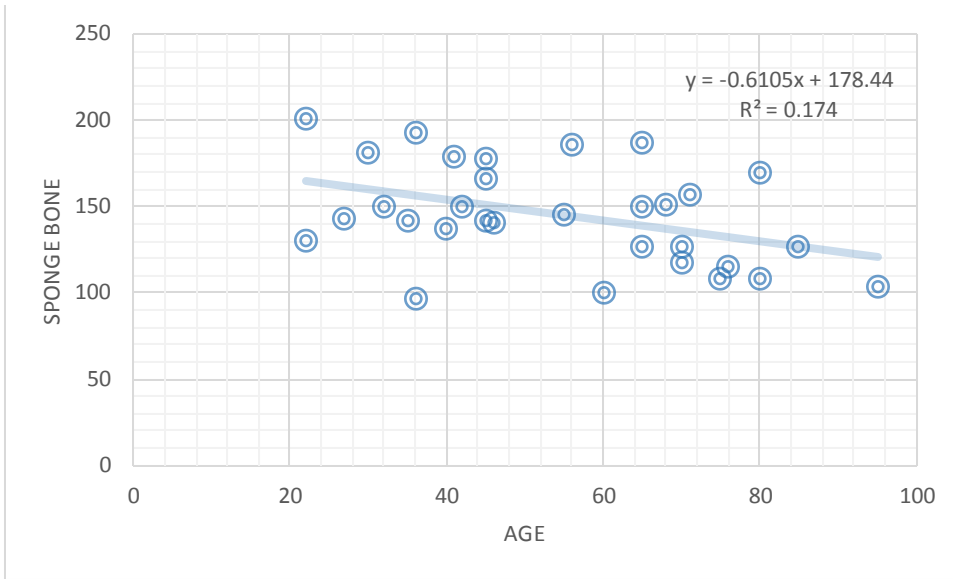**Figure (4.2): Shows the range of cortical bone and spongy**

Figure (4.3): shows the relationship between age range and average of spongy bone which is weak and opposite propagation:
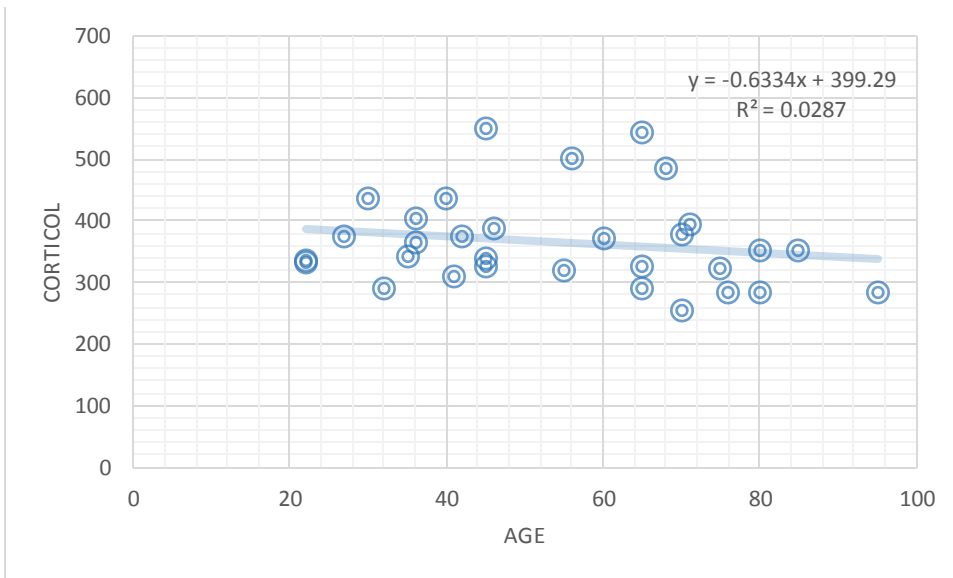
Figure (4.4): shows the relationship between age range and average of cortical bone which is weak and opposite propagation:

Table (4.2): shows the mean, Std. Deviation,variance, Minimum and Maximum of age, cortical bone and spongy bone in female cases:

	Age	cortical	Sponge
Valid	20	20	20
Mean	49.40	337.11	140.72
Std. Deviation	20.184	69.513	31.398
Variance	407.400	4832.105	985.859
Minimum	22	249	100
Maximum	85	548	201
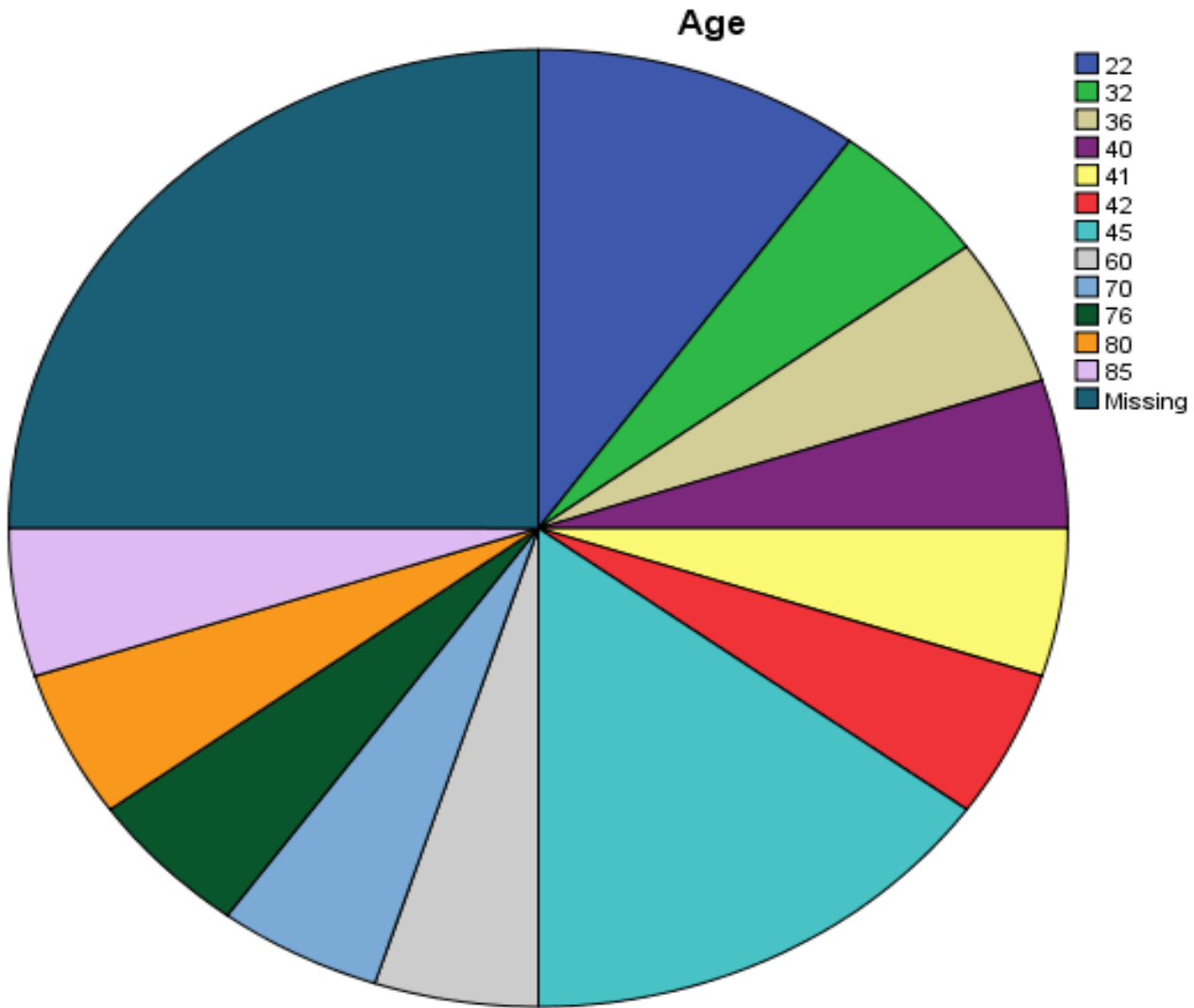
Figure (4.5): shows the age Distribution in female samples and percentage of them

Table (4.3): shows the mean, Std. Deviation,variance, Minimum and Maximum of age, cortical bone and spongy bone in male cases:

	Age	cortical	sponge
Valid	20	20	20
Mean	58.69	387.30	149.75
Std. Deviation	19.338	82.996	28.578
Variance	373.963	6888.326	816.724
Minimum	27	284	96
Maximum	95	574	189

Age

Legend:
- 27
- 30
- 35
- 36
- 46
- 55
- 56
- 65
- 68
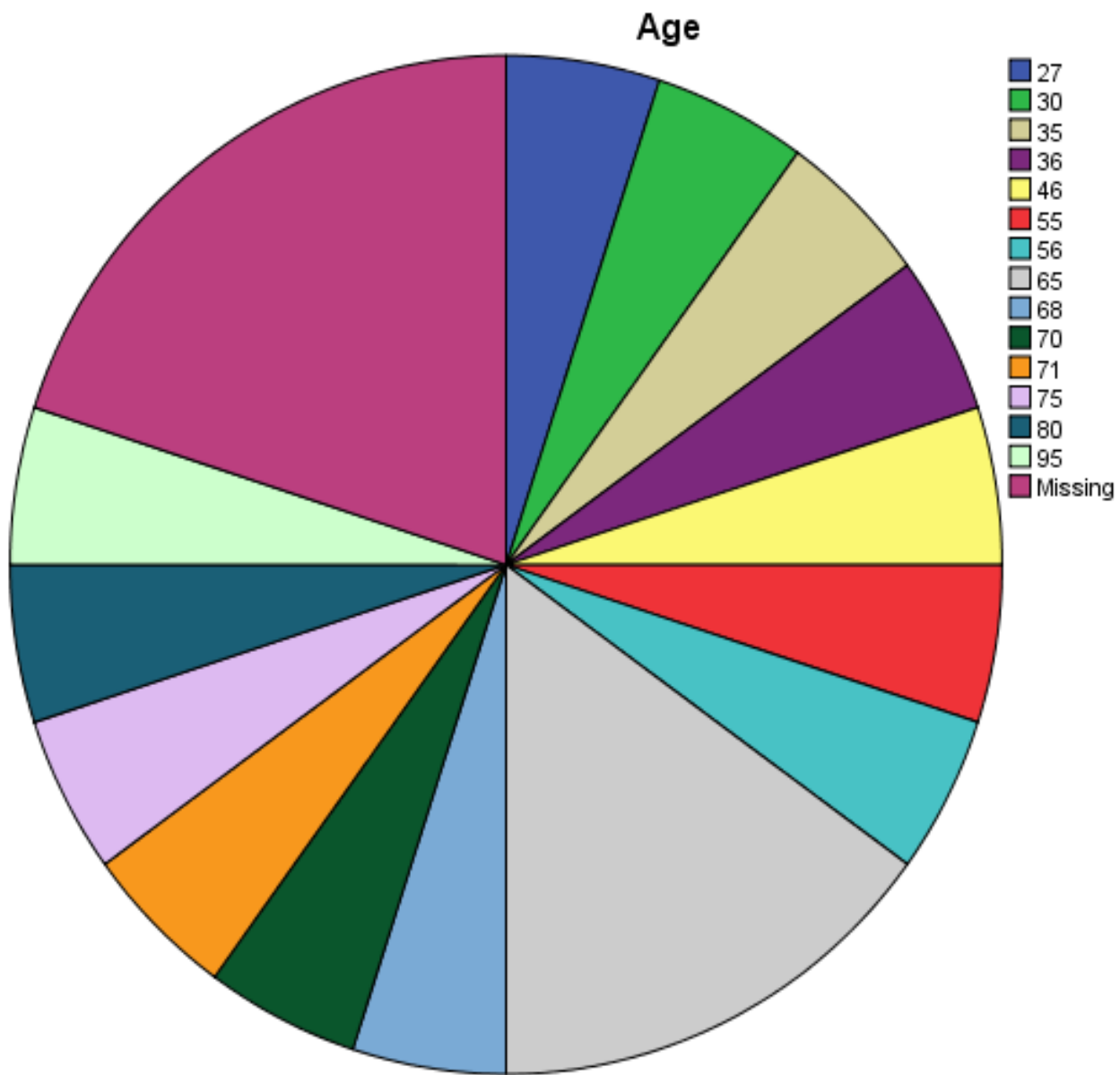- 70
- 71
- 75
- 80
- 95
- Missing

Figure (4,6): shows the age Distribution in male samples and percentage of them
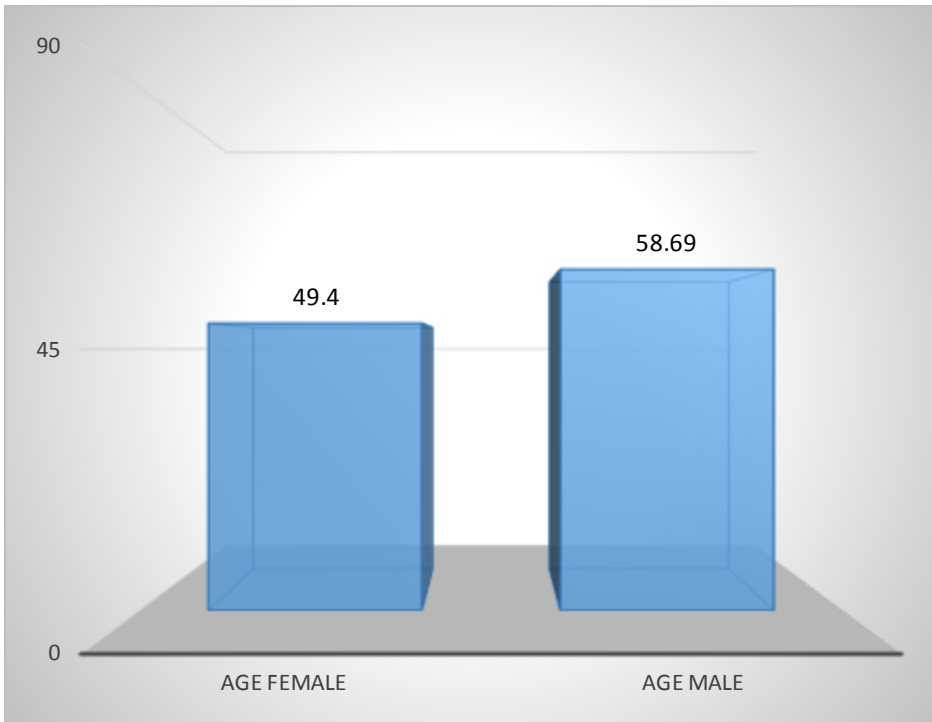
Figure (4.7): shows the average of age of each sex
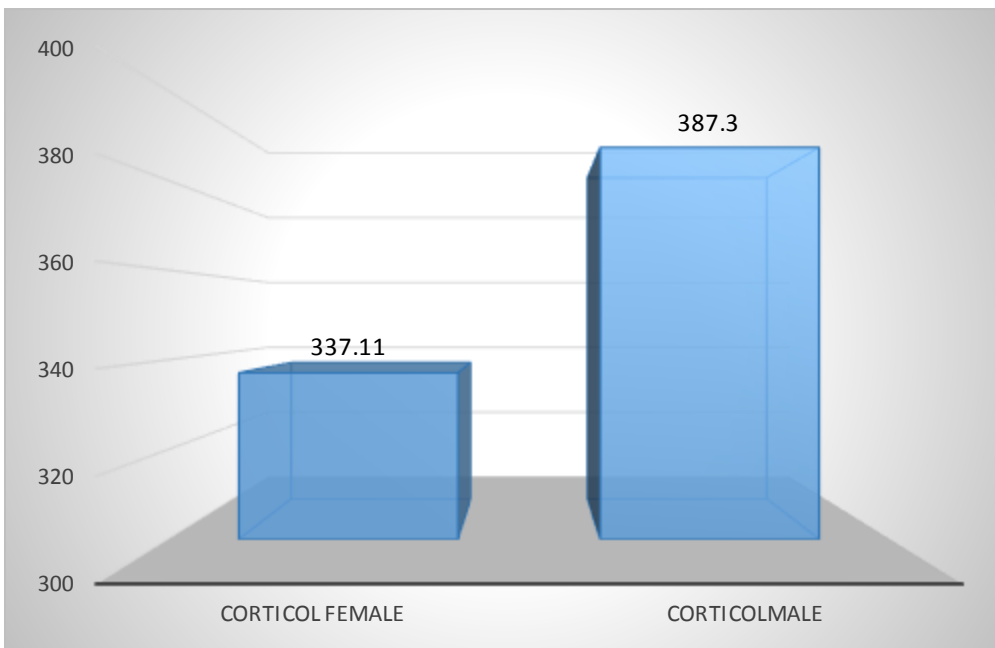

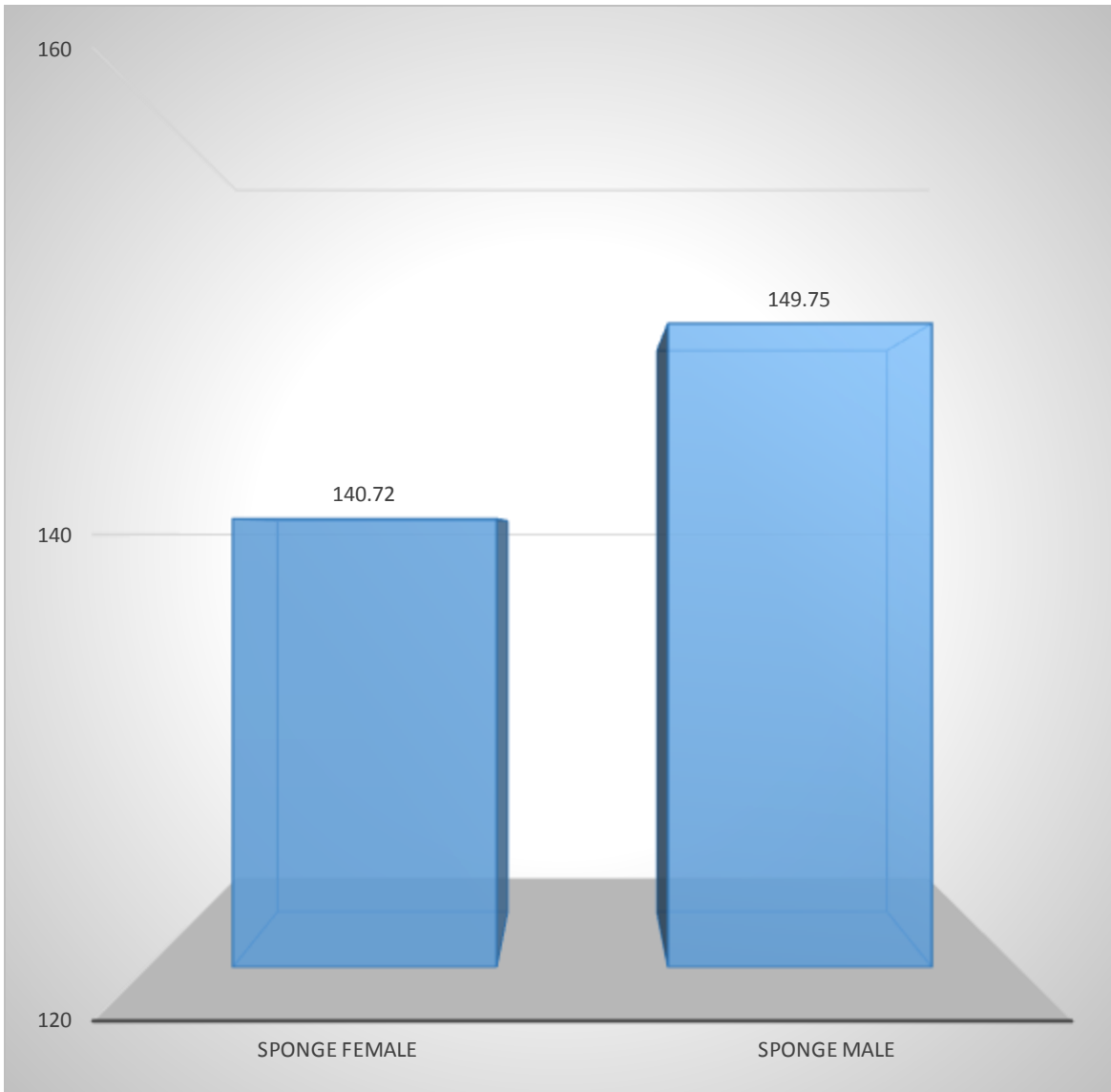**Figure (4.8): shows the average of cortical bone of each sex**

Figure (4.9): shows the average of spongy bone of each sex

Chapter five

5-1 Discussion:

As our hurry life rhythm, there aren't care about the health as general and inconsiderable specially about, bone health till there are urgent problem such as sudden bone trauma which continues occur during a day life that we take care and start to research the main cause of this problem and when return to the origin of this problem it related to body nutrition which effect direct in bone dense positively or negatively and that reflected on body and bone resistance to face the daily problem.

The main important things static on study are mean and SD the first one is known as sum of data that collected divided on number of it, but the second one is measure the variability of spread of data values from the mean .

This study performed in randomly sample in Antalya medical center to attempt to have real reading and reach the number of it till 40 cases 20 from them are male and percentage 50% d 20 sample are female and percentage of them 50% from total sample , with different age variable from (22-95) years old which explained in table (1) and figure (4.5)explains the average of age of each sex on bar chart which appear clearly by high average of male than female.

The table (4.1) shows the mean SD, and variance of age, average of compact & spongy which record 54.19for age, 357.10 for compact and 144.60 for spongy with SD 19.984 for first one,82.940 to compact and 29.995 to spongy and that demonstrated clearly on figure (4.2) , which shows high values of compact rather than spongy.

Table (4.2) explains the mean of compact &spongy related in female cases which record 337.11for cortical and140.72 for spongy bone with SD of 69.513 for cortical bone and 31 .398 for spongy bone.

Table (4.3) explains the mean of compact &spongy related in male cases which record 387.30 for cortical bone and149.5 for spongy bone with SD of 82.996 for cortical bone and 28.578 for spongy bone.

Figure (4.8) and figure (4.9) show the high reading record to male than female in mean of compact bone and spongy bone and that related to effect of sexual hormone of female which start before male hormone due to puberty of female before male.

Figure (4.3) and (4.4) show the relation between age range and average of spongy and compact bone which is weak and opposite propagation and that means as the age increase the dense of the bone will decrease.

Figure (4.5) and figure (4.6) just show the age distribution in male and female and percentages of them.

5-2 Conclusion:

As anyone know there are no time and no certain age to occur the bone problem for this study tray to put the outline plane to circle of bone dense to avoid any risk may be occur in future. This study clear that the bone dense of female decrease than the male and that often related to effect of estrogen hormone on the early life of women due to early maturation when comparing with male, the effect of testosterone hormone appear with increasing age of male at range age (40-60, over 60) on the second appear more clearly but if bone dense decrease on early age that often due to metabolic problem Female at the period of menopause the bone dense decrease The male bone dense average is (387.30 - 149.75) this reading for compact and spongy respectively but female bone dense average is (337.11 - 140.72) this reading for average of compact and spongy respectively, with (+or-) 68.77 for male and for female And as previous study that mention in chapter (2) in (8) study we see the average of male bone dense less than it and that refer to two main reason and there are:

1/ the most male have bad habit smoking and tobacco which effect in bone absorption and that lead to decrease bone dense by related to effect by GIOP-SIOP disease .

2/ bad nutrition habit and never take care about take different type from meal to have balance diet

The relation of average spongy and compact with sex and age range is week and opposite propagation.

The relation between average of compact and spongy bone generally not strong but there are positive propagation and that refer to union body nutrient.

5-3 Recommendations:

- Nutrition of the body must be balance and should contain satisfy amount of calcium, phosphate and vitamin C, D to have healthy bone.

- The bone nutrition started from early age step of life to decrease the future risk and the best when start from uterine life.

- The routine investigations of body must include the bone dense exam ,if not available in far village as CT center at least the investigation of calcium , phosphate as routinely on blood stream.

- Raise the awareness of society to important of bone dense and the danger risk that may be faced on future by simple method on multimedia which can reach to all levels of people.

- Apply this routinely method in all orthopedic departments due to high cost of DEXA and not all people could perform it.

- I encourage my colleagues to continuous study on bone dense due to high benefit and fetal role of it in our life , and the available of DEXA on Sudan as first time open new window of knowledge .

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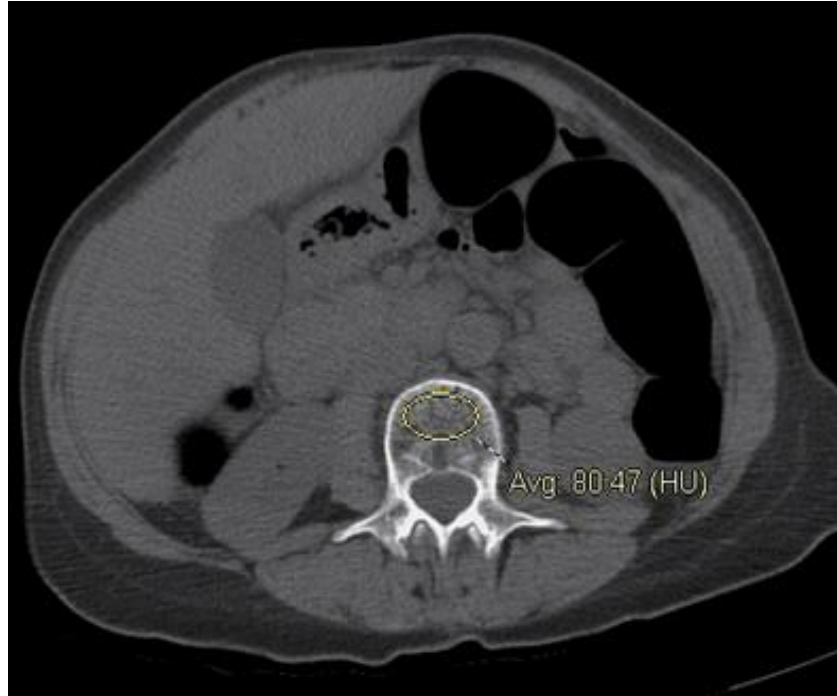
5.5Appendices
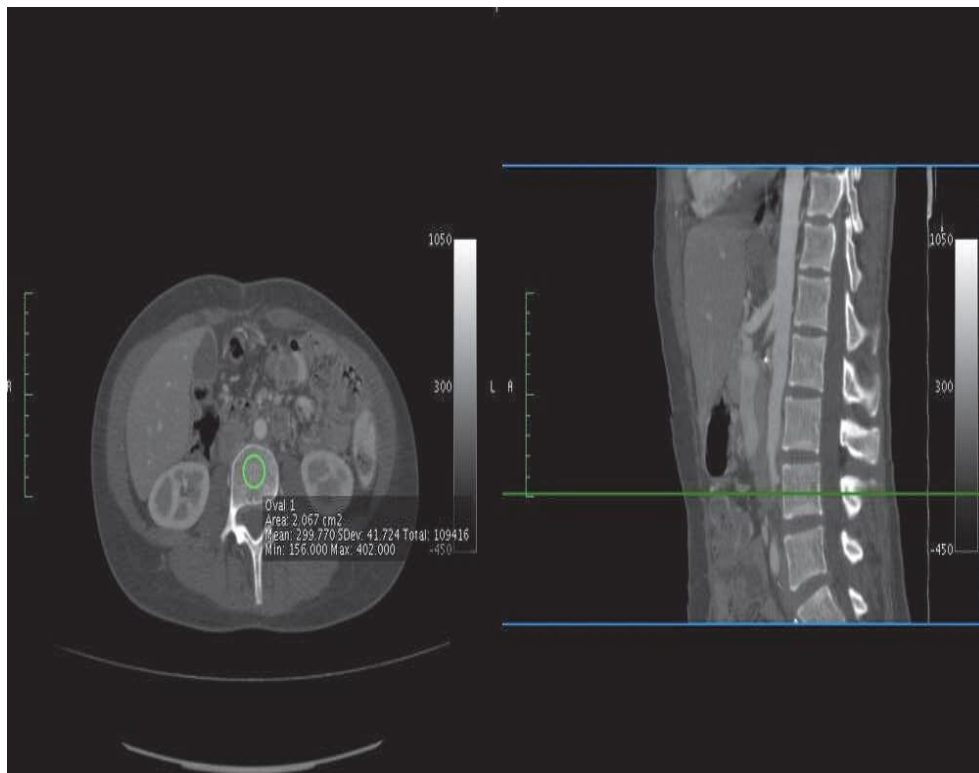

Figure (5.1) show the area of measurement axial

Figure (5.2) show the area of measurement saggital and axial cuts

Table(5.1) Master Data Sheet

no	hospital	Gender		Age	Vertebral readings											
		Male	Female		Cortical bone						Sponge bone					
					1	2	3	4	5	Avr	1	2	3	4	5	Avr