THE SKELETAL SYSTEM: BONE TISSUE

Chapter 6

Anatomy and Physiology Lecture

THE SKELETAL SYSTEM: BONE TISSUE

Bone (Osseous) Tissue forms most of the skeleton:

Skeletal System - the framework of bones and cartilage that protects our organs and allows us to move.

Osteology - is the study of bone structure and treatment of bone disorders.

(Without the skeletal system we would be unable to perform movements such as walking or grasping. The slightest jar to the head or chest could damage the brain or heart. It would even be impossible to chew.)

FUNCTIONS OF THE SKELETAL SYSTEM

1. Support: Provides a framework for the body - supports soft tissues and provides a point of attachment for many muscles.

2. Protection: The brain is protected by the cranial bones; the spinal cord by the vertebrae; the heart and lungs by the rib cage; and internal reproductive organ by the pelvic bones.

3. Movement Facilitation: In conjunction with the muscles.

4. Storage: Store several minerals (e.g. calcium and phosphorus) that can be distributed to other parts of the body upon demand, are stored. Lipids stored in cells of yellow marrow are an important source of chemical energy.

   Yellow Marrow - consists primarily of adipose cells and a few scattered blood cells.

5. Blood Cell Production: Red marrow in certain bones is capable of producing blood cells, a process called Hematopoiesis or

CARTILAGE

Three Types of Cartilage;

1. Hyaline Cartilage
2. Fibrocartilage
3. Elastic Cartilage

Most of the bones in the body develop from Hyaline cartilage.

Specialized Cells of Hyaline Cartilage:

1. **Chondroblasts** – Cells that produce new cartilage matrix.

2. **Chondrocyte** - A Chondrocyte surrounded by matrix.

Perichondrium – Is a double-layered connective tissue sheath covering most cartilage.

Articular Cartilage – Is the cartilage covering the ends of bones where they come together to form joints.

BONE ANATOMY

Bones are classified according to their shape as long, short, flat or irregular.

Long Bones – Are longer than they are wide.

Most of the bones of the upper and lower limbs are long bones.

Short Bones – Are about as broad as they are long.

Are nearly cube-shaped or rounded, mainly of the wrist (carpals) and ankle (tarsals) bones.

Flat Bones – Have a relatively thin, flattened shape and are usually curved.

Bones of the skull, ribs, the breastbone (sternum). Shoulder blade (scapulae).

Structure of a Typical Long Bone

A typical bone consists of the following parts:

1. Diaphysis: The shaft or long, main portion of the bone. Composed mainly of Compact Bone (bone matrix with few small spaces)

2. Epiphyses: The extremities or ends of the bone. Consists of Cancellous or Spongy bones.

3. Epiphyseal plate: Is hyaline cartilage located between the epiphysis and diaphysis . It is where growth in bones occur.

4. Articular Cartilage: a thin layer of hyalin cartilage covering the epiphysis where the bone forms a joint with another bone.

   -Reduces friction and absorbs shock at freely movable joints.

5. Periosteum: A dense, white fibrous covering around the surface of the bone not covered by articular cartilage.

   Consists of two layers:

   a. Fibrous layer - composed of connective tissue containing blood vessels, lymphatic vessels, and nerves that pass into the bone. (outer layer)

   b. Osteogenic Layer - contains elastic fibers, blood vessels,

osteoprogenitor (osteogenic) cells, osteoclasts, and osteoblasts. (inner layer)

*Periosteum is essential for bone growth, repair, and nutrition; and also serves as a point of attachment for ligaments and tendons.

6. Medullary or Marrow Cavity: The space within the diaphysis that contains the fatty yellow marrow in adults.

   Yellow marrow consists primarily of fat cells and a few scattered blood cells.

   *Yellow marrow functions in fat storage (adipose tissue).

7. Endosteum: Is a connective tissue membrane that lines the internal surfaces of all cavities within bone.

   Is a single layer of cells, which includes osteoblasts, osteoclasts and osteochondral progenitor.

*(Note: Bone is not completely solid. In fact, all bone has some spaces between its hard components. The spaces provide channels for blood vessels that supply bone cells with nutrients. The spaces also make bones lighter.)

BONE HISTOLOGY

(Microscopic structure of bone tissue.)

Bone consists of extracellular bone matrix and bone cells.

Bone Matrix:

Mature bone by weight consists of 35% organic and 65% inorganic material.

Organic Material – Consists of Collagen and Proteoglycans

Inorganic Material – Consists of a Calcium Phosphate crystal called Hydroxyapatite.

Bone Cells:

1. **Osteoblasts** - Are associated with bone formation.

Have extensive endoplasmic reticulum and numerous ribosomes.

Ossification or Osteogenesis – Is the formation of bone by osteoblast

2. **Osteocytes** - Are mature bone cells.

Are the principal cells of bone tissue.

Lacunea – Are spaces occupied by the osteocyte cell bodies.

Canaliculi (little canals) – Are spaces occupied by the osteocyte cell processes.

3. **Osteoclasts** - Develop from circulating monocytes (one type of white blood cells).

Are found around the surfaces of bone;

Function in bone resorption (degradation)

Important in the development, growth, maintenance, and repair of bone.

Origin of Bone Cells:

Connective tissue develops embroyologically from mesenchymal cells.

Stem Cells – Have the ability to replicate and give rise to more specialized cell types.

Osteochondrial progenitor cells – Are stem cells that have the ability to become osteoblasts and chondrioblasts.

Note: Osteoblasts are derived from osteochondral progenitor cells, and osteocytes are derived from osteblasts.

Woven and Lamellar Bone

According to the organization of collagen fibers within the bone matrix, bone tissue is classified as (a) Woven bone or (b) Lamellar bone.

(a) **Woven bone** – Collagen fibers are randomly oriented in many direction.

(b) **Lamellar bone** – Is mature bone that is organized into thin sheets or layers called lamellae.

Cancellous and Compact Bone

Bone woven or lamellar are classified according to the amount of bone matrix relative to the amount of space present within the bone.

Cancellous bone has less matrix and more space while Compact bone has more matrix and less space.

Cancellous Bones

Consists of interconnecting rods or plates of bones called trabeculae.

Between the trabeculae are spaces that in life are filled with bone marrow and blood vessels.

Note: Cancellous bone is sometimes called **Spongy Bones** because of its porous appearance.

Compact Bone

Compact bone is denser and has fewer spaces than Cancellous bone.

Perforating (Volkmann's) Canals - through which the blood vessels and nerves from the periosteum penetrate the compact bone.

Central (Haversian) Canals - run longitudinally through the bone.

-Blood vessels and nerves of medullary cavity (marrow cavity), perforating (Volkmann's) canals, and central (Haversian) canals connect each other.

Concentric Lamellae - rings of hard, calcified, intercellular substance.

Lacunae (little lake) - are small spaces forward between the Lamellae.

-Contains Osteocytes.

Osteocytes - are mature osteoblasts that no longer produce new bone tissue and function to support daily cellular activities of bone tissue.

Canaliculi - radiate in all directions from the Lacunae as minute canals.

-Contain slender processes of osteocytes and extracellular fluid.

-Help to form an intricate network throughout the bone.

Circumferential lamellae – Are flat plates that extend around the bone that forms the outer surfaces of compact bones.

Intestitial lamellae – Are remnants of concentric or circumferential lamellae that were partially removed during bone remodeling.

BONE DEVELOPMENT

Ossification or Osteogenesis - is the process by which bone forms in the body.

(The "skeleton" of a human embryo is composed of fibrous membranes and hyaline cartilage.)

(Both are shaped like bone and provide the medium for ossification.)

*Ossification begins around the sixth or seventh week of embryonic life and continues throughout adulthood.

Two Kinds of Bone Formation

1. **Intramembranous Ossification**

Intramembranous Ossification - Is the formation of bone directly on or within the fibrous membranes.

It is the most simpler and direct form of bone formation.

Examples: Skull bones;
The clavicles (collarbones)

(a) **Center of Ossification** -Cluster site of osteoblasts in a fibrous membrane.

(b) **Calcification** - deposition of calcium salts.

© **Trabecula** - when a cluster of osteoblasts is completely surrounded by

the calcified matrix.

2. **Endochondral Ossification**

Endochondral (Intracartilaginous) Ossification is the replacement of cartilage by bone.

-Best observed in a long bone.

Proceeds as follows:

a. Development of the Cartilage Model

-At the site of bone formation (site where bone is going to form),
-Mesenchymal cells crowd together in the shape of the future bone;
-Mesenchymal cells differentiate into chondroblasts which form the hyaline cartilage model
-Perichondrium develops around the cartilage model

b. Growth of the Cartilage Model

Two types of growth are involved here:

(i) **Interstitial growth** - a growth from within, results in an increase in length.

(ii) **Appositional growth** - a growth by which matrix is deposited on its surface (from outside).

c. Development of the Primary Ossification Center

-Near the middle of the model, capillaries of the periosteum grow into the disintegrating calcified cartilage.

(Note: The vessels, Associated osteoblasts, Osteoclasts, Red Marrow cells are known as Peristeal Bud. On growing into the cartilage model, the capillaries produce a Primary ossification center).
Primary Ossification Center – Is a region where bone tissue will

replace most of the cartilage.

d. Development of the Diaphysis and Epiphysis

-Diaphysis (shaft), which was once a solid mass of hyaline cartilage; is replaced by compact bone; the central part of which contains a real marrow-filled medullary cavity.

Secondary Ossification Center develop usually around the time of birth, when blood vessels (epiphyseal arteries) enter the epiphyses.

*Chondroblast - a cartilage forming cell.
*Chondroclast - a cartilage destroying cell.
*Chondrocyte - a mature cartilage cell.

BONE GROWTH

Bones increase in size only by **Appositional Growth**.

Unlike Cartilage, bone cannot grow by **Interstitial Growth**.

Growth of Bone Length

Long bones and bony projections increase in length because of growth at the **Epiphyseal Plate**.

(Note: Growth at the epiphyseal plate involves the formation of new cartilage by interstitial cartilage growth followed by appositional bone growth on the surface of the cartilage).

Four Zones of the Epiphyseal Plate

a. **Zone of Resting Cartilage** is near the epiphysis and consists of small chondrocytes that are scattered irregularly throughout the

intercellular matrix.

-Do not function in bone growth; they anchor the epiphyseal plate to the bone of the epiphysis.

b. **Zone of Proliferating Cartilage** consists of slightly larger chondrocytes arranged like stack of plates or coins.

-Functions to make new chondrocytes by cell division to replace those that die at the diaphyseal surface of the epiphyseal plate.

c. **Zone of Hypertrophic Cartilage or Maturing Cartilage**: consists of even larger chondrocytes that are also arranged in columns, with the more mature cells closer to the diaphysis.

d. **Zone of Calcified Cartilage** is only a few cells thick and consists mostly of dead cells because the intercellular matrix around them has calcified.

Calcified; that is, minerals are deposited within it.

-Nutritive materials required by the cartilage cells can no longer diffuse through the intercellular substance, and this may cause the cartilage cells to die.

Metaphysis is the region between the diaphysis and epiphysis of a bone where the calcified matrix is replaced by bone.

Growth of Articular Cartilage

Epiphyses increase in size because of growth at the articular cartilage.

Growth at the articular cartilage increases the size of bones that do not have an epiphysis, such as short bones.

(Note: When the epiphyses reach their full size, the growth of cartilage and its replacement by bone ceases. The articular cartilage, however, persists throughout life and does not become ossified as does the epiphyseal plate).

Growth of Bone Width

Long bones increase in width (diameter) and other bones increase in size or thickness because of appositional bone growth beneath the periosteum.

Factors Affecting Bone Growth

1. Nutrition:

Vitamin D – Is necessary for the normal absorption of calcium from the intestine

Vitamin C – Is necessary for collagen synthesis by osteoblasts.

2. Hormones:

Growth Hormones – From the anterior pituitary increases general tissue growth, including overall bone growth, by stimulating interstitial cartilage growth and appositional bone growth.

Thyroid Hormones - Is required for normal growth of all tissues, including cartilage; therefore, a decrease in this hormone can result in decreased size of individual.

Sex Hormones – Influences bone growth. Estrogen (a class of female sex hormones) and Testosterone (a male sex hormone) initially stimulate bone growth, which accounts for the burst of growth at the time of puberty, when production of those hormones increases.

Note:

a. The homeostasis of bone growth and development depends on a balance between bone formation and resorption.

b. Normal growth depends on calcium, phosphorus, and vitamins, especially vitamin D, and is controlled by hormones that are responsible for bone mineralization and resorption.

BONE REMODELING

Bone Remodeling – Is the process by which old bones are replaced by new bones.
Osteoclasts remove old bones.

Osteoblasts deposit new bones.

Note: Remodeling is also responsible for the formation of new osteons in compact bone in two ways:

(1) Within already existing osteons, osteoclasts enter a central canal through the blood vessels and begin to remove bone from the center of the osteon, resulting in an enlarged tunnel through the bone.

(2) A few osteoclasts in the perioteum remove bone, resulting in groove formation along the surface of the bone.

BONE REPAIR

As a living thing, bone undergoes repair if damages.

Four Major Steps of Bone Repair:

1. **Hematoma Formation** – Hematoma forms when bones is fractured, the blood vessels in the bone and surrounding periosteum are damaged

2. **Callus Formation** – Callus is a mass of tissue that forms at a fracture site and connects the broken ends of bone.

3. **Callus Ossification** – Like the cartilage models formed during fetal development, the cartilage in the external callus is replaced by woven, cancellous bone through endochondral ossification.

4. **Remodeling of Bone** – Filling the gap between bone fragments with an internal callus of woven bone.

EXERCISE AND THE SKELETAL SYSTEM

a. Bone can alter its strength in response to mechanical stress.

b. Bone that is stressed produces a minute electric current, by way of it mineral salt crystals (Piezoelectric effect), that stimulates osteoblastic activity.

c. Regular exercise can stimulate osteoblasts and inhibit osteoclasts.

AGING AND THE SKELETAL SYSTEM

a. The principal effect of aging is a loss of calcium from bones, which may result in Osteoporosis.

b. Another effect is a decreased production of organic matrix, which makes bones more susceptible to fracture.

DEVELOPMENTAL ANATOMY OF THE SKELETAL SYSTEM

a. Bones form from mesoderm by intramembranous or endochondral ossification.

b. Extremities develop from limb buds, which consists of mesoderm and ectoderm.

Notochord is a flexible rod of tissue that lies in a position where the future vertebral column will develop.

DISORDERS: HOMEOSTATIC IMBALANCES

a. Osteoporosis is a decrease in the amount and strength of bone tissue owing to decrease in hormone output (decreased level of estrogens).

b. Vitamin Deficiencies

(i) Rickets - a deficiency of vitamin D in children.

-Characterized by an inability of the body to transport calcium and phosphorus from the gastrointestinal tract into the blood for utilization by bones.

(ii) Osteomalacia - Deficiency of Vitamin D in adults causes the bones to give up excessive amounts of calcium and phosphorus.

-This is called Demineralization.

c. Paget's Disease is the irregular thickening and softening of bones, related to a greatly accelerated remodeling process.

d. Osteomyelitis is a term for the infectious diseases of bones, marrow, and periosteum.

-It is frequently caused by "staph" bacteria.

e. Fracture (FX) any break in a bone.

Closed reduction - restoration of fracture to normal position by manipulation without surgery.

Open reduction - exposed by surgery before the break is rejoined.

Classification of Bone Fractures – A Clinical Focus

1. Partial (Incomplete) a fracture in which the break across the bone is incomplete.

2. Complete a fracture in which the break across the bone is complete, so that the bone is broken into two or more pieces.

3. Closed (Simple) a fracture in which the bone does not break through the skin.

4. Open (Compound) a fracture in which the broken ends of the bone protrude through the skin.

5. Comminuted a fracture in which the bone is splintered at the site of impact, and smaller fragments of bone are found between the two main fragments.

6. Greenstick a partial fracture in which one side of the bone is broken and the other side bends; occurs only in children.

7. Spiral a fracture in which the bone is usually twisted apart.

8. Transverse a fracture at right angles to the long axis of the bone.

9. Impacted a fracture in which one fragment is firmly driven into the other.

10. Pott's a fracture of the distal end of the fibula with serious injury of the distal tibial articulation.

11. Colle's a fracture of the distal end of the radius in which the distal fragment is displaced posteriorly.

12. Displaced a fracture in which the anatomical alignment of the bone fragments is not preserved.

13. Nondisplaced a fracture in which the anatomical alignment of the bone fragments is preserved.

14. Stress a partial fracture resulting from inability to withstand repeated stress due to a change in training, harder surfaces, longer distances, and greater speed.

    -About 25% of all stress fractures involve the fibula, typically the distal third.

15. Pathologic a fracture due to weakening of a bone caused by disease processes such as neoplasia (cancerous), osteomyelitis, osteoporosis, or osteomalacia.