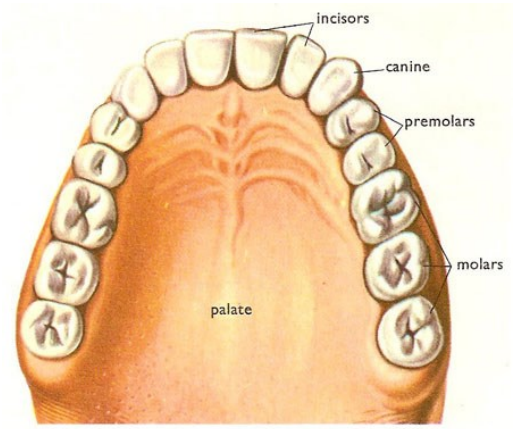
Kerbala University-College of Dentistry
Medical Physics-Lecture (3)

Physic of the skeleton

Function of the bones in the body

1) **Support** الدعم**: -** It's obvious in the leg, muscles are attached to the bone by tendonsالأوتار and ligament . The system of bones plus muscle supports the body.
2) **Locomotion** التحرك**:-**Bone joints permit movement of one bone with respect to another. These hinges المفاصل are very important for walking as well as for many of the other motions of the body.
3) **Protection:-**The skull الجمجمة protects the brain and several of the most important sensory organs (eyes, and ears), ribsالأضلاع protect heart and lungs, spinal column protect spinal cordالحبل الشوكي.
4) **Storage of chemicals:-**Bones acts as a chemical bank for storing elements for future use by the body. For example, a minimum level of calcium is needed in the blood, if the level falls too low, the calcium sensor causes parathyroid gland to release more Parathormone into the blood; this causes the bone to release the needed calcium
5) **Nourishment:-**Teeth are specialized bones that can cut food by incisors القواطع, tear it by canines الأنيابand grind it by molarsالأضراس and thus serve in providing nourishment for the body.



6) **Sound transmission:-** The smallest bones of the body are Ossicles in the middle ear. the ossicles acts as levers ,its provide an impedance matching system for converting sound vibrations in air to sound vibrations in fluids.

What is bone made of ?

By using X-ray, the bones show large percentage of Ca^{+2} in bone (22%). Ca^{+2} has high atomic number (Z=40). So that it absorbs X-ray much better than soft tissue.

Bone consists of two different materials plus water: -

A- Collagen, the major organic fraction, which is about 40% of the weight of the solid bone 60% of its volume.

B-Bone mineral, the so-called "inorganic" component of bone, which is about 60% of the weight of the bone and 40 % of its volume.

Composition of compact bone

H= 3.4%	Mg=0.2%
C=15.5%	P=10.2%
N=4.0%	S=0.3%
O=44.0%	Ca=22.2 %
Miscellaneous = 0.2%	

How strong are your bones?

If we cut the bones apart, we can find it's composed of one or a combination of two quite different types of bones Solid (compact) bone and Spongy (trabecular) bone

Solid or compact bone	*Trabecular bone*
compact	Spongy
found in the central shaft	Found in the ends of the long bones
Stronger	Weaker due to reduced amount of bone in the given volume

Note: Bone tissue is the same in the trabecular and compact bone

Mechanical properties of bone

Mechanical properties of bone are:

1) Density

The density of compact bone is constant through life at about 1.9 g/cm^3 (or 1.9 times as dense as water). In old age the bone become more porous and disappears from the inside or surface. The density of the remaining compact bone is still about 1.9 g/cm^3; it is reduced in strength because it is thinner, not because it is less dense.

2) Length: All materials change in length when placed under tension or compression when a sample of fresh bone is placed in a special instrument for measuring the elongation under tension, as show in figure1, the strain (ΔL /L) increases linearly at first, indicating that it is proportional to the stress (F/A) "Hook's law" . As the force increases the length increases more rapidly ,and the bone breaks at a stress of about 120 N/mm^2 (~17,000 lb/in.^{2}).The ratio of stress to strain in the initial linear portion is young's modulus Y. that is.

$$Y = \frac{LF}{A\Delta L} \qquad\qquad \Delta L = \frac{LF}{AY}$$

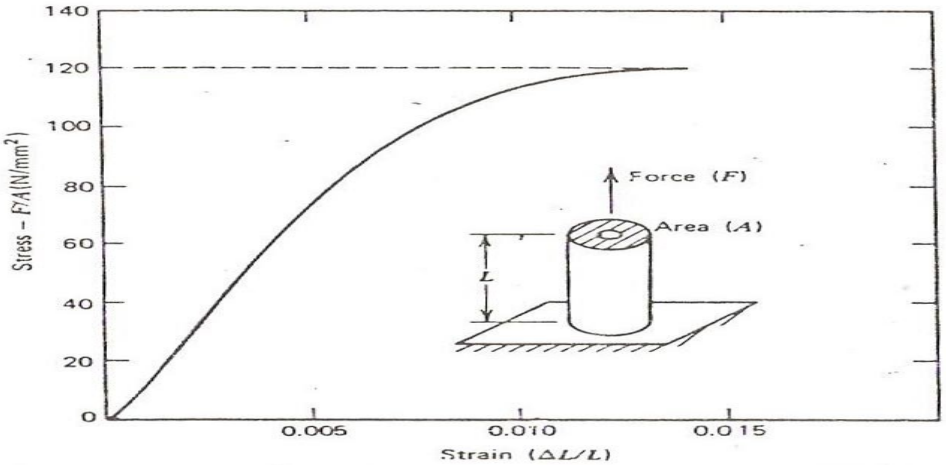


Figure 1: A piece of bone is placed under increasing tension

Example:- Assume a leg has a 1.2 m shaft of bone with an average cross-sectional area of 3 cm^2 (3×10^{-4}m^2) what is the amount of shortening when all of the body weight of 700 N is supported on this leg?

$$\Delta L = \frac{LF}{AY} = (1.2m)\ (7\times10^{2}N)/\ (3\times10^{-4}m^{2})\ (1.8\times10^{10}N/m^{2})$$

$$=1.5\times10^{-4}m = 0.15mm$$

What is the built-in safety factor (عامل الأمان)in the bones that support the body's weight?
Healthy compact bone is able to withstand (يقاوم) a compressive stress of about 170 N/mm^2 before it fractures , the mid shaft of the femur (عظم الفخذ) has a across-sectional area of about 3.3 cm^2(0.5 in^2); it would support a force of about 5.7×10^4 N(12,000 lb,or 6 tons).
The bones are not as strong under tension as they are in compression; a tension stress of about 120 N/mm^2 will cause a bone to break.

Measurements of bone mineral in the body
The strength of bones depends on the mass of bone mineral present. Bone mineral mass decreases slowly 1-2% per year, so physical techniques needed to show changes:
1)X-ray image: - The ideal of using an X-ray image to measure the amount of bone mineral is an old one(figure2).
The major problems of using an ordinary X-ray are:
a. The usual X-ray beam has different energies and the absorption of the X-ray by Ca^{+2} varies rapidly with energy in this range of energies.
b. Large beam contains much scattered radiation when it reaches the film
c. The film is poor detector for making quantitative measurements since it is non linear with respect to both the amount and the energy of X-ray.

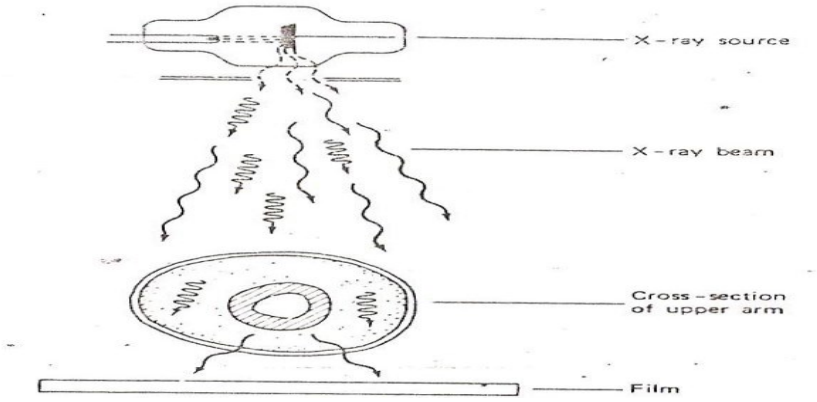


Figure2: conventional X-ray imaging

2) *Photon absorptiometry*

The problems with the X-ray technique were largely eliminated by using photon absorptiometry as shown in figure 3.

The basic components used in photon absorptiometry are:

- Monoenergetic X-ray or gamma rays source.
- A narrow beam to minimize scatter.
- Scintillation detector that detects all photons and permits them to be sorted and counted individually.

To determine of bone mineral mass:
Bone mineral mass (BM gm/cm ^{2}) =K log I_0/I .
Where K is a constant that can be determined experimentally.
I (intensity of X-ray that transmit the bone).
I_o (intensity before the beam enter the bone),

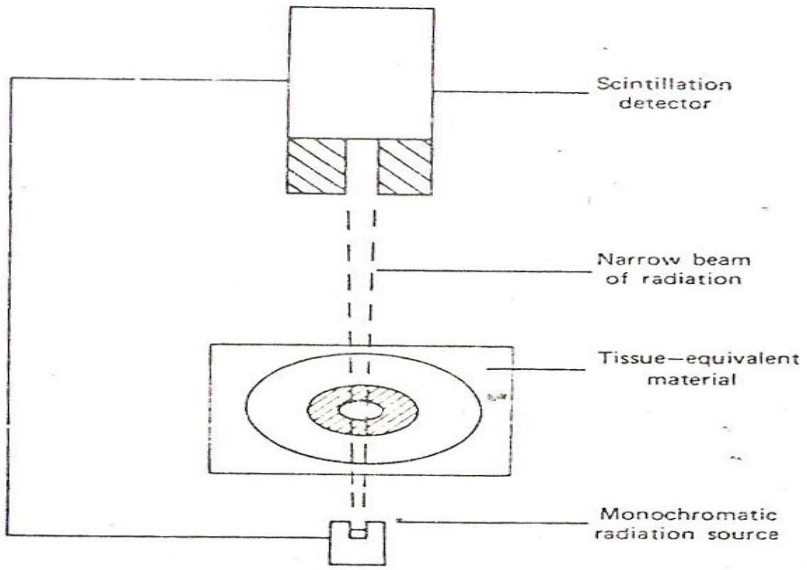


Figure 3: The basic components used in photon absorptiometry

3) ***In vivo activation***: whole body is irradiated with energetic neutrons that convert a small amount of the Ca^{+2} and some other elements into radioactive form that give off energetic gamma rays then detected and counted. This detected to give the amount of Ca^{+2}.
Disadvantages of this technique:

1. Expensive technique.
2. Hazard of large radiation exposure.