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Bone Mineral Density (BMD)

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Introduction

Bone, the main constituent of the skeletal system is a hard tissue that results from the impregnation of a soft organic matrix (35%) (collagen fibers and non-collagenous proteins) by calcium and phosphorous, mainly in form of hydroxyapatite, (Ca10(PO4)6(OH)2), as well as carbonate, citrate, magnesium, fluoride, and strontium (65%) [1]. As calcium deposits, bone serves a critical function acting as reservoir from which the mineral, vital to many physiologic processes, can readily be obtained. Other major functions of the skeletal system are:

I. protection of organs and soft tissues of the three corporal cavities

II. accommodation the delicate assembly of cells that constitute bone marrow

III. as framework for bodily form, and, thanks to the power of muscles, movement and locomotion

The most remarkable characteristic of bone is its ability to perceive changes in mechanical demands bestowed upon its components and realize the required structural transformation to adapt to new conditions. By way of this complex process of modeling and remodeling, bone cannot only grow stronger and harder, but can also modify its form.

What is Bone Mineral Density (BMD)

Mechanical properties of bone are determined by various factors, such as size and shape of individual bone, cortical thickness, porosity and the orientation of collagen fibers, and, to a greater extent, degree of mineralization or bone mineral density (BMD), which is defined as "the mass of inorganic (mineral) matter per unit volume.". BMD must be analyzed in bone's three levels of biological organization: in bone material (BMDmaterial), in a bone's trabecular and cortical tissue compartments (BMDcompartment), and in the entire bone (BMD total) [2].

Why does BMD Change?

In healthy individuals, BMD changes occur under circumstances such as ageing, adaptation, healing Pathologically, BMD can be modified under many different conditions, affecting bone's behavior under physical stress:

a. Disorders in bone mineral homeostasis:

i. Rickets and Osteomalacia, Hyperparathyroidism, Hypogonadism, Hyperthyroidism, Diabetes Mellitus Type I, Cushing Disease.

b. Disorders related to bone remodeling imbalance:

ii. Paget Disease, Disuse Osteoporosis, Osteopetrosis.

c. Disorders related to collagen production:

iii. Osteogenesis Imperfect a, Scurvy, Marfan Syndrome, Ehlers Danlos Syndrome.

d. Certain drugs can affect bone metabolism:

iv. Glucocorticoids, heparin, warfarin, cyclosporine, medroxyprogesterone, cytostatics, thyroide hormone, antiseizure drugs, chemotherapeutic agents, anti-rheumatics (DMARD) and bisphosphonates [3].

How does Bone Modify BMD?

Changes in bone size, shape, micro-architecture and mineral content depend on a complex processes in which cells and signaling mechanisms interact, enabling a coordinated interplay of apposition and resorption of bone tissue. In order to increase bone mass, maintain or change bone shape, especially during growth and development, bone modeling must take place, fundamentally mediated by changes in local tissue strain. On the other hand, bone remodeling refers to the coupled action of osteoblastic and osteoclastic activity at the same location, a mechanism by which bone matrix is replaced and micro-

damage is repaired. Remodeling can be a specifically targeted event (responding to micro-damage and/or consequent cell apoptosis), or of stochastic or random nature, a phenomenon associated with maintenance of calcium homeostasis. Levels of BMD have an inverse dependency relationship with rates of bone remodeling. When high rates of remodeling are observed, BMD is reduced [4].

How is BMD Measured

Different invasive methods for measuring BMD include: Radiogrammetry (RG), Compton scattering technique, Radiographic Photodensiometry (RF), Single energy photon absortiometry (SPA), Dual energy photon absortiometry (DPA), Neutron activation analysis, Quantative computed tomography (QCT), Dual energy X-ray absortiometry (DXA), panoramic X-ray [5].

The physio-pathologic mechanisms of BMD regulation are still essentially unknown. In order to advance in the understanding of these fundamental metabolic processes, ambitious research efforts must be continued. A major limitation in these efforts is the lack of a cost effective, safe method for repetitive intra-subject measurement of BMD, an absolute necessity if pathologic processes and effects of intervention are to be evaluated. For repeated measurement of BMD, current techniques have limited applicability due to noxious effects of ionizing radiation and high cost [6].

An additional limitation encountered with existing technologies is proposed by Rauch et al.:"BMD cannot be determined with currently available noninvasive densitometric techniques, because the spatial resolution does not allow for the determination of the volumes of the marrow (in trabecular bone) orosteonal canals (in cortical bone). However, BMD can be assessed in bone biopsy specimens, for example, by using backscattered electron microscopy"[2].

EMI as an Alternative

An alternative that is being studied and could be considered as safe, low cost effective method for measuring BMD. The main idea is to couple a device to the bone, specifically an electromechanical device with which it will be possible to detect bone variations. To detect those variations a technique applied in structural health monitoring (aerospace, civil and mechanical engineering) can support the idea of detecting changes in stiff biological structures like bone. Different studies have shown a truly opportunity to implement the EMI technique in bone monitoring [7-9]. We see a challenge to achieve that those techniques permit in a short term to monitor BMD frequently the bone without affect the human health.

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