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Improving the New Definition of Fascial System

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Keywords
Fascia · Fascial system · Osteopathy · Manual therapy · Chiropractic

Abstract
Background/Aims: Bone tissue is defined as connective tissue with an embryological derivation that reflects the origin of the fascial system. The surface of the bone tissue makes the bone system the largest organ in the human body, whose most representative cells are the osteocytes. It is essential for the general health of the individual, influencing different organs and systems, through the hormonal paracrine production of the osteocytes. In the modern scientific panorama, bone tissue has been included in the definition of fascial continuum only in one of our articles. The intent of this article is to enrich the motivations that led to the introduction of the bone in the fascia description, illustrating its local and systemic properties. The final theme of the current text will be to give a definition of the fascial system more congruent with modern scientific notions. ***Methods:*** The article collects the embryological and anatomical information on bone and exposes the most recent information in a narrative review. ***Results:*** The results of the literature show that bone is specialized connective tissue. ***Conclusion:*** Bone tissue must be included in the definitions of what is considered fascial tissue, so as to have a better view of the fascial system.

Verbesserte Neudefinition des Fasziensystems

Schlüsselwörter
Faszien · Fasziensystem · Osteopathie · Manuelle Therapie · Chiropraktik

Zusammenfassung
Hintergrund/Ziele: Definitionsgemäß handelt es sich bei Knochengewebe um Bindegewebe embryonaler Abstammung, das den Ursprung des Fasziensystems widerspiegelt. Aufgrund der Oberfläche des Knochengewebes ist das Knochensystem das größte Organ im menschlichen Körper, mit Osteozyten als charakteristischen Zellen. Es ist für die individuelle allgemeine Gesundheit von entscheidender Bedeutung und beeinflusst durch parakrine Hormonproduktion der Osteozyten verschiedene Organe und Systeme. Entsprechend der modernen wissenschaftlichen Sichtweise wurde das Knochengewebe nur in einem unserer Artikel in die Definition des Faszienkontinuums eingeschlossen. Ziel der vorliegenden Arbeit ist es, die Beweggründe, die zur Einbeziehung von Knochen in die Beschreibung der Faszien geführt haben, zu erweitern und seine lokalen und systemischen Eigenschaften darzustellen. Abschließendes Thema des vorliegenden Textes ist eine Definition des Fasziensystems, die sich stärker mit den modernen wissenschaftlichen Vorstellungen deckt. ***Methoden:*** Der Artikel fasst die embryologischen und anatomischen Informationen über Knochen zusammen und stellt die neuesten Erkenntnisse in einer beschreibenden Zusammenfassung dar. ***Ergebnisse:*** Die

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Ergebnisse in der Literatur zeigen, dass es sich bei Knochengewebe um ein spezialisiertes Bindegewebe handelt. ***Schlussfolgerung:*** Knochengewebe muss in die Definition dessen, was als Fasziengewebe gilt, aufgenommen werden, um so zu einer besseren Sichtweise des Faszien-systems zu gelangen.

Introduction

The fascial system has not yet found a shared connotation of its definition that is accepted by all researchers. One of the most used definitions derives from the Fascia Nomenclature Committee (2014), created by the Fascia Research Society, founded in 2007:

> "The fascial system includes adipose tissue, adventitia, neurovascular sheaths, aponeuroses, deep and superficial fasciae, dermis, epineurium, joint capsules, ligaments, membranes, meninges, myofascial expansions, periostea, retinacula, septa, tendons (including endotendon/peritendon/epitendon/paratendon), visceral fasciae, and all the intramuscular and intermuscular connective tissues, including endomysium/perimysium/epimysium" [1].

The fascial system is an anatomical continuum that connects every part of the body. A recent study showed that the thoracolumbar fascia is in contact with the fascia of the abdomen muscles [2]. From a microscopic point of view, we know that there are no layers, because there is an absolute anatomical and functional continuity [3, 4]. Reporting a phrase already published in a previous work, "by studying the connective organization from the skin to the bone, the collagen fibrils form a network in absence of real separate layers, as the same structures are found from the surface to the depth; the so-called layers are distinguishable only for the different fibrillar density" [3].

In a previous article, we tried to give a new definition of the fascial system, considering the tissue from a functional and embryological point of view, including the epidermis and the bone tissue, which had been excluded from the previous classifications:

> "The fascia is any tissue that contains features capable of responding to mechanical stimuli. The fascial continuum is the result of the evolution of the perfect synergy among different tissues, capable of supporting, dividing, penetrating and connecting all the districts of the body, from the epidermis to the bone, involving all the functions and organic structures. The continuum constantly transmits and receives mechanometabolic information that can influence the shape and function of the entire body. These afferent/efferent impulses come from the fascia and the tissues that are not considered as part of the fascia in a biunivocal mode" [5].

The definition poses a new perspective of what fascia is. Let's not talk again of a single tissue or single cell! The concept defining fascia is the ability to adapt to mechanometabolic stimuli.

In addition to the solid state of the fascia, recently, we tried to introduce the concept of a liquid fascia, that is, a specialized connective tissue that is an integral part of the fascial system: blood and lymph. To do this, we have developed a new theoretical model that takes liquids into account in the biotensegretive vision: Rapid Adaptability of Internal Network (RAIN) [6].

Currently, only the periosteum is considered by scholars as an integral part of the fascial system, which is a connective tissue sheath (dense connective tissue) that covers the richly vascularized bone. It is divided into 2 layers; the first outer layer is rich in vascular and nerve vessels, fibroblasts, elastin, and collagen. The first layer determines the mechanical stability of the periosteum [7]. The second deepest layer consists of osteoblasts, smaller fibroblasts, and a homogeneous diameter (isodiametric), with adult mesenchymal skeletal progenitor cells. This last layer becomes fundamental for regenerative processes [7].

The article reviews the bone tissue in its local and systemic functions in order to improve what could be a new definition of fascia, since bone is connective tissue.

Embryological Derivation of Bone Tissue

The bodily fascia derives from the mesoderm, while the fascia that affects the cranial-cervical area derives from the ectoderm [5]. The bone tissue or specialized connective tissue follows the same development process, with a greater admixture between the 2 embryological sheets: the bone tissue comes from the mesoderm and from the ectoderm [5].

The bones of the skull and the first cervical vertebrae originate from the mesoderm and the ectoderm. To give examples of the bones of the skull, the sphenoid bone (the orbitosphenoid and basal-post-sphenoid portion) originates from the cephalic mesoderm and neural crest cells (alisphenoid and basal-pre-sphenoid portion) [8]. The occipital bone is formed from the paraxial mesoderm (basiocciput, jugular tubercles, foramen magnum, anterior tubercle of the clivus, occipital condyles) and from the neural crests of the notochord (the remaining parts of the occipital bone) [9, 10]. The facial bones or splanchnocranium derive mainly from the cells of the ectoderm, except for some parts of the mandible (mesoderm); the bones of the cranial vault originate from both the ectoderm (frontal bone) and the endoderm (parietal bones) [11, 12].

The first vertebra in particular develops from the notochord, while the remaining vertebral column derives from the paraxial mesoderm as well as the ribs and the scapula [10, 13]. The sternal bone derives from the lateral plate of the mesoderm; the cells migrate from a different area of the mesoderm, laterally towards the mediality [14]. The bones which will constitute the limbs derive from the lateral plate of the mesoderm [15].

Bone Tissue Is an Organ

Bone is traditionally regarded as a target for different hormonal substances (vitamin D – 1.25[OH], calcitonin, sex hormones and growth hormones, thyroid hormones), growth factors (transforming growth factor-β [TGF-β], insulin-like growth factor [IGF-1], fibroblast growth factor [FGF], bone morphogenic proteins [BMPs], and platelet-derived growth factor), as well as inflammatory substances (interleukins [IL-1β and IL-6], tumor necrosis factor-α) [16–18].

Bone tissue is the largest organ capable of producing autocrine and paracrine substances, influencing its own metabolism and that of other organs [16]. The osteocyte is the most abundant bone cell capable of secreting sclerostin; the latter influences the bone metabolism (autocrine action) and the systemic metabolism (paracrine action) [16]. A blood increase in sclerostin is found in particular when the bone has a decreased stimulation to the load. While autocrine action stimulates a minor remodeling of the bone (osteoporosis), paracrine action influences the action of insulin [16]. Another molecule produced by osteocytes is a phosphatonin, more precisely, FGF23. The transmembrane receptor of FGF23 (a protein called Klotho) is found on the osteocytes and other tissues, such as the thyroid gland and the kidneys [16]. A lower presence of FGF23 and its Klotho receptor is correlated with premature aging and systemic endothelial dysfunction; the optimal presence of FGF23 positively influences renal function, protecting the kidney from phosphate retention and excessive production of parathormone [16]. An excess of FGF23 is detrimental to the health of the central nervous system. FGF23 is also found in the flow of liquor, and its increase beyond the physiological threshold values causes an alteration of the hippocampal morphology and a cognitive decline [16].

Osteocalcin, a peptidic hormone synthesized by osteoblasts, is essential for optimal adaptation of muscle fibers after exercise, probably due to an increase in insulin sensitivity with myofibers [16]. It is able to stimulate, through a membrane receptor (GPRC6A), the production of insulin from the pancreatic beta cells and influence the lipid metabolism of the liver [16].

Recently, on an animal model, the ability of osteocalcin/GPRC6A to stimulate the synthesis of luteinizing hormone, as well as the production and release of testosterone from Leydig cells, has been demonstrated. The bone is thus another way to control the male hormones, with a path independent of the hypothalamus-pituitary axis [16]. Bone tissue is fundamental for the general health of the individual, influencing different organs and systems, through the production of hormonal paracrine of the cells that make up the bone.

Bone Tissue Cells

Adult bone contains 3 major cell types: the osteocyte, which accounts for about 90–95% of all bone cells; the osteoblast, derived from mesenchymal stem cells; and the osteoclast, derived from hematopoietic progenitor cells [19].

The osteocyte develops from the osteoblast and is found in the bone matrix and on the bone surface. This last cell is considered fundamental to regulate the turnover of bone metabolism through the production of the sclerostin protein and its receptor-activator (NF-kB ligand – RANKL) [19]. The osteocyte controls the activity of osteoblasts (they create and repair bone tissue) and osteoclasts (they disassemble the bone tissue), allowing the bone to adapt, reflecting the mechano-metabolic stimuli that arrive [19].

Osteocytes are the main sensors of the mechanical stimulus. The osteocytes form a network within the entire bone tissue (lacuna-canalicular), so that a stimulus can be transported and felt by the entire bone area; mechanical energy will be converted into electrical energy or a biochemical signal [20]. This transductive mechanism of the osteocyte is favored by the Wingless-related integration site (Wnt) (canonical pathway) biochemical pathway, proteins that help to transport the message inward [21]. The Wnt signaling pathways are transduction pathways that regulate the fate of the cell. They can be divided into 3 distinct groups: canonical Wnt pathway, noncanonical planar cell polarity pathway, noncanonical Wnt/calcium pathway. All Wnt signaling pathways are activated by binding of a Wnt protein ligand to a receptor in the Frizzled family (transmembrane proteins), which sends the biological signal to the Dishevelled (cytoplasmic phosphoprotein) protein inside the cell. The canonical way of Wnt leads to gene transcription [21].

Each osteocyte is aware of what happens to the entire bone, thanks to junction or gap-junction proteins, in particular connexin-43; together they constitute the osteocyte or lacuna-canalicular network [20].

How is the mechanical message with respect to the whole bone managed by the cells? The osteocytes are dispersed in the bone matrix, which consists of type I collagen (and other noncollagenous proteins, such as osteopontin, bone sialoproteins, and proteoglycans), minerals (carbonated apatite crystals), and water [22]. The osteocytes act as mechanical sensor, but water will play a fundamental role in the distribution of the mechanical signal [22].

At the ultrastructural level (nanomillimeters) of the bone, we can recognize collagen fibrils and hydroxyapatite crystals, a bond which will constitute a large part of the matrix; this bond makes it possible to create a pretension situation [22, 23]. When the mechanical message to the bone comes through the osteocyte via Wnt, the bone matrix is deformed, generating electrical charges or movements of water (fluid flow shear stress).

The water moves for the entire bone, deforming the structures to its passage, due to slipping between the collagen fibers and hydroxyapatite crystals (bone elasticity), interacting simultaneously with all osteocytes [22, 23]. Hydration is an important component for the correct survival of bone tissue; the water represents about 15–25% of the total volume of the bone, constituting a variable pressure gradient [24, 25].

Vascular System and Bone Innervation

The whole bone system is richly vascularized from the bone marrow to the periosteum. Inside the matrix in the cortical area (the innermost layer of the bone), there are pores called Haversian canals inside the lacuna-canalicular network (also called active osteonal bone) [26]. In these Haversian canals, surrounded by a thin bony lamella (called a cement line), we find the blood and nerve vessels [25]. Haversian canals have a longitudinal pattern but at an angle of about 15–30° from the median line of the bone [26, 27]. Volkmann canals, positioned transversely, link the Haversian canals, creating a shared blood network [27]. It is the heart and the movements of the muscles that allow the entry and exit of the blood to and from the bones [27]. The presence of the lymphatic system inside the bone is not yet clear; probably, the waste metabolites are transported by the outgoing venous system [27].

The bone is innervated by parasympathetic fibers, which communicate with acetylcholine (ACh) bone receptors, with a bone growth function. Vagal innervation to the bone is stimulated by the production of the central nervous system by interleukin-1; in this modality, the vagus stimulates the apoptosis of the osteoclasts [28]. Precise data on the topographic presence of the vagus on the bone are lacking.

The bone is also affected by the innervation of the sympathetic system, with a penetration of the tissue that is more complex than the parasympathetic system, involving the cortical area and the bone marrow [29]. The sympathetic activation of the bone has the effect of suppressing bone growth, stimulating the activity and production of osteoclasts, from the production of nerve endings of various inflammatory substances (prostaglandins, bradykinins, endothelin, and nerve growth factor) [29].

In the bone and in the periosteum, there are mechanosensitive fibers of the nociceptive type, which respond quickly in the presence of mechanical distortions of the tissue [29]. Bone tissue has a direct relationship with the autonomic and central nervous system.

Bone Marrow

Bone red marrow or myeloid tissue (yellow bone marrow, consisting mainly of adipose tissue that determines its color) is a key component of the lymphoid system, producing the lymphocytes that form part of the body's immune system. Myeloid cells are recruited in the presence of inflammation by the sympathetic nervous system [30].

The leukocytes and neutrophils produced by the bone marrow are released into the systemic circulation starting from the venous sinuses of irregular caliber called sinusoids (or vascular sinuses). Immune cells will be recruited from the inflamed or injured site [31].

The bone marrow participates in the repair and defense of the body system; for bone tissue and for all other organs and tissues.

Improving the New Definition of Fascial System

Bone tissue corresponds perfectly to the definition of fascia [5]. It is able to remodel in the presence of mechanical stimuli; it is in synergy with other structures of the human body, influencing the systemic health of the individual. The osteocyte is in communication with all osteocytes of the bone where it resides. The bone is part of the fascial continuum. We can think of the mechanical stimulus of a voluntary movement, such as walking, where the tension felt by the epidermis of the foot passes through all the tissues to the bone, which participates in the adaptation of the whole body in a biunivocal mode through autocrine and paracrine actions.

Compared to our last definition of fascia, we added the term "feeding," as the arterial blood nourishes the fascia and is an integral part of the fascial continuum. In the concept of nurturing, the action of venous blood and lymph is inherent, the latter being integral parts of the definition of fascia; an adequate metabolic environment is created to best utilize the nutrients that the arteries carry [4, 6]. Moreover, the whole fascial system transmits substances between the different tissues and between the cells to inform what happens from a mechanometabolic point of view and to allow an adequate mechanotransduction process [32, 33]. Getting information is vital to be able to adapt and survive, from the whole tissue to the single cell. We can define this process as an informational "nutrition."

Finally, we added 2 other words to improve the definition of the band: liquids and solids. The fascia inside the human body is present both as a solid structure and as a liquid structure [4, 6].

We reiterate our previous definition of fascia, with some words added (highlighted in italics):

"The fascia is any tissue that contains features capable of responding to mechanical stimuli. The fascial continuum is the result of the evolution of the perfect synergy among different tissues, *liquids and solids*, capable of supporting, dividing, penetrating, *feeding* and connecting all the districts of the body, from the epidermis to the bone, involving all the functions and organic structures. The continuum constantly transmits and receives mechanometabolic information that can influence the shape and function of the entire body. These afferent/efferent impulses come from the fascia and the tissues that are not considered as part of the fascia in a biunivocal mode. In this definition, these tissues are included: epidermis, dermis, fat, blood, lymph, blood and lymphatic vessels, tissue covering the nervous filaments (endoneurium, perineurium, epineurium), voluntary striated muscle fibers and the tissue covering and permeating it (epimysium, perimysium, endomysium), ligaments, tendons, aponeurosis, cartilage, bones, meninges, tongue."

Conclusion

The article reviewed the main functions of bone and the related anatomy, as well as the bone capacity to adapt in the presence of mechanometabolic stimuli. We have emphasized the skeletal relationships with the systemic health of the individual, with biunivocal modalities, inserting the skeletal network into the definition of fascia. We have added the term "feeding" to the description because the liquid band, like the blood and the lymph, has peculiarities that allow the nourishment of the different tissues. The same tissues feed on mechanometabolic informations, which are mutually exchanged with the ultimate aim of adapting and surviving. Other words added to enrich the definition of fascia are "liquids and solids" because the fascial tissue is composed of both solid and liquid material.

We believe that other articles will be needed to complete the definition of the fascia in the light of pressing and constant new scientific information.

Statement of Ethics

The article did not employ humans or animals and did not need the approval of an ethics committee.

Disclosure Statement

The authors report no conflicts of interest in connection with this work.

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