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Alveolar bone in health

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Abstract

Alveolar bone is the component of the maxilla and the mandible that accommodates and supports the alveoli of the teeth. The alveolar bone comprises of two parts-alveolar bone proper which lines the socket of the tooth along with root, cementum and the periodontal ligament (periodontium) constitutes the Attachment apparatus; and the supporting alveolar bone. This attachment apparatus provides support to the tooth in the jaw as well as distributes forces generated by the teeth uniformly to the alveolar bone surrounding it. These functional changes are expressed by the process of 'Bony remodelling' in alveolar process. Therefore, this review provides an understanding of the anatomical aspect of alveolar bone and the molecular events that balance the formation and remodelling of alveolar bone.

Keywords: Alveolar Bone, Attachment Apparatus, Bony Remodelling.

Introduction

Bone is a remarkably dynamic as well as an active tissue, which constantly undergoes renewal in response to physiologic and pathologic stimulations.(1)

The alveolar bone is the component of the maxilla and the mandible that accommodates and supports the alveoli of the teeth. The alveolar process forms with the development and the eruption of teeth, and it gradually decreases in height after the loss of teeth.(2)

The forces transferred to the jaw generally, influence the structure, architecture, size and density of the cancellous bone trabeculae. This bony remodelling creates the coupled balance between the bone resorption by osteoclasts and bone formation by osteoblasts. Under physiologic conditions, these processes are very carefully regulated by systemic hormones and local factors.(3)

Bone resorption is a physiologic process that lies central to the understanding of many key pathologies, with its most common oral manifestation seen as the alveolar bone destruction in periodontitis.(4) The two major categories of periodontal diseases are gingivitis and periodontitis that are distinguished from one another based on the extent of tissue loss that directly supports the teeth.(5)

Thus, re-establishment of the natural architecture of the alveolar process is essential for both functional harmony and esthetic restoration; if missing teeth are to be restored with implant supported prostheses, restoring these dimensions is of crucial importance. Also, many of the factors that affect bony remodelling have gained importance for developing pharmacological and clinical strategies to regulate the rate of bone formation and resorption that will play an important role in maintenance of a healthy periodontium.(6)

This review provides a description of the alveolar bone's anatomical and functional aspects including analysis of its role in periodontal diseases and systemic diseases.

Composition of Alveolar Bone

Alveolar bone is a mineralized connective tissue. Alveolar bone consists of 23% is mineralized tissue (inorganic portion) out of which 37% is the organic matrix which mostly is collagen and 40% is water.(6,7)

Inorganic portion is composed of hydroxyapatite crystals (primarily), calcium, phosphorus, hydroxyl, citrate, carbonate and traces of sodium, magnesium, fluorine.(4)

Organic portion is composed of cells, and matrix which includes collagen type 1 and non-collagenous proteins. Cellular component of alveolar bone consists of mainly three cell types namely osteoblasts, osteocytes, osteoclasts, others like adipocytes, endothelial cells.(8)

Osteoblasts are mononucleated specialized cells that are responsible for bone apposition and are differentiated from pluripotent follicle cells. Osteoblasts are known to regulate osteoclastic function as well as deposition of bone matrix.(9) The osteoblasts have cytoplasm rich in alkaline phosphatase (an organic phosphate-cleaving enzyme) and contains receptors for parathyroid hormone and estrogen.(10)

Osteocytes are star shaped cells that form an extensive interconnecting network in canaliculi and may act as mechano-sensors which guide osteoclasts regarding bone resorption and osteoblasts regarding bone formation.(11,12) Osteocytes are interlinked through gap junctions which are composed primarily of connexin.(13)

Osteoclast is a large multinucleated giant cell which help in ion transport, protein secretory and vesicular

transport of many macrophages on a localized area of bone.[14] Osteoclasts have a foam like appearance and a homogenous cytoplasm which is due to a high concentration of vesicles and vacuoles filled with acid phosphatase.[15] One of the most unique feature of osteoclast is the presence of an action, vinculin and talin-containing clear (sealing) zone. After fulfilling the resorption function, they are likely to be removed by apoptosis.[16]

Matrix component of alveolar bone consist of collagenous proteins and non-collagenous proteins. Collagenous portion comprises the major (80–90%) organic component in mineralized bone tissues. It includes type I collagen (95%) with type V (5%) collagen. Type III and XII are also present. Type I, V and XII are produced by osteoblasts and type III is produced by fibroblasts.[17,18]

Numerous non-collagen proteins, such as osteocalcin, osteonectin, osteopontin, sialoproteins, proteoglycans etc., represent approximately 8% of the organic matrix. Non-collagenous components of alveolar bone have been categorized by Robey et al into Proteoglycans and Glycoproteins.

Proteoglycans have a core protein to which one or more hetero-polysaccharides called glycosaminoglycans are covalently linked. Examples of proteoglycans include versican, decorin, biglycan, fibromodulin, osteoglycin and osteoadherin.[19]

Versican is a chondroitin sulfate proteoglycan that takes a large solvent space in the interstitial spaces of the connective tissue matrix. This molecule has been thought to be secreted by fibroblasts.[20]

Decorin and biglycan are the two important proteins found in alveolar bone. They bind to TGF- β and collagen in order to regulate fibrillogenesis. Decorin and biglycan are also associated with the collagen matrix of bone.[21]

Osteocalcin is a 5.8 KD a acidic protein that is altered by vitamin k-dependent carboxylating enzymes that convert two to three glutamic acids into γ-carboxyglutamic acids (gla groups).[22,23]

Bone morphogenic proteins are low molecular weight proteins and are a component of transforming growth factor- (TGF-β) superfamily genes.[24] The pre-osteoblasts synthesize a cementing substance over which new tissue was laid down and further expresses bone morphogenic proteins (BMP) responsible for their differentiation.[25]

Phosphoproteins are proteins with single phosphate group and may bind calcium, thereby acting as mineral nucleators. They include bone sialoprotein and proteoglycans as minor constituents of the bone matrix.[26]

Osteopontin is synthesized by osteoblasts and also plays a role in osteoclast attachment and resorption.[27]

Fibronectin is a cell attachment protein made locally by bone cells, transported by the vasculature.[28] It role is uncertain in bone.[29]

Bone sialoprotein (BSP) like osteopontin, is a significant part of the extracellular matrix of bone and has been suggested to constitute approximately 8% of all non-collagenous proteins found in bone and cementum.[30]

The glycosaminoglycans consist of repeating carbohydrate units that are sulfated such as chondroitin sulfate, dermatan sulflate, keratan sulfate and heparin sulfate.[31]

Chondroitin sulfate has a protein core of 35 kDa and has been identified as the predominant glycosaminoglycan component in various extracts from cortical bone.[32]

Dermatan sulflate is also widely distributed throughout mammalian tissues, but occurs predominately in fibrous connective tissues such as skin and tendon.[33]

Keratan sulfate is distinct from other glycosaminoglycans, in that it does not contain any uronic acid and displays both mineral and cell-binding properties.[34]

Heparin sulfate consists of alternating uronic acid and d-glucosamine residues and regulates a wide variety of biological activities.[35]

Structure of the alveolar bone

In the anterior part of the maxilla, alveolar process fuses with their respective palatine process. Where as in the posterior part of the mandible, the oblique line laterally is fused to the bone of the alveolar process.[36]

On the basis of function alveolar bone is categorized into alveolar bone proper and supporting alveolar bone.[4,37] The alveolar bone proper comprises of compact bone which is seen clinically as cribriform plate because it contains numerous holes through which volkmann canals provide passage from the alveolar bone into the periodontal ligament. It also encircles the roots of the tooth and provide attachment to the principal fibers of the periodontal ligament.[7,38] The lamellar bone is composed of osteons each of which contains a blood vessel in a haversian canal. Blood vessel is surrounded by concentric lamellae together they form osteon. Few lamellae in the lamellated bone are aligned parallel to the surface of the adjacent marrow spaces, whereas other lamellae constitute haversian systems. Histologically

Lamellar bone comprises of Osteon, Haversian system, Lamellae, Bone marrow.

Osteon is the structural and functional component of the lamellar bone. Osteon comprises of haversian canal in the center in which blood vessel is present. Every osteon is encircled by the concentric, mineralized lamellae known as concentric lamellae. Void between the different osteons is occupied by interstitial lamellae.[4]

The *Haversian canal* in the center of the osteon has a diameter ranging between 50 to 90 µm. Within the haversian canal is a blood vessel typically 15 µm in diameter. Since nutritional supply to cells and tissues can diffuse a limited distance through mineralized tissue, these blood vessels are necessary for bringing nutrients within a reasonable distance (about 150 µm) of osteocytes or bone cells which exist interior to the bone tissue. In addition to blood vessels, haversian canals contain nerve fibers and other bone cells called bone lining cells.[39]

Lamellae contains osteocytes which form the empty spaces called lacunae. They are mainly of three types:
Circumferential Lamellae: are bony lamellae that encircles the entire bone.
Concentric Lamellae: constitutes the body of the bone and osteon.
Interstitial lamellae: are lamellae that are present between two concentric lamellae.[40]

The *Supporting alveolar bone* can be divided into cortical plates and spongy bone. Supporting alveolar bone surrounds the alveolar bone proper and provides support to the alveoli of the tooth. The cortical bone is made up of plates of compact bone present on the facial and lingual surfaces of the alveolar bone. Histologically these cortical plates are formed by longitudinal lamellae and haversian system. On the other hand, compact bone is dense and fuses with compact bone of the body of maxilla and mandible.[7,9] These cortical plates vary in thickness considerably in anterior teeth but they are about 1.5 to 3 mm thick in posterior teeth. The second part of supporting alveolar bone i.e. spongy bone is composed of cancellous bone which is located in between the alveolar bone proper and the cortical plates. Spongy bone can be seen in radiographs as two types:

Type 1- In this spongy bone contains interdental and inter-radicular trabeculae which are arranged in a continuous and horizontal fashion giving a ladder like arrangement. Most commonly observed in mandible.

Type 2- In this spongy bone shows irregularly arranged interdental and inter-radicular trabeculae. Most commonly observed in maxilla.[41]

Interdental Septum comprises of cancellous bone which surrounds the tooth sockets and adjacent cortical plates. If interdental septum is narrow then only cribriform plate is present. If roots are too close together, an irregular gap can be seen in the bone.[7]

Red bone marrow is responsible for the formation red blood cells and white blood cells. In maxilla it is found in maxillary tuberocity and maxillary molars whereas in mandible it is present in mandibular molars, mandibular premolar areas, mandibular symphysis and angle of ramus.[4]

Yellow bone marrow is seen as a zone of radiolucency. However, the yellow marrow can convert to red if there is an increased demand for red blood cells, such as in blood loss.[4]

Periosteum is thin connective tissue membrane that forms outer covering of compact bone. Its outer layer is composed of blood vessels, nerve fibers, collagen fibers and fibroblasts whereas its inner layer comprises of osteoblasts which are surrounded by the progenitor bone cells.[4]

Endosteum outlines the internal surface of basal bone. Its outer layer is fibrous in nature whereas inner layer is composed of osteoblast and osteoprogenitor cells.[3,7]

Nerve supply in the buccal and labial area of maxillary teeth is through the posterior superior alveolar nerve, middle superior alveolar nerve, anterior superior alveolar nerve. In palatal aspect blood supply is via greater palatine nerve and nasopalatine nerve. Whereas the nerve supply of the buccal, labial and lingual area of mandibular teeth is through the inferior alveolar nerve, lingual nerve, and long buccal nerve.

Blood supply of the maxilla and mandible is through the branches of the inferior and superior alveolar arteries.

Lymphatic drainage lies just beneath the junctional epithelium and pass into periodontal ligament parallel to the blood vessels into periapical region.[42]

Bone remodelling begins with quiescent phase in which the flat cells lining the bone are seen in the endosteal membrane and are responsible for initiation of activation phase characterized by cell retraction with resorption of membrane by activated osteoclast cells. These osteoclast cells create a scaffold for the resorption of bone and creates howship's lacunae. Then there is the formation phase where the osteoclasts are replaced by osteoblasts. These osteoblast cells lay down the osteoid matrix which becomes mineralized later.[43,44]

Conclusion

"Alveolar bone forms an architectural base for the healthy periodontium."

Alveolar bone, which has an interdependence with the dentition, has a specialized function in the support of teeth.

While there are certain structural specifications of alveolar bone that relate to its functional role, the basic cellular and matrix components are still consistent with other bone tissues. Similarly, the cellular activities involved in the formation or remodelling of the alveolar bone and the factors that influence these cellular processes are common to bone tissues generally. However, specific features, such as the rate of bone remodelling, may be unique to alveolar bone and may be important for its adaptability.

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