Oral histology
Second stage
Lec. Noor Natik

Dentin Formation (Dentinogenesis)

Dentinogenesis starts at the late bell stage, and occurs in the crown as well as root regions. Differentiated odontoblasts are secretory cells with characteristic apical cytoplasmic called Tomes fibers (odontoblastic process) which connect the cells with the surface of dentin. Tomes fibers elongate as dentin matrix formation (predentin) continues. Dentinogenesis occurs prenatally as well as postnatally, and can be seen during the whole life when secondary and tertiary dentin is formed. Dentin formation continues throughout the life of the tooth, and its formation results in a gradual but progressive reduction in the size of the pulp cavity.

Odontoblasts

Odontoblasts differentiate from the peripheral cells of the dental papilla by signaling molecules and growth factors of the inner enamel epithelium (IEE) . Odontoblasts first appear at sites of tooth development at 17–18 weeks in utero and remain present until death unless killed by bacterial or chemical attack, or indirectly through heat or trauma (e.g. during dental procedures).

Histologically

odontoblasts are large columnar cells in the crown to flatter cells near the apex of root, whose cell bodies are arranged along the interface between dentin and pulp. The cell is rich in endoplasmic reticulum and Golgi complex, especially during primary dentin formation, which allows it to have a high secretory capacity. As more dentine matrix is deposited, the odontoblast cells retreat in the direction of the pulp leaving an elongated process known as the odontoblastic process or Tomes fibers. During secretion , its nucleus is aligned away from the newly formed dentin (toward the pulp side), with its Golgi complex and endoplasmic reticulum towards the dentin. Shape of the odontoblasts also reflect the functional activity of the cell. During active phase or secretory phase, cells show increase in length about 40µm and 7µm in width with increase endoplasmic reticulum, Golgi apparatus and secretory vesicles. While

during resting phase cells or Quiescent phase are flattened with little cytoplasm condensed chromatin and decrease number of endoplasmic reticulum. Numerous junctions such as gap junctions, tight junction and desmosomes are found between odontoblasts indicating exchange of ions and small molecules and also promote cell to cell adhesion

Dentinogenesis occur in two stages:

1-Secretion of dentin matrix (predentin):

The first unmineralized organic matrix secreted by odontoblasts. A narrow layer of predentin is always present on the surface of the pulp adjacent to odontoblasts. Odontoblasts form approximately 4 μm of predentin daily during tooth development. The odontoblasts form the main components of the dentin matrix, the collagen fibers and non-collagenous protein which forms the ground substance. The main non-collagenous proteins in the predentin are: 1. Bone morphogenic proteis (BMP 2,4 ,7) 2. Dentin phosphoprotein /phosphoryn (DPP) 3. Osteocalcin, Osteonectin and Osteopontin 4. Dentin sialoproteins (DSP) The first indication of forming predentin is the development of the vonKorff's fibers which are bundles of type III collagen fibers secreted by odontoblasts and they are perpendicular to the basement membrane. This fibers is is present in Mantle dentin(first type mineralized primary dentin).Then smaller collagen fibril (type I) form a network in the dentin adjacent to the mantle dentin, which is called Circumpulpal dentin(second type mineralized primary dentin).

2-Mineralization of dentin:

It occurs parallel to predentin formation and it begins at the tip of the crown and it proceeds in a rhythmic pattern to gradually complete cervically. The first layer of predentin begins its mineralization in a globular pattern, where small centers of calcification(crystals) which come from matrix vesicle(electrone microscopic vesicle attached to cell membrane of odontoblast which contain first Hydroxyapatite crystals and alkaline phosphatase enzyme). When the crystals grow the matrix vesicles rupture and their content spread in predentin until they fuse together and form globules. Mineralization of predentin or maturation of dentin takes place in two phases: primary and secondary. Initially, the

calcium hydroxyapatite crystals form as globules, or calcospherules, in the collagen fibers of the predentin, which allows for both the expansion and fusion during the primary mineralization phase. Later, new areas of mineralization occur as globules form in the partially mineralized predentin during the secondary mineralization phase. These new areas of crystal formation are more or less regularly layered on the initial crystals, allowing them to expand. In areas where both primary and secondary mineralization have occurred with complete crystalline fusion, these appear as lighter rounded areas on a stained section of dentin and are considered globular dentin. In contrast, the darker arclike areas in a stained section of dentin are considered interglobular dentin. In interglobular area, only primary mineralization has occurred within the predentin, and the globules of dentin do not fuse completely. Thus, interglobular dentin is slightly less mineralized than globular dentin. Interglobular dentin is especially evident in coronal dentin, near the DEJ.

Pattern of mineralization in dentin:

Histologically, two patterns of dentin mineralization can be observed during dentinogenesis globular and linear mineralization that seem to depend on the rate of dentin formation. Globular (or calcospheric) calcification involves the deposition of crystals in several discrete areas of predentin. Mantle dentin mineralization occur in a globular pattern (matrix vesicles) The mineralization goes then in linear or occasionally globular pattern in the remnant or bulk thickness of dentin which is called circumpulpal dentin. The mineralization begins by crystal deposition in form of fine plates of hydroxyapatite crystals on the surface of the collagen fibrils. The long axes of the crystals are paralleling to the collagen fibrils.

Pattern of Dentin formation

Dentin of the crown(coronal dentin) formation begins at the bell stage of tooth development in the papillary tissue adjacent to the inner enamel epithelium, the site where cuspal development begins. From that point, dentin formation spreads down the cusp slope as far as the cervical loop of the enamel organ, and the dentin thickens until all the coronal dentin is

formed. In multicusped teeth, dentin formation begins independently at the sites of each future cusp tip and again spreads down the flanks of the cusp slopes.

Root dentin(Radicular dentin)

forms at a slightly later stage of development and requires the proliferation of epithelial cells (Hertwig's epithelial root sheath) from the cervical loop of the enamel organ around the growing pulp to initiate the differentiation of root odontoblasts. Root dentin is considered different from dentin of the crown because of the different orientation of collagen fibers, as well as less mineralization. The onset of root formation precedes the onset of tooth eruption, and by the time the tooth reaches its functional position, about two thirds of the root dentin will have been formed. Completion of root dentin formation does not occur in the deciduous tooth until about 18 months after it erupts and in the permanent tooth until 2 to 3 years after it erupts. During this period the tooth is said to have an open apex.

Dentinogenesis imperfecta(DGI)

: Hereditary condition associated with abnormal dentin mineralization and varying degrees of changes in tooth morphology. DGI type I is associated with osteogenesis imperfecta(brittle bone disease), whereas the clinically similar DGI type II is not associated with a syndrome and is caused by mutations in the gene encoding dentin sialophosphoprotein (DSPP). The DGI tooth phenotype is highly variable and is characterized by blue-gray to yellow-brown coloration.

Dentin Structures Dentin is a calcified tissue of the body, and along with enamel, cementum, and pulp is one of the four major components of teeth. It is usually covered by enamel on the crown and cementum on the root and surrounds the entire pulp. By weight, 70% of dentin consists of the mineral hydroxylapatite, 20% is organic material, and 10% is water. Yellow in appearance, it greatly affects the color of a tooth due

to the translucency of enamel. Dentin, which is less mineralized and less brittle than enamel, is necessary for the support of enamel. Unlike enamel, dentin continues to form throughout life and can be initiated in response to stimuli, such as tooth decay or attrition.

Dentin structural units

1- Dentinal tubules(D.T.) and its odontoblastic process: Dentin consists of microscopic channels, called dentinal tubules, which radiate outward through the dentin from the pulp to the exterior cementum or enamel border. The dentinal tubules extend from the dentinoenamel junction (DEJ) in the crown area, or dentinocemental junction (DCJ) in the root area, to the outer wall of the pulp. These tubules contain fluid and cellular structures(Tomes fiber). As a result, dentin has a degree of permeability, which can increase the sensation of pain and the rate of tooth decay. The strongest held theory of dentinal hypersensitivity suggests that it is due to changes in the dentinal fluid associated with the processes, a type of hydrodynamic mechanism or theory. The course of D.T. is somewhat curved, resembling an S shape known as primary curvature. Starting at right angles from pulpal surface, the first convexity of this doubly curved course directed toward the apex of the root ending perpendicular to D.E.J, this configuration indicate the course taken by odontoblasts during dentinogenesis. Secondary curvature also can be distinguished over the entire length of D.T., they may reflect the minor changes in the direction of movement of odontoblasts. In the root and in the area of incisal edge or cusps, the dentinal tubules are almost straight. The ratio between surface areas at the outside and inside of the D. is about 5:1, so the tubules are farther apart in the peripheral layers and are more closely packed near the pulp. In addition D.T. are larger in diameter near the pulpal cavity (3- 4µm) and smaller at their outer ends(1µm). The terminal part of D.T. branched into2-3 branches near D.E.J resulting in the increase number of D.T. in this area. Also there are lateral branches of D.T. which called canaliculi .

2-Peritubular D.: It's the D. that surrounds the D.T. and form 1µm thick sheath around each tubule(about 0.75 µm near DEJ and 0.4 µm

near the pulp). Peritubular D. is missing in D.T. in interglobular D. indicating that this is a defect of mineralization in this area. Peritubular D. is highly calcified and its about 40% more calcified than adjacent intertubular D.

3-Intertubular D.: It's the D. located between the D.T., and its formed the most of the body of D. Its less mineralized than the peritubular D., and it consist of network course of collagen fibers in which apatite crystals deposited on it.

Types of dentin: There are three types of dentin, primary, secondary and tertiary. Primary dentin is the outermost layer of dentin and borders the enamel. Secondary dentin is a layer of dentin produced after the root of the tooth is completely formed. Tertiary dentin is created in response to a stimulus, such as a carious attack.

Primary dentin

Primary dentin, the most prominent dentin in the tooth, lies between the enamel and the pulp chamber. The outer layer closest to enamel is known as mantle dentin. This layer is unique to the rest of primary dentin. Mantle dentin is formed by newly differentiated odontoblasts and forms a layer approximately 150 micrometers wide. Unlike primary dentin, mantle dentin lacks phosphorylation, has loosely packed collagen fibrils and is less mineralized. Below it lies the circumpulpal dentin, a more mineralized dentin which makes up most of the dentin layer and is secreted after the mantle dentin by the odontoblasts. Circumpulpal dentin is formed before the root formation is completed. Newly secreted dentin is unmineralised and is called predentin. It is easily identified in haematoxylin and eosin stained sections since it stains less intensely than dentin. It is usually 10-47 micrometer and lines the innermost region of the dentin. It is unmineralized and consists of collagen, glycoproteins and proteoglycans. It is similar to osteoid in bone and is thickest when dentinogenesis is occurring.

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Secondary dentin

Secondary dentin is formed after root formation is complete, normally after the tooth has erupted and is functional. It grows much more slowly than primary dentin, but maintains its incremental aspect of growth. It has a similar structure to primary dentin, although its deposition is not always even around the pulp chamber. It is the growth of this dentin that causes the decrease in the size of the pulp chamber with age. This is clinically known as pulp recession; cavity preparation in young patients therefore carries a greater risk of exposing the pulp. If this occurs, the pulp can be treated by different therapies such as direct pulp capping. Tertiary dentin Tertiary dentin is deposited by odontoblasts or replacement odontoblasts from the pulp(undifferentiated mesenchymal cells) at specific sites in response to injury.

Tertiary dentin can be divided into reactionary or reparative dentin. Tertiary dentin secreted by odontoblasts is often due to chemical attack, or by diffusion of toxic bacterial metabolites down the dentinal tubules in the instance of a carious attack with dental decay. This tertiary dentin is called reactionary dentin. This is an attempt to slow down the progress of the caries so that it does not reach the pulp. In the case of an infection breaching the dentin to or very near the pulp, or in the instance of odontoblast death, undifferentiated mesenchymal cells can differentiate into odontoblast-like cells which then secrete another type, reparative dentin, underneath the site of attack. This is not only to slow the progress of the attack, but also prevents the diffusion of bacteria and their metabolites into the pulp, reducing the probability of partial pulp necrosis. The distinction of the two kinds of tertiary dentin is important, because they are secreted by different cells for different reasons. Reactionary dentin is secreted at varying speeds, dependent on the speed of progression of caries in the outer dentin surface. Histologically, it is easily distinguishable by its disordered tube structure, its the location of the secretion (its protrudes into the pulpal cavity) and its slightly lower degree of mineralization than normal. The tooth is often able to be saved by a simple restoration. In contrast, reparative

dentin is secreted when the tooth has a poor prognosis. Tertiary dentin is deposited rapidly, with a sparse and irregular tubular pattern and some cellular inclusions; in this case it is referred to as "osteodentin". However, if the stimulus is less active, it is laid down less rapidly with a more regular tubular pattern and without cellular inclusions. Stimuli of different nature not only induce additional formation of reparative D. but also lead to changes in the D. itself, calcium salts may be deposited in or around degenerated odontoblastic processes and may obliterate the tubules. This type of D. called transparent or sclerotic D., and can be demonstrated only in ground sections. It appear light in transmitted light and dark in reflected light, because the light passes through the transparent D. but reflected from the normal D. In ground section of D., the odontoblastic process disintegrated as a result of sever stimuli to the pulp like caries, attrition or abrasion, and the empty tubules are filled with air. They appear dark in transmitted light and white in reflected light, this type of D. called dead tracts and its area of decreased sensitivity. Reparative D. seals these dead tracts at their pulpal end.

Incremental lines in D.

1- Imbrication or von Ebner lines: It appear as fine lines, which in cross section run at right angles to the D.T. The course of the lines indicates the growth pattern of the D. The distance between the lines corresponds to the daily rate of opposition, which in crown varies from 4- 8µm and becomes decreasingly less as root formation progress.

2- Counter lines of Owens: Its hypocalcified line, it distinguish in longitudinal ground section as accentuated few lines. These lines arises due to disturbances in D. matrix and mineralizing process.

3- Neonatal lines: This line separating between prenatal and postnatal D., and mostly found in deciduous and first permanent molar. This line is the result of incomplete calcification, due to metabolic disturbances at the time of birth to the abrupt changes in environment and nutrition.

Interglobular D.: Mineralization of the D. sometimes beings in small globular areas that normally fused to form a uniformly calcified D. layer. If fusion does not take place, hypomineralized regions (only primary mineralization phase occur) remain between the globules, which termed interglobular D. This type of D.is found in the crown in both sections (decalcified and ground sections) near the D.E.J. and in the root near C.D.J. In ground sections is sometimes lost and replaced by air ,so it appear black.

Tomes' granular layer: In the ground sections a thin layer of D. adjacent to the cementum almost appears granular and only found in the root, this is known as Tomes' granular layer. Its thought to represent an interference with mineralization of the entire surface layer of the root D. prior to the beginning of cementum formation. Dentinoenamel junction: The junction between enamel & dentin termed dentinoenamel junction. Is scalloped which assures the firm hold of the enamel cap on the dentin. The convexities of the scallops are directed toward the dentin. In addition to scalloping DEJ, other features like enamel spindles & fine branching of the terminal tubules are found within the junction.

Clinical consideration: 1-Odontoblasts should not be exposed to bacterial toxins, strong drugs, operative trauma, unnecessary thermal changes, or irritating restorative materials, because 1mm2 of dentin when exposed about 30000 living cells are damaged. 2-The rapid penetration & spread of caries in the dentin is the result of the tubules provide a passage for invading bacteria & their products 3-dentin sensitivity of pain, unfortunately, may not be a symptom of caries until the pulp is infected & responds by the process of inflammation, leading to toothache.