

Oral Histology

Lec. 4

Dr. Nada AL-Ghaban

Dentinogenesis

Dentinogenesis is the formation of dentin by odontoblasts of mesenchymal origin located at the periphery of the dental pulp. It is initiated by the inductive influence of the inner enamel epithelial cells of enamel organ involving molecular signaling pathways.

Dentinogenesis starts at the late bell stage, and occurs in the crown as well as root regions. Differentiated odontoblasts polarized secretory cells with characteristic apical cytoplasmic Tomes fibers (odontoblastic process) which connect the cells with the surface of dentin. Tomes fibers elongate as matrix formation (predentin) continues.

Rates of dentin deposition vary not only within a single tooth but also among different teeth. 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.

Dentinogenesis occurs prenatally as well as postnatally, and to a lesser extent can be seen during the whole life when secondary and tertiary dentin is formed.

Dentinogenesis occur in two stages:

1-Secretion of dentin matrix (predentin):

The first unmineralized organic matrix secreted by odontoblasts. A narrow layer of predentine is always present on the surface of the pulp adjacent to odontoblasts. Odontoblasts form approximately $4 \mu\text{m}$ of predentin daily during tooth developme

The odontoblasts form the main components of the dentin matrix, the collagen fibers and the mucopolysaccharides(non-collagenous protein which forms the ground substance). The main non-collagenous proteins in the predentin are:

1. Bone morphogenic proteins (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 and attached to it. This fibers is main part of the *Mantle dentin*(first type mineralized primary dentin). Then korffs fibers fade gradually and smaller fibrils(type I) form a network in the dentin subsequent 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 maturation in a globular pattern, where small centers of calcification(crystals) which come from *matrix vesicle*(electrone microscopic bud from 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 concentrically until they fuse together and form globules.

Maturation of dentin or mineralization of predentin 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 these areas, 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, and in certain dental anomalies, such as in *dentin dysplasia*.

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.

Odontoblast

Odontoblasts differentiate from cells of the dental papilla by an expression of 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 other means such as heat or trauma (e.g. during dental procedures).

Histologically odontoblasts are large columnar cells in the crown to flatter cells near the apex, 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 , it is noted that it is polarized so its nucleus is aligned away from the newly formed dentin, 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 40 μ m and 7 μ m 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. They promote cell to cell adhesion and play a role in maintaining polarity of odontoblasts.

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 concave tip of the folded 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 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 of the tooth because of the different orientation of collagen fibers, as well as the possible decrease of phosphoporyn levels and 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:

Hereditary dentin defects have been classified as dentinogenesis imperfectas (DGIs) and dentin dysplasias (DDs). These hereditary conditions are associated with abnormal dentin mineralization and varying degrees of changes intooth morphology. DGI type I is associated with osteogenesis imperfecta, 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). Osteogenesis imperfecta or brittle bone disease is caused by mutations in the genes coding for type I collagen. The DGI tooth phenotype is highly variable and is characterized by an opalescent blue-gray to yellow-brown coloration due to the discolored dentin shining through the relatively normal translucent enamel.