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Tooth development

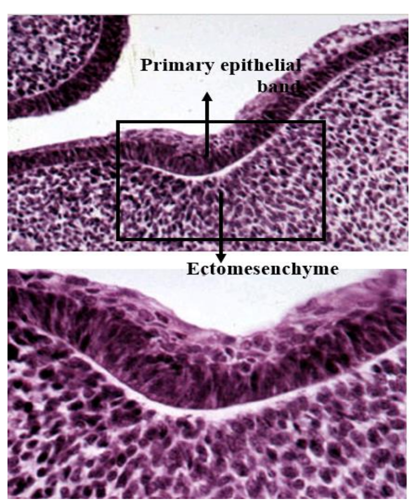
A process is also known as **odontogenesis**.
Tooth development is the complex process by which teeth form from embryonic cells, grow, and erupt into the mouth. It is started at **6th week** of gestation.

odontogenesis involves the development of primary (deciduous) and permanent (secondary) dentition, and overlapping period between the primary and secondary dentition is referred to as the mixed dentition period.

The process of development for both dentitions is similar, only the time of development is different.

Two embryonic tissues are responsible for the development of a tooth:

1. **Ectomesenchymal** tissues (neural crest in origin) which give rise to the dentin, pulp, periodontal ligament, cementum and part of alveolar bone
2. **Oral epithelium** (ectoderm) which gives rise to enamel of the tooth



Nutrition and tooth development:

As in other aspects of human growth and development, nutrition has an effect on the developing tooth. Essential nutrients for a healthy tooth include calcium, phosphorus, and vitamins A, C, and D. Calcium and phosphorus are needed to properly form the hydroxyapatite crystals, and their levels in the blood are maintained by Vitamin D. Vitamin A is necessary for the formation of keratin, as Vitamin C is for collagen. Fluoride, although not a nutrient, is incorporated into the hydroxyapatite crystal of a developing tooth and bones.

FORMATION OF PRIMARY DENTITION

Stages of development:

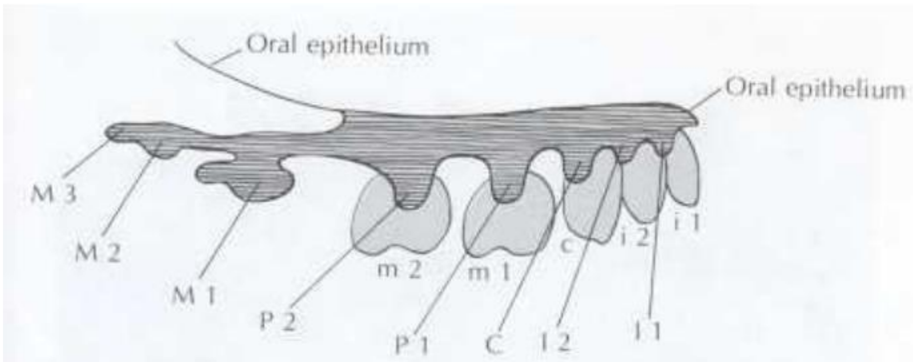
1. **INTIATION STAGE:**

   The first sign of tooth development is appearance of condensation of ectomesenchymal tissue and capillary network beneath the presumptive dental epithelium. Certain areas of basal cells of oral ectodermal epithelium proliferate more rapidly than do the cells of the adjacent areas, to form the primary epithelial band. During initiation stage there is an interaction between ectodermal epithelium and the ectomesenchymal underlying tissue.

   The **dental lamina**, which is a band of epithelium, invades the ectomesenchymal cells along each of horse shoe-shaped future dental arch. At the front of the mouth this growth is in lingual direction.

   The dental lamina of each jaw shows at intervals, **down growths**, along its length, in a form of **small rounded swellings** which involves the whole thickness of the lamina, from its free edge to its base where the lamina is attached to the mouth epithelium. These epithelial swellings of the lamina represent **the tooth buds of deciduous teeth**. The developments of enamel organs of permanent molars arise directly from a distal backward extension of the dental lamina of the second molar.

They arise according to the following sequence: The first permanent molar is initiated at fourth month in utero, the second permanent molar is initiated at 1st year after birth, and the third permanent molar is initiated at 4th or 5th years.



The successors of the deciduous teeth (permanent teeth) develop from the lingual extension of the free (lingual) end of the dental lamina opposite to enamel organ of each deciduous tooth. The lingual extension of dental lamina is named the **successional lamina** and developed during the 5th month in utero (permanent central incisor) to 10th month of baby age (second permanent premolar).

A timetable to remember

- Entire primary dentition initiated between 6 and 8 weeks of embryonic development.
- Successional permanent teeth initiated between 20th week in utero and 10th month after birth.
- Permanent molars between 20th week in utero (first molar) and 5th year of life (third molar).

FATE OF DENTAL LAMINA: -

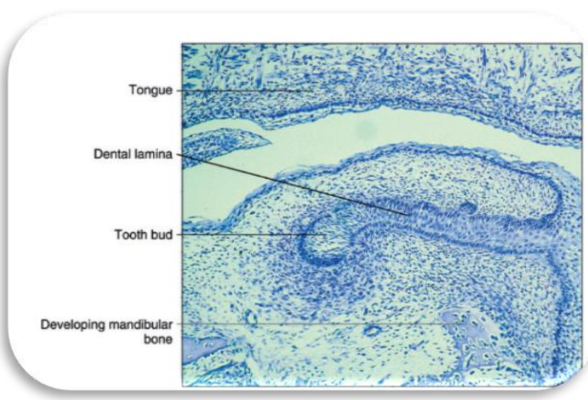
The activity of dental lamina extends over a period of at least 5 years. During these five years the dental lamina still active in the third molar region after it has disappeared elsewhere. As the teeth continue to develop, they lose their connection with dental lamina. They later break up by mesenchymal invasion. Remnants of the dental lamina persist as **epithelial pearls of Serres** within the jaw and gingiva.

2) BUD STAGE: -

It occurs at 8 week. The epithelium of the dental lamina is separated from the underlying ectomesenchymal cells by a basement membrane. It is named so, because there is an extensive proliferation or in growth of the dental lamina into buds or ovoid swelling (masses) penetrating into the ectomesenchyme. This penetration is occurring at 10 different locations involving the primary (deciduous)

dentition of maxillary arch and 10 sites for mandibular arch. The underlying ectomesenchyme also undergo proliferation.

These buds are representing the primordial of the enamel organs of primary dentition.



3) CAP STAGE: -

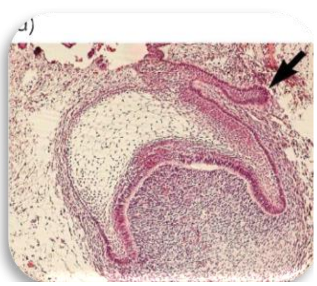
By the eleventh week, the tooth bud continues to proliferate. There is unequal growth in different parts of the tooth bud leading to formation of cap shape structure attached to the dental lamina, which is characterized by a shallow invagination on the deep surface of the bud. The epithelial cells now become the **enamel organ** and remain attached to the dental lamina. Due to the invagination of the deep surface of the bud the following layers could be outlined in the enamel organ:

a. inner enamel epithelium
b. outer enamel epithelium
c. Stellate reticulum: the polygonal shaped cells located in the center of the enamel organ between the inner and outer enamel epithelium begin to separate as more intercellular fluid is attracted to this area because the cells of the stellate reticulum produce hydrophilic extra cellular matrix rich in glycosaminoglycan. The cells of this region assume a stare shape, hence the name Stellate reticulum. The volume of extracellular space starts to increase and reached its maximum size during the next stage i.e. the bell stage.

The ectomesenchymal cells form the dental papilla. The **dental papilla** is the formative organ of the dentin and the pulp. The tissue surrounding these two structures is the **dental follicle**.

The dental follicle: Is a marginal condensation of the ectomesenchyme surrounding the enamel organ and dental papilla. It has a dense fibrous and vascular content. The cells of the dental sac are important for the formation of cementum,

periodontal ligament (PDL) and part of alveolar bone. After further growth of the papilla and the enamel organ, the tooth reaches the bell stage.



4) BELL STAGE: -

The bell stage is known for the histodifferentiation and morpho-differentiation that taken place. The enamel organ is bell-shaped during this stage, and the majority of its cells are called stellate reticulum because of their star-shaped appearance. Cells on the periphery of the enamel organ separate into three important layers. Cuboidal cells on the periphery of the enamel organ are known as outer enamel epithelium. The columnar cells of the enamel organ adjacent to the dental papilla are known as inner enamel epithelium. The cells between the inner enamel epithelium and the stellate reticulum form a layer known as the stratum intermedium. The rim of the dental organ where the outer and inner enamel epithelium joins is called the cervical loop. It has two sub stages **early bell and late bell stage**. The enamel organ has deep epithelial invagination and its margin continue to grow.

Early bell stage: It occurs between twelve to fourteenth week. Four types of epithelial layers could be seen in the enamel organ at this stage

Inner enamel epithelium: Consists of a single layer of cells that differentiate prior to amelogenesis into tall columnar cells called ameloblasts. These cells attached to each other by junctional complex and the cells of stratum intermedium by desmosomes. The cells of inner enamel epithelium exert an organizing influence on the underlying ectomesenchymal cells in the dental papilla which later differentiates into odontoblasts which produce dentin in the crown and root. The function of the inner enamel epithelium includes;

1- Determine the form and size of the crown.
2- By its effect on dental papilla, they initiate the differentiation of dentine forming cells (odontoblasts) by a process called epithelia-ectomesenchymal interaction.
3- Differentiate into ameloblasts, which lay down enamel.

ii. Stratum intermedium: consists of 3-5 squamous cell layers between the inner enamel epithelium and stellate reticulum. These cells are attached by desmosomes and gap junctions. This layer is essential for the enamel formation because its cells contain alkaline phosphatase. It is absent in the part of the tooth germ that outlines the root portions of the tooth germ.

iii. Stellate reticulum: expands in this stage further due to an increase in the amount of intercellular fluid. The cells are star-shaped with long processes that attach with each other by desmosomes and gap junctions. Its function includes: Protection of stratum intermedium and inner enamel epithelium,

iv. Outer enamel epithelium: become low cuboidal cells, their outer surface is indented by capillaries which provide nutrition for the different cells of the enamel organ.

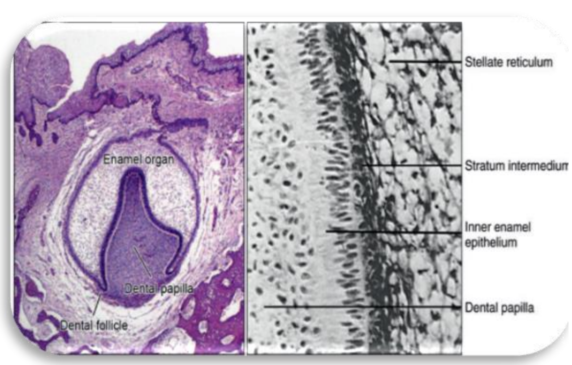
Dental papilla: at this stage the peripheral cells of the ectomesenchyme under the influence of the inner enamel epithelium differentiate into odontoblasts.

Dental sac (follicle): shows increase in amount of collagen fibers, which form a circular arrangement around the enamel organ. With the development of the root these fibers differentiate into PDL fibers. The functions of the dental sac include: 1- the nutrition of the enamel organ.

2- Maintain the relationship of enamel organ with the oral mucosa during growth.

3- Controls the form and size of the bony cavity in which the developing tooth germ lies.

4- Finally, the cells (ectomesenchyme) of the dental follicle will form the cementum, PDL and part of alveolar bone.



b. Late bell stage: the late bell stage is associated with the formation of dental hard tissue commencing at about the 18th week of gestation.

In late bell stage:

a. The boundary between inner enamel epithelium and odontoblasts outlines the future dentin-enamel junction.

b. The cervical loop of enamel organ gives rise to the epithelium root sheath of Hertwig.

c. The first laid dentin occurs also in this stage and that is an indication of the transition of the tooth germ from early to late bell stage.

d. The stellate reticulum starts to reduce in size at the site of hard tissue formation which starts at the occlusal surfaces. This will reduce the distance for the passing of nutrition to the preameloblast and later the ameloblasts. The dental hard tissue formation is having occluso-cervical direction.

The formation of dentin marks the onset of the crown stage of tooth development.

5) APPOSITION (CROWN) STAGE: -

Hard tissues, including enamel and dentin, develop during this stage. The enamel and dentin are secreted in successive layers in occluso-cervical direction.

6) MATURATION STAGE: -

During which the dental hard tissues are fully mineralized.

Note: - The time period for the last two stages varies according to the tooth involved.

Epithelio-ectomesenchymal interaction during tooth development:

The development of the tooth germ involves many reciprocal interactions between the epithelium of the enamel organ and the ectomesenchymal cells of dental sac and dental papilla. These interactions are termed epithelio-ectomesenchymal

interaction during tooth development. A chemical substance is produced by one cell layer and diffuses the narrow intervening space to be taken up and cause induction in the other cell layer.

Epithelial root sheath of Hertwig:

The development of the roots begins after enamel and dentin formation has reached the future cemento-enamel junction. The enamel organ is forming the epithelial root sheath of Hertwig, which molds the shape of the roots and initiates radicular dentin formation. The epithelial root sheath of Hertwig is consisting of the outer and inner enamel epithelium only. It is extending by proliferation from the cervical loop. This area is having the outer enamel epithelium becomes continuous with the inner enamel epithelium. The cells of the inner enamel epithelium remain short and normally do not produce enamel, but the inner enamel epithelium has the potential to induce the differentiation of the cells of dental papilla to become odontoblast to form the radicular dentin. During its formation the root sheath grows apically to enclose the dental papilla and separates the papilla from the dental follicle ectomesenchymal cells. The root sheath also helps in the formation of the epithelial diaphragm when both ends bend inward to enclose the dental papilla to form the limit for the primary apical foramen. The root sheath ultimately undergoes fragmentation, after root formation. Remnants of the root sheath do persist in close proximity as a cluster of cells knows as epithelial rest cells of Malassez. In adult the rest cells found, in PDL. These rest cells may be involved in formation of dental cysts.

Root formation:

It begins when the enamel and dentin formation has reached to the future cement enamel junction (CEJ). When a tooth first erupts, only about 2/3 of the length of its root is completed. Root development is concomitant with the start of eruptive movement. Prior to the beginning of root formation, the root sheath forms the epithelial diaphragm. The outer and inner enamel epithelium bends at the future cemento-enamel junction (CEJ) into a horizontal plane, narrowing the wide cervical opening of the tooth germ. The proliferation of the cells of the epithelial diaphragm is accompanied by proliferation of the cells of the dental papilla adjacent to the diaphragm. The free end of the diaphragm does not grow into connective tissue but the epithelium proliferates above the epithelial diaphragm, so that the epithelial root sheath proliferates apically at the same rate at which the developing tooth is erupting. The inner enamel epithelium of the root sheath induces the peripheral cells of the dental papilla to differentiate into odontoblasts. When the odontoblasts are differentiated and begin to deposit dentin the continuity of root sheath is lost. The breakdown of root sheath at the level of developing root, at which dentin production has begun, allows the undifferentiated ectomesenchymal cells of the dental sac to move toward the surface of root dentin. The remnants of root sheath stayed in periodontal ligament as cell rests of Malassez. The factor which leads to differentiation of the cells of dental sac into cementoblasts probably is coming from the recently deposited root dentin. Cementoblasts start to lay down the cementum on the surface of the dentin. In single rooted teeth, the epithelial root sheath simply grows apically as an epithelial cylinder.

In teeth with two to three roots the single cervical opening must be divided into two or three opening. This subdivision is done by the horizontal outgrowth of two or three epithelial flaps across the cervical opening. These flaps meet in the center of cervical opening where they fuse. Then from the edges of this opening two to three root sheaths grow apically.

DEVELOPMENT OF THE SECONDARY DENTITION: -

1- The incisors, canines, and premolars of 2nd dentition: -

These teeth are developed from tooth buds growing off the dental lamina as successional lamina at the level of the tooth germs of the primary dentition, which are at that time, were in the bell stage. The secondary enamel organs remain temporarily attached to the parent dental lamina by a successional dental lamina. The secondary tooth germs developed lingual to the primary tooth germ. The lingual extension of the dental lamina (successional lamina) develops from the 5th month in utero for permanent Central incisor, to tenth month of age for second premolar.

2. The molars of the secondary dentition:

They have no primary predecessors. Their enamel organs develop from a blind backward extension of the dental lamina of the primary dentition. This blind extension grows backward in the jaw, underneath the oral mucosa, from the dental lamina of the second molars of the primary dentition. This extension give rise, in succession, to the enamel organs of first, second and third molars of secondary dentition. The development of the first permanent molar is initiated at the fourth month in utero, the second molar is initiated at about first year after birth, the third molar at the fourth or fifth years. Both the primary and secondary teeth are in different stages of development, but they share a common bony crypt.

THE ROOT FORMATION ANOMALIES:

1- **Formation of accessory root canal**: If the continuity of the root sheath were broken before dentin formation, the result could be missing or defective epithelial cells. The odontoblasts would not differentiate, and dentin would not form opposite the defect in the root sheath. The result would be a small lateral canal connecting the PDL with the main root canal. The supplemented canal called accessory root canal.

2- **Exposed root dentin:** - This caused by failure of degeneration of the epithelial root sheath at the proper time, and remains adherent to the root dentin surface, so ectomesenchymal cells of the dental follicle will not come in contact with the dentin. Thus, ectomesenchymal cells of the dental follicle will not differentiate into cementoblasts and no formation of cementum. The exposed dentin areas could be found in any place of the root surface especially in cervical zone, and may be the cause of cervical sensitivity late in life when gingival recession takes place.

3- **Formation of enamel pearls**: The epithelial root sheath may also remain adherent to the dentin in the cervical area near the furcation zone. In this case the inner cells of the epithelial root sheath may differentiate in functional ameloblast and produce enamel known as enamel pearls. It is found lodged between the roots of permanent molars.

Agents affecting tooth and bone development:

1- Vitamin A deficiency:

- In vitamin A deficiency the ameloblast fail to differentiate properly. Consequently, their organizing influence on the adjacent mesenchymal cells is disturbed and atypical dentin known as osteodentin is formed.
- Metaplasia of enamel organ result in defective enamel and dentin formation.
- Bone is laid down in abnormal location.
- Enamel hypoplasia.

2- Vitamin C deficiency:

- Scurvy the disease results in cease of bone, dentin and cementum deposition, and the formative cells to atrophy.
- Gingival bleeding.
- Loosening of the tooth due to bone resorption.

3- Vitamin D deficiency:

- Hypoplasia of the enamel.
- Hypomineralized cementum.

4-Parathyroid hormone: Both hypo and hyperparathyroidism produce calcium imbalance results in hypo and hyper calcified bands in the forming dentin.

5-Pituitary gland: Retarded eruption occurs in persons with hypopitutiarism.

6- Thyroid gland: hypothyroidism results in small clinical crown.

7- Tetracycline and fluorides:

The first formed dentin is showing staining if tetracycline is deposited to the mother from the 5th month of pregnancy until term i.e. during the period of mineralization. The same effect is in the child up to 12 years of age because the period is marked by mineralization of crown extends from 5 months in utero (transplacental crossing) to 12 years of age and include the mineralization of both also include hypoplasia and loss of the enamel. The staining of teeth with tetracycline is permanent while with the bone is not due to the process of remodeling of the bone which continuously throughout life.

8. Fluoride at concentration of 0.5 PPM prevents caries. But higher concentration (3 ppm) causes mottled enamel.