Oral histology
Second stage

Lec. Noor Natik

Tooth development(Odontogenesis)

Odontogenesis is the complex process by which teeth form from embryonic cells, grow, and erupt into the mouth.

The primitive oral cavity, or stomodeum, is lined by stratified squamous epithelium called the oral ectoderm or primitive oral epithelium. The oral ectoderm contacts the endoderm of the foregut to form the buccopharyngeal membrane. At about the 27 days of gestation this membrane ruptures and the primitive oral cavity establishes a connection with the foregut.

Most of the connective tissue cells underlying the oral ectoderm are of neural crest or ectomesenchyme in origin. These cells are thought to anterior portion of what will be instruct or induce the overlying ectoderm to start tooth development, which begins in the future maxilla and mandible and proceeds posteriorly. Teeth development results from an interaction of the oral epithelial cells and the underlying ectomesenchymal cells. From this interaction, 20 deciduous and 32 permanent teeth developed. Each developing tooth grows as an anatomically distinct unit. The fundamental developmental process is similar for all teeth(deciduous & permanent teeth).

Dental organ or tooth germ: is a term used to constitute the structure that has enamel organ, dental papilla and dental follicle.

Primary epithelial band:

Two or three weeks after the rupture of the buccopharyngeal membrane, when the embryo is about 6 weeks old, certain areas of basal cells of the oral ectoderm proliferate more rapidly than do the cells of the adjacent areas. This leads to the formation of the Primary epithelial band which is a band of epithelium that has invaded the underlying ectomesenchyme along each of the horseshoe-shaped future dental arches .At about 7th week the primary epithelial band divides into an inner (lingual) process called Dental lamina and an outer (buccal) process called Vestibular lamina.

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Dental lamina

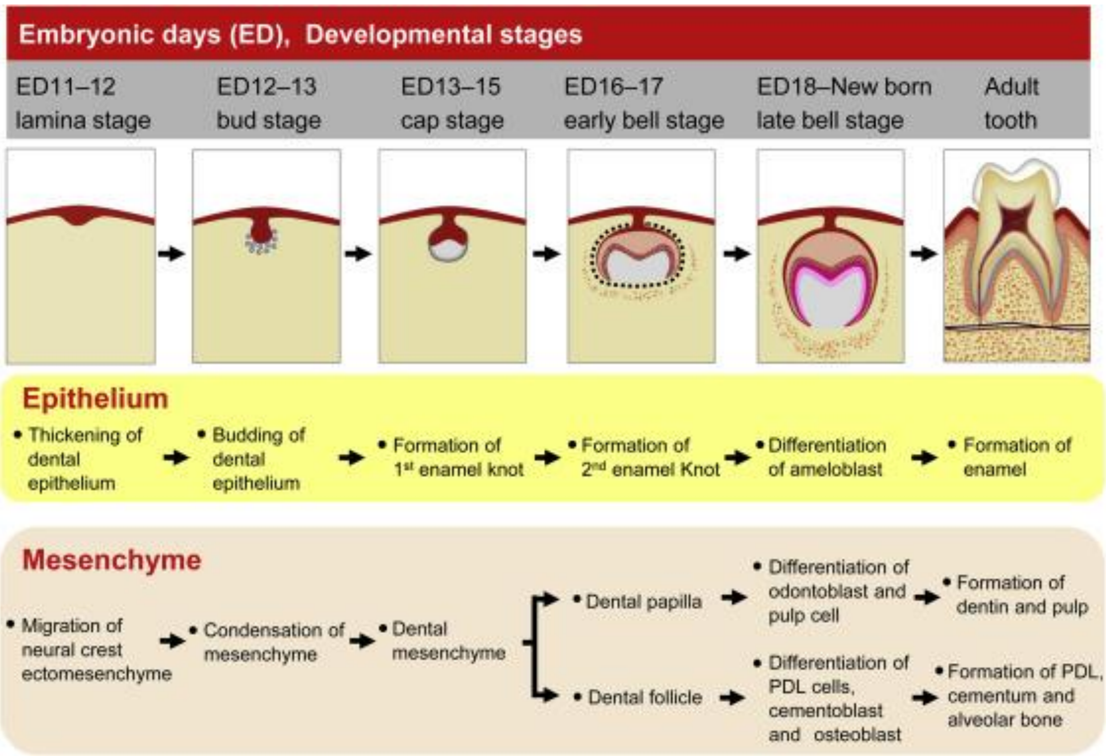
The dental laminae serve as the primordium for the ectodermal portion of the deciduous teeth. Later, during the development of the jaws, the permanent molars arise directly from a distal extension of the dental lamina.

the jaws, the neural crest cells induce the oral epith. to proliferate and form the dental lamina, which is the first sign of tooth development. This lamina then invaginates as a sheet of epith. cells into the underlying mesenchyme around the perimeter of both maxillary and mandibular jaws. Along the leading edges of the lamina 20 areas of enlargement next appear, which are the forming buds of the 20 primary teeth, and the leading edge of the lamina continues to develop the 32permanent tooth buds.

Successional tooth buds form the permanent dentition lingual to the buds of the primary predecessors. Permanent molars develop posterior to the primary molars, and the general dental lamina grows posteriorly to form the permanent molar buds. The last teeth to arise from dental lamina are the third molars, which developed in about 4 years after birth.

The dental lamina is thus functional in developing the 52 teeth from the sixth prenatal week until 4 years after birth.

So the activity of dental lamina extends over a period of about five years and disintegrates completely or remains as remnants in the gingiva and the jaw and they are called epithelial rests of Serres(Serres' pearls).



Vestibular lamina

Labial and buccal to the dental lamina in each dental arch, another epithelial thickening develops independently and somewhat later. It is the vestibular lamina, also termed the lip furrow band. It subsequently hollows and forms the oral vestibule between the alveolar portion of the jaws and the lips and cheeks.

Physiological phases in tooth development

Tooth development can be divided into the following overlapping phases, which are:

1-Initiation : During this phase, the sites of the future teeth are established with the appearance of tooth germs along an invagination of the oral epithelium called dental lamina.

2-Prolifertion: During this phase, Proliferative growth causes regular changes in the size and proportions of the growing tooth germ

3-Histodifferentiation: During this phase, differentiation of cell (begun during morphogenesis) proceed to give rise to the fully formed dental tissues, both mineralized (such as enamel, dentin and cementum) and unminaralized (such as pulp and periodontal ligament).

4- Morphodifferentiation : During this phase, the shape of the teeth are determined by a combination of cell proliferation and cell movement.

5-Apposition: During this phase, the deposition of dental hard tissue occur in the tooth like dentin and enamel.

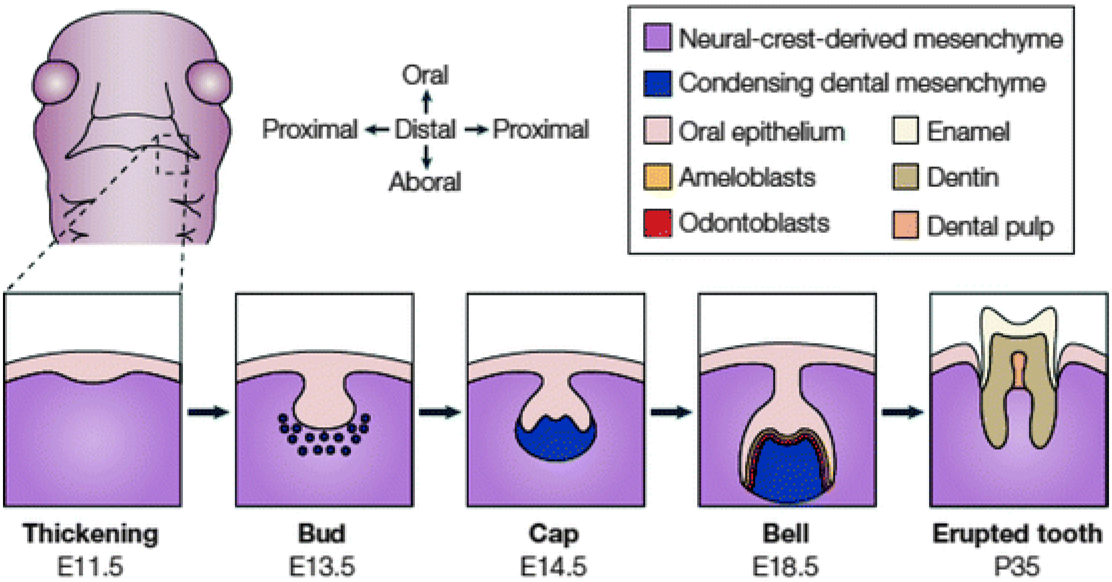
Morphological stages of tooth development

For descriptive purposes, tooth germs are classified into bud, cap and 2 bell stages according to the degree of morphodifferentiation and histodifferentiation of their epith. components (enamel organs). Leading up to the late bell stage, the tooth germ changes rapidly both in its size and shape, the cells are dividing and morphogenetic processes are taking place.

Bud stage

Round or ovoid swellings at ten different points arise from dental lamina in each jaw, corresponding to the future position of deciduous teeth. They are the primordial of enamel organs (the tooth buds), thus the development of the tooth germ is initiated, proliferation of cells is still faster than adjacent ectomesenchymal cells. These epith. condensation is poorly morphodifferentiated and histodifferentiated.
The cells of the tooth bud have a higher RNA content than those of the overlying oral epith., a lower glycogen content and an increased oxidative enzyme activity. Enamel organ histology in this stage consist of peripherally located low columnar cells and centrally located polygonal cells. The enamel organ is separated from the adjacent ectomesenchyme by basement membrane. Many cells of the tooth bud and the surrounding mesenchyme undergo mitosis. As a result of the increased mitotic activity and the migration of neural crest cells into the area the ectomesenchymal cells surrounding the tooth bud condense. The area of ectomesenchymal

condensation immediately subjacent to the enamel organ is the dental papilla. The condensed ectomesenchyme that surrounds the tooth bud and the dental papilla is the dental sac. Both the dental papilla and the dental sac become more well defined as the enamel organ grows into the cap and bell shapes.



Cap stage

As the epith. bud continues to proliferate into the ectomesenchyme, morphogenesis has progressed, the deeper surface of the enamel organ invaginating to form a cap-shaped structure. Although, enamel organ appearing relatively poorly histodifferentiated, a greater distinction develops between the more rounded cells in the central portion of the enamel organ and the peripheral cells which are becoming arranged to form the outer and inner dental epith.

In the late cap stage of tooth development, the central cells of the enlarging enamel organ have become separated (through maintaining contact by desmosomes), the intercellular spaces containing significant quantities of glycosaminoglycans. The resulting tissue is termed the stellate reticulum, although it is not fully developed until the late bell stage.

The cells of the outer enamel epith. remain cuboidal, where as those of inner e. epith. become more columnar and show an increase in RNA content, and hydrolytic and oxidative enzyme activity. The adjacent ectomesenchymal cells are continue to prolipherat and surround the E. organ. The part of the ectomesenchyme lying beneath the inner E. epith..

is called dental papilla. The ectomesenchymal tissue surrounding both enamel organ and dental papilla is called dental sac or dental follicle.

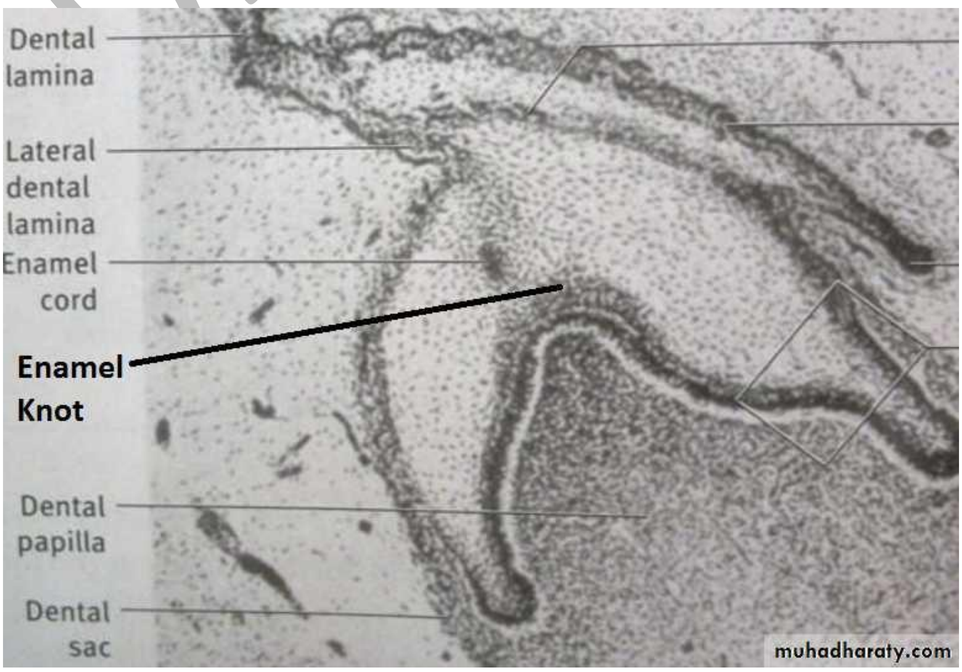
Transitory structures

During the early stages of tooth development, three transitory structures may be seen, which are E. knot, E. cord and E. niche.

1- Enamel knot: It's a localized mass of cells in the center of the inner E. epith. Once thought that E. knot played a role in the formation of crown pattern by outlying the cusp number. However, the E. knot soon disappears and seems to contribute cells to the E. cord. Although its transitory, recent studies of E. knot suggest it may represent an important signaling center during tooth development. Unlike adjacent cells, those within the E. knot are non proliferative and produce molecules associated with signaling in other sites. These molecules include bone morphogenic proteins and fibroblast growth factor.

2- Enamel cord: It's a strand of early bell stage of development. It arises in the increasingly high enamel organ as a vertical extension of the E. knot. Its termed E. septum when E. cord extend from E. knot to the outer E. epith.

3- Enamel niche: Its an apparent structure in the histologic section, created because the dental lamina is a sheet rather than a single strand and often contains a concavity filled with C.T. A section through this arrangement creates the impression that the tooth germ has a double attachment to the oral epithelium by two separate strands.



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Bell stage

The dental organ is bell-shaped during this stage, and the majority of its cells are called stellate reticulum because of their star-shaped appearance. The bell stage is known for the histodifferentiation and morphodifferentiation that takes place.

The bell stage is divided into the early bell stage and the late bell stage . Characteristic features of bell stage:

1-Tooth crown assumes its final shape (Morphodifferentiation), and the cells that will be making the hard tissues of crown (Ameloblasts and odontoblasts) acquire their distinctive phenotype (Histodifferentiation).

2-The enamel organ is bell-shaped and it composed of 4 distinctive cell layers. Cuboidal cells on the periphery of the enamel organ are known as outer enamel epithelium (OEE). The columnar cells of the enamel organ adjacent to the enamel papilla are known as inner enamel epithelium (IEE). The cells between the IEE and the stellate reticulum(SR) form a layer known as the stratum intermedium(SI).

3-The rim of the enamel organ where the outer and inner enamel epithelium join is called the cervical loop.

4-Other events occur during the bell stage, the dental lamina disintegrates, leaving the developing teeth completely separated from the epithelium of the oral cavity.

A-Early bell stage High degree of histodifferentiation is achieved in the early bell stage .The enamel organ shows four distinct layer:

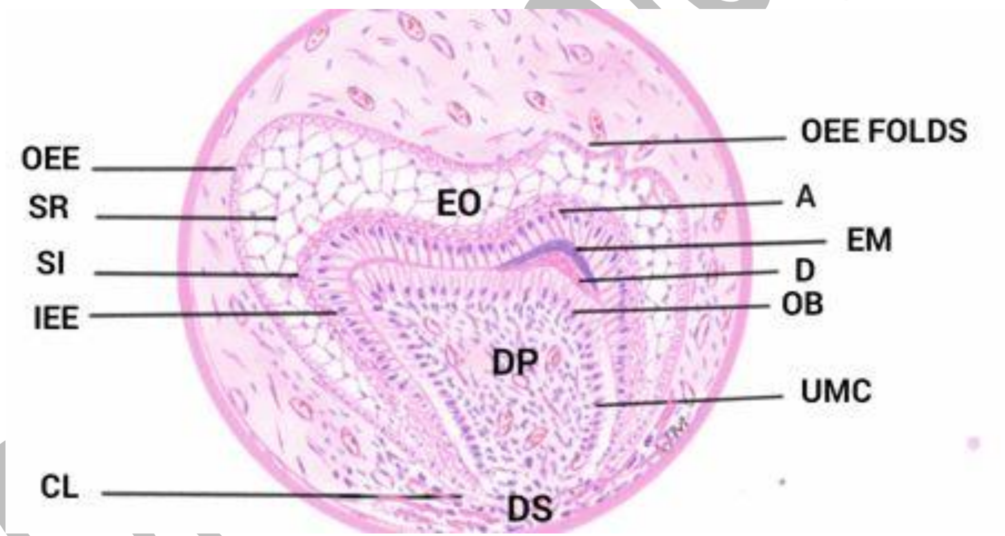
1- Inner enamel epithelium(IEE): It consists of a single layer of cells that differentiate prior to amelogenesis into columnar cells, the ameloblasts. These elongated cells are attached together by junctional complex laterally and by desmosomes to stratum intermedium .The IEE cells rich in RNA. The IEE. is separated from the peripheral ells of dental papilla by a basement membrane and cell free zone about 1-2 µm wide. The function of cells of this layer first is exert an organizing influence on the undelying ectomesenchymal cells of dental papilla to differentiate into odontoblasts, and then it differentiate into ameloblasts which form enamel. Also when the enamel formation of the crown completed, the IEE with OEE formed the structure from cervical loop which called Hertwig’s epithelial root sheath which formed root.

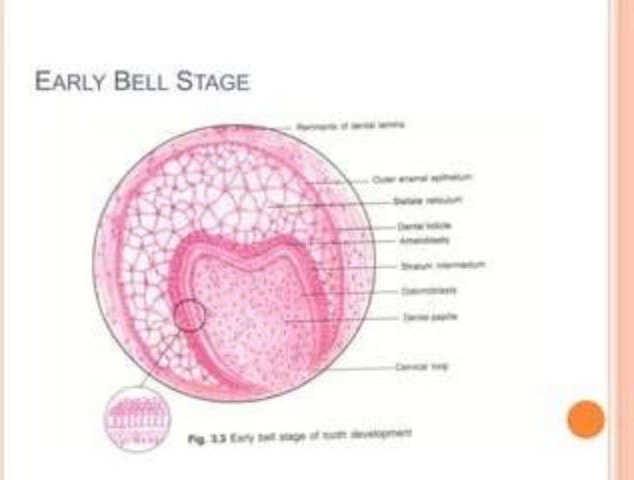
2- Stratum intermedium (SI): This first appears at the early bell stage and as layers of flattened cells lying between the IEE and stellate reticulum. The cells of this layer consists of several layer of squamous cells, closely attached by desmosomes and gab junction. The function of cells of stratum intermedium is important in the mineralization of the enamel during amelogenesis because it characterized by high degree of alkaline phosphatase enzyme. Also the cells of this layer concern in the transport of materials to and from the IEE which later differentiate to ameloblasts.

3. The stellate reticulum(SR): The intercellular spaces become fluid filled, presumably related to osmotic effects arising from the high concentration of glycos-aminoglycans. In addition , the cells also contain alkaline phosphatase. But have only small amounts of RNA and glycogen. The cells are star-shaped with bodies containing prominent nuclei and many branching processes. The cells of this layer have numerous tonofilaments and few endoplasmic reticulum and mitochondria which present within the cytoplasm. The desmosomes and gap junctions are present between the cells. The main function of stellate reticulum is a mechanical one. This relates to the protection of the underlying IEE against physical disturbance and to the maintenance of tooth shape. The hydrostatic pressure generated within the stellate reticulun is in equilibrium with that of the dental papilla, allowing the proliferative pattern of the IEE cells to determine crown morphogenesis, however, a change in either of these pressures might lead to change in the outline of the IEE and this could be important for crown morphogenesis.

4- The outer enamel epithelium (OEE) As its name suggests, this forms the outer layer of cuboidal cells which limits the enamel organ. It is separated from the surrounding ectomesenchymal tissue of dental sac or follicle by a basement membrane 1-2µm thick, which , at the ultrastructural level(under electron microscope), corresponding to basal lamina and hemidesmosomes. The OEE cells contain large, centrally placed nuclei.

Ultrastructurally, they contain small amounts of the intracellular organelles associated with protein synthesis (e.g. endoplasmic reticulum, Golgi complex, mitochondria) and they contact each other via desmosomes and gap junctions. The function of OEE is thought to be involved in the maintenance of the shape of the enamel organ and in the exchange of substances between the enamel organ and the environment. At the advance bell stage, when dentin lay down, the formerly smooth surface of the outer enamel epithelium is laid in folds. Between the folds, adjacent mesenchyme of the dental sac forms papillae that contain capillary loops and thus provide nutritional supply for the intense metabolic activity of the avascular enamel organ during enamel formation.





Dental papilla: The dental papilla is enclosed in the invaginated portion of the enamel organ. Before the inner enamel epithelium begins to produce enamel, the peripheral cells of the mesenchymal dental papilla differentiate into odontoblasts under the organizing influence of the epithelium. The dental papilla ultimately gives rise to dental pulp, once the dentin formation begins at the cuspal tip of the bell stage tooth germ. The basement membrane that separates the enamel organ and the dental papilla just prior to dentin formation is called the membrana preformativa.

Dental sac (d.S.): Before formation of dental hard tissue begins, the d.S. shows a circular arrangement of its fibers and it resemble a capsular structure. With the development of the root, the fibers of d.S. differentiate into periodontal ligament fibers that become embedded in the cementum and alveolar bone.

B -Advance (late) bell stage or crown stage: Hard tissues, including enamel and dentin, develop during advance bell stage. This stage is also called the crown, or apposition stage, by some researchers. Important cellular changes occur at this time. In prior stages, all of the IEE cells were dividing to increase the overall size of the tooth bud, but rapid dividing, called mitosis, stops during the crown stage at the location where the cusps of the teeth form. The first mineralized hard tissues form at this location is dentin. At the same time, the IEE cells change in shape from cuboidal to columnar and become pre-ameloblasts. During this stage the boundary between inner E. epithelium and odontoblasts outlines the future D.E.J. (dentino enamel junction).

In addition, the basal margin of the E. organ (cervical loop) gives rise to the Herwig's epithelial root sheath.

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Function of dental lamina:

First the functional activity of the dental lamina is concerned with the initiation of the entire deciduous dentition that begins at the 6 weeks of intra-uterine life of embryo.

Second it deals with the initiation of the successors of the deciduous teeth.. It is preceded by the growth of the free end of the dental lamina (successional lamina), lingual to the enamel organ of each deciduous tooth, and occurs from about the 5 th month in embryo for the permanent central incisors to 10 months of age for the second premolar.

Third is the extension of the dental lamina distal to the enamel organ of the second deciduous molar and the formation of permanent molar tooth germs.

Fate of dental lamina

1- Dental lamina is functional in developing 52 teeth from 6 prenatal weeks until 4 years after birth (development of third permanent tooth).

2- The dental lamina degenerates by mesenchymal invasions in late bell stage.

2- Developing tooth lose its connection with dental lamina. 4- Sometimes remnants of dental lamina remains in the jaws as epithelial rests of Serres(Serres' pearls) .

Nutrition and tooth 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 6 phosphorus are needed to properly form the hydroxyapatite crystals(minerals), and their levels in the blood are maintained by Vitamin D. Vitamin A is necessary for the formation of keratin, and Vitamin C is for collagen. Fluoride is incorporated into the hydroxyapatite crystal of a developing tooth and makes it more resistant to demineralization and subsequent decay. Deficiencies of these nutrients can have a wide range of effects on tooth development:

- In situations where calcium, phosphorus, and vitamin D are deficient, the hard structures of a tooth may be less mineralized.
- A lack of vitamin A can cause a reduction in the amount of enamel formation.
- Fluoride deficiency causes increased demineralization when the tooth is exposed to an acidic environment, and also delays remineralization.
- Furthermore, an excess of fluoride while a tooth is in development can lead to a condition known as fluorosis.

Developmental disturbances of teeth:

1-Anodontia: is a complete lack of tooth development. Anodontia is very rare, most often occurring in a hereditary condition called ectodermal dysplasia.

2-Hypodontia (congenital missing tooth or teeth): It is one of the most common developmental abnormalities. The absence of third molars is very common, followed in prevalence by the second premolar and lateral incisor.

3-Hyperdontia(supernumerary teeth): It is believed to be associated with the remanent of dental lamina or epithelial rest of Serres.

4-Dilaceration is an abnormal bend found on a tooth, and is nearly always associated with trauma that moves the developing tooth bud.

5-Regional odontodysplasia is rare, but is most likely to occur in the maxillary anterior teeth. The enamel, dentin, and pulp of teeth are affected, so the teeth are very brittle. On radiographs the teeth appear more radiolucent than normal, so they are often described as "ghost teeth".

6-Amelogenesis imperfect: is hereditary condition characterized by a defect in dental enamel formation. Teeth are often free of enamel, small, misshapen, and tinted brown.

7- Dentinogenesis imperfecta: is hereditary condition characterized by a defect in either dentin matrix formation or mineralization of dentin.

8-Natal and neonatal teeth : Natal teeth are present at the time of birth. Neonatal teeth will erupt during the first 30 days after birth. Natal teeth are three times more common than neonatal teeth.

9- Gemination: arises when 2 teeth developed from one tooth bud, as a result patient have extra tooth