# Odontogenesis

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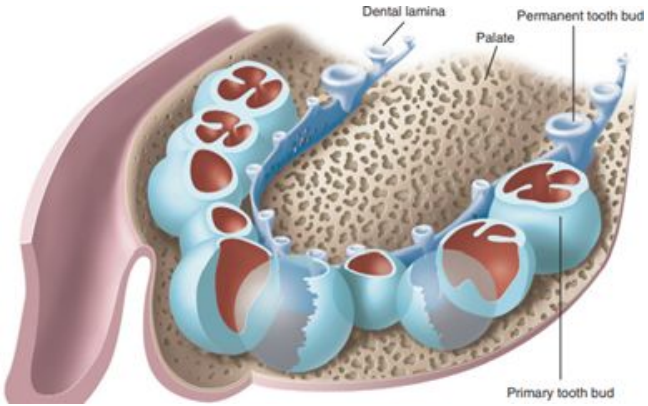
# Odontogenesis

# Primary vs. permanent tooth development

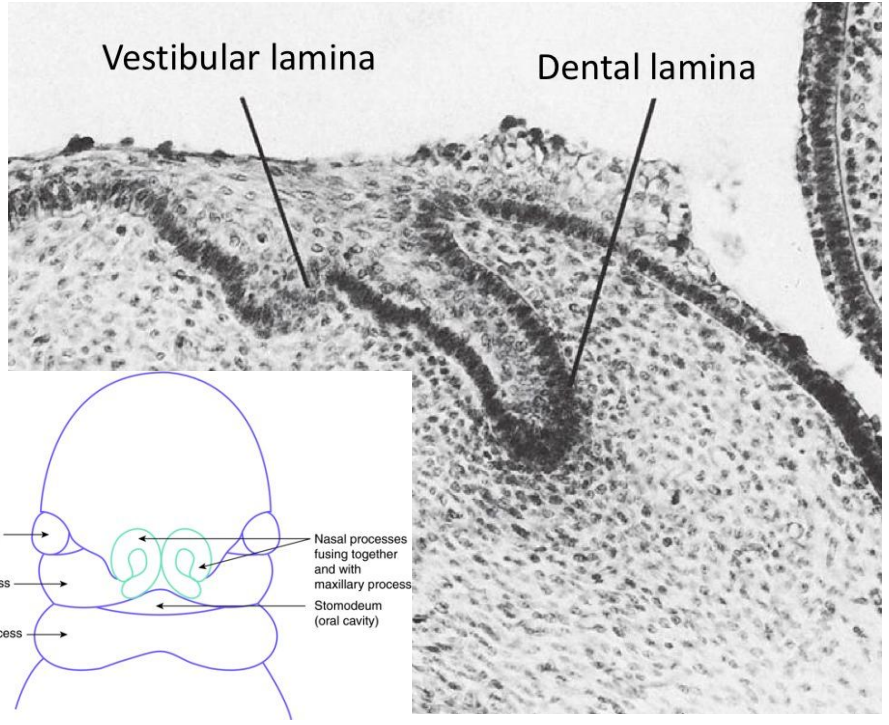
The primary teeth form from deciduous tooth germs while the permanent incisors, canines and premolars develop from successional dental lamina located lingual to the deciduous tooth germs. Permanent molars have no deciduous predecessors (grow directly from the dental lamina).

The primary dentition is initiated 6-8 wks in utero while the secondary dentition is initiated around wk 14 in utero. Following times are for the development of primary teeth, timings in utero.

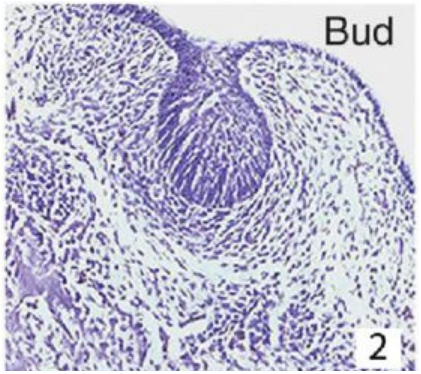


# Initiation (6th-7th Week)

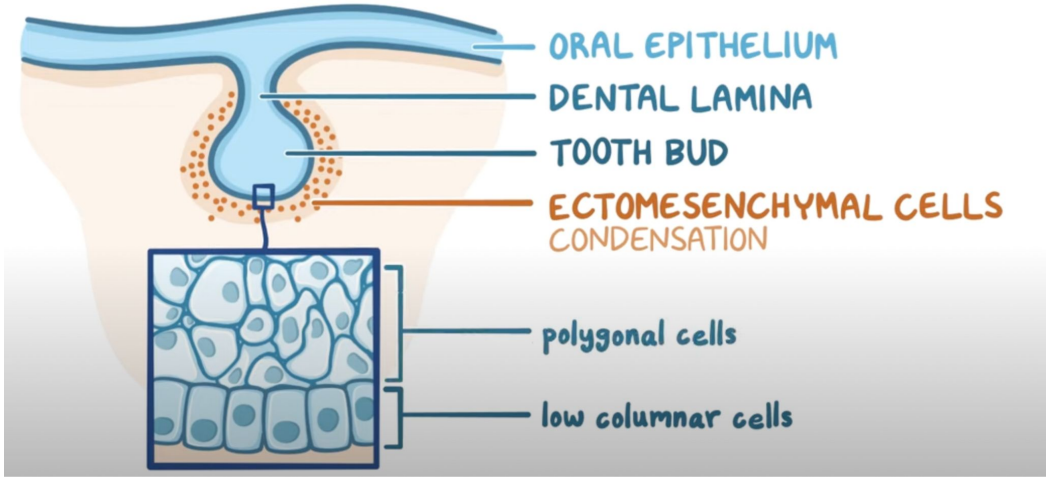
- Primary epithelial band forms in the primitive oral cavity in the 6th week
- Forms the dental and vestibular lamina in the 7th week
- Reciprocal signalling from the ectoderm to mesenchyme to ectoderm
- Oral epithelium invaginates into the ectomesenchyme -> dental lamina -> dental placodes



# Bud Stage (8th Week)

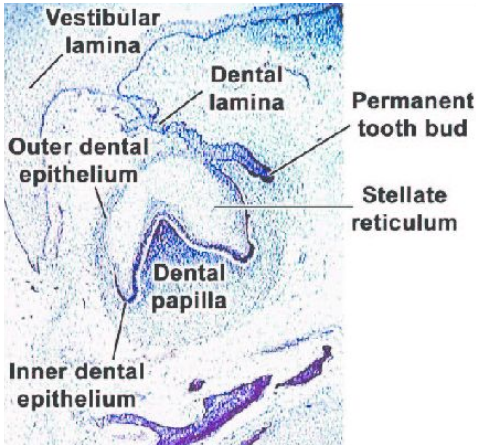


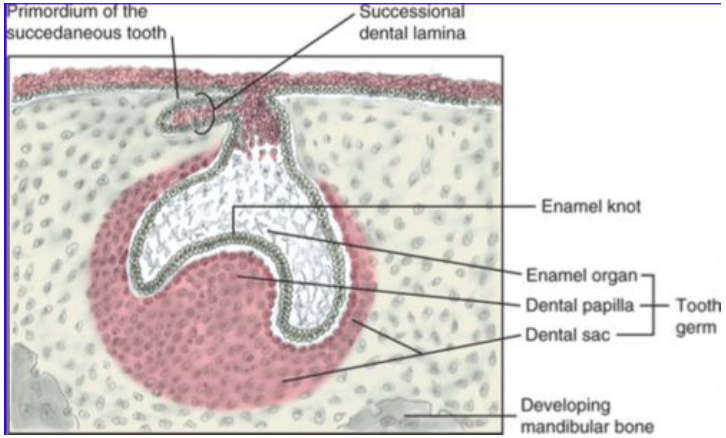

- Extensive proliferation of the dental lamina into buds
- Continual condensation of ectomesenchyme
- These buds together with surrounding ectomesenchyme will develop into a tooth germ



# Cap Stage (9-10th Week)

- Superiorly attached to the dental lamina
- Differentiation occurs and first example of morphogenesis
- Depression results in the deepest part of each tooth bud of dental lamina -> enamel organ
    - Outer surface -> crown of the tooth
    - Inner part -> cusps (occur through nondividing cells in the enamel knot)
- Part of the ectomesenchyme deep to the buds has condensed to form the dental papilla -> produce the dentine and pulp
- Remaining ectomesenchyme condenses into the dental sac -> periodontium, cementum, PDL and alveolar process
- Enamel organ + dental papilla and dental sac = tooth germ



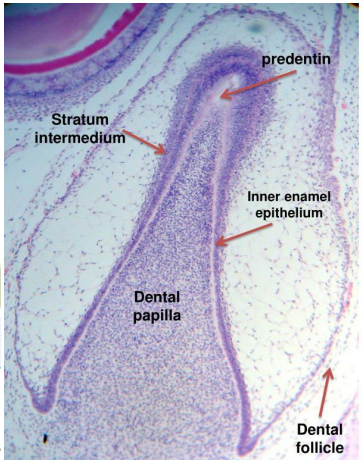



# Bell Stage (11-12th Week)

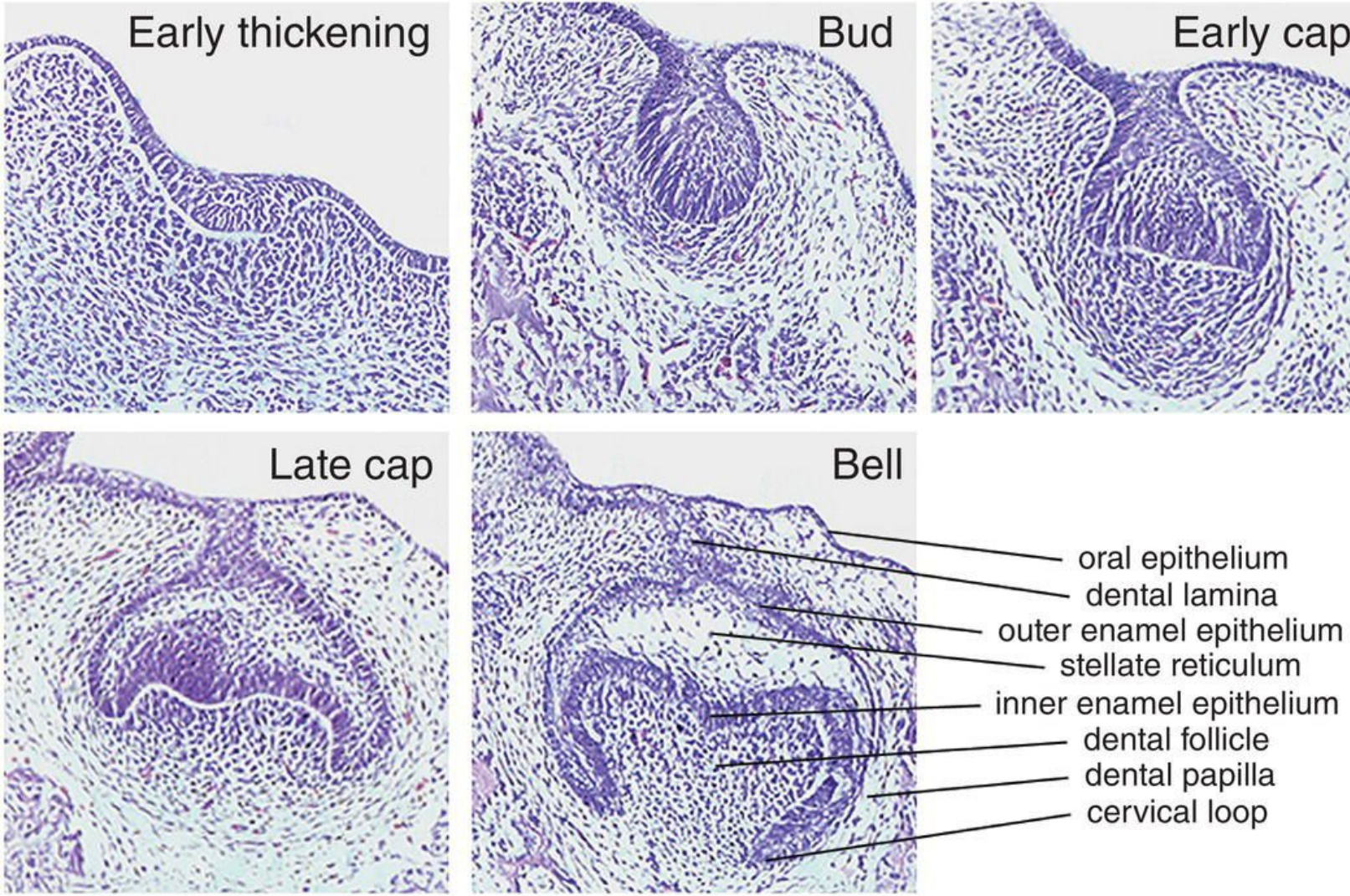
- Continual proliferation, differentiation and morphogenesis

**TABLE 6-4 Bell Stage Structures (from Outer to Inner)**

| CELL LAYERS | HISTOLOGIC FEATURES | ROLE IN TOOTH FORMATION |
|---|---|---|
| Dental sac | Increasing amount of collagen fibers forming around the enamel organ | Will differentiate into cementum, periodontal ligament, and alveolar process |
| Outer enamel epithelium | Outer cuboidal cells of enamel organ | Serves as protective barrier for enamel organ |
| Stellate reticulum | More outer star-shaped cells in many layers, forming a network within the enamel organ | Supports the production of enamel matrix |
| Stratum intermedium | More inner compressed layer of flat to cuboidal cells | Supports the production of enamel matrix |
| Inner enamel epithelium | Innermost tall, columnar cells of enamel organ | Will differentiate into ameloblasts that form enamel matrix |
| Outer cells of dental papilla | Outer layer of cells of the dental papilla nearest the inner enamel epithelium of the enamel organ. A basement membrane is between this outer layer and the inner enamel epithelium. | Will differentiate into odontoblasts that form dentin matrix |
| Central cells of dental papilla | Central cell mass of the dental papilla | Will differentiate into pulp tissue |

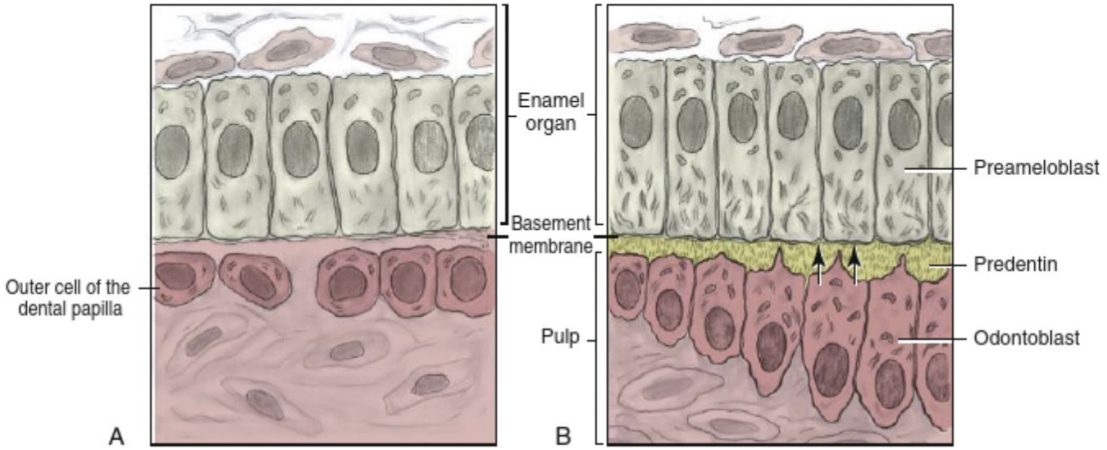



**Credit:** Margaret Fehrenbach and Tracy Popowics, 2019


Early thickening
Bud
Early cap
Late cap
Bell
oral epithelium
dental lamina
outer enamel epithelium
stellate reticulum
inner enamel epithelium
dental follicle
dental papilla
cervical loop

# Apposition and Maturation Stages

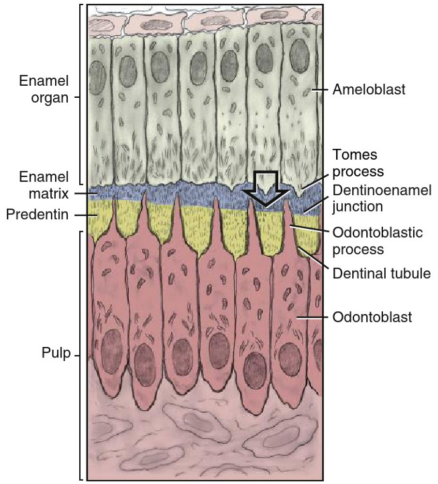
# Presecretory Stage (Week 8-14)




- After IEE formation, differentiate into preameloblasts lining up alongside the basement membrane
  - Nucleus moves away from the centre of the cell further away from the basement membrane
- **Reciprocal Induction**
  - IEE become more columnar -> preameloblasts -> induces dental papilla cells to produce odontoblasts -> predentine -> basal lamina disintegrates contacts preameloblasts -> ameloblasts
  - Histologically: Increased RER and golgi apparatus (golgi app also moves away from the dentine)

# Apposition (Secretory) Stage

- Enamel, dentine and cementum are secreted initially as a matrix which serves as a framework for mineralisation
- Ameloblasts begin amelogenesis (appositional growth of enamel matrix) down the side of the disintegrating basement membrane
    - Starts at the cusp tips/incisal edge – near the forming DEJ then moves cervically to the CEJ
    - Ameloblasts' trajectory: outwards away from the cusp tips
- Enamel matrix is secreted from the Tomes process (distal part of the ameloblast)
- Transitional Phase – apoptosis of 25% of ameloblasts



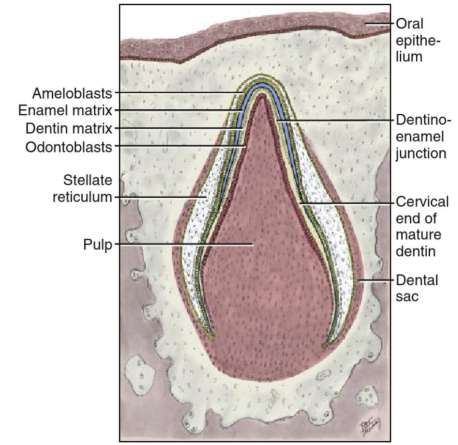
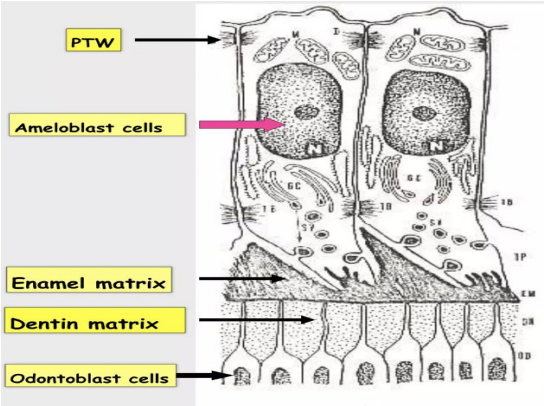




**FIGURE 6-13** Apposition stage demonstrating both enamel and dentin matrix formation.



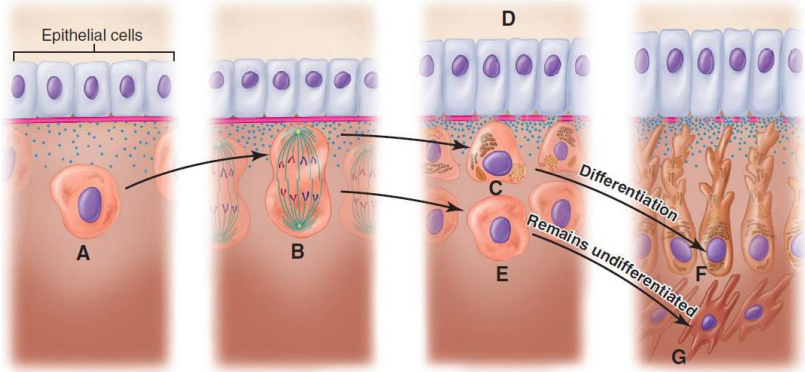
# Maturation Stage (Week 18+)

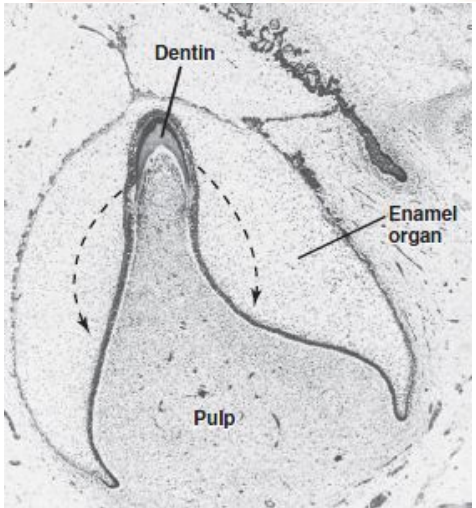
- Matrix of the hard tissues subsequently mineralise
- Ameloblasts then work on actively transporting minerals and proteins – inorganic material (ruffle – ended ameloblasts, increase SA, introduce more inorganic materials)
- Ameloblasts then undergo morphologic changes (decrease in height and volume of organelles) for the removal of water and organic material (smooth – ended ameloblasts)
- After ameloblasts finish their job – become part of the REE which fuses with the oral mucosa – creates a canal for the enamel cusp tip to erupt
    - Dormant stage – protection and inactivity

# Dentinogenesis

# Differentiation of odontoblasts

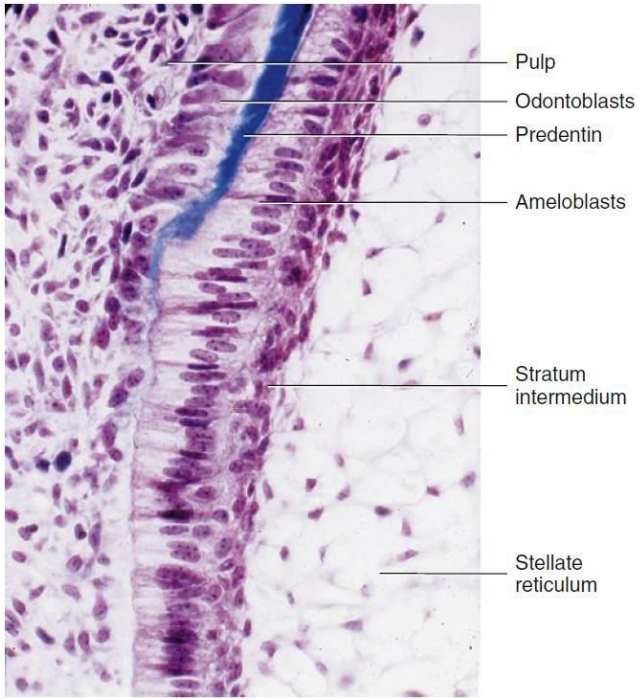
- Dental papilla cells (preodontoblasts) > odontoblasts
  - Signalling molecules from inner enamel epithelium (IEE)
  - Odontoblasts are bigger in size, highly polarized and have more protein-synthesizing organelles
- 1 Dental papilla cell > 2 cells (1 terminally differentiated odontoblast & 1 undifferentiated)
  - Undifferentiated serves as a reservoir for damage
- The whole formation occurs in a cusp tip to root direction



# Mantle dentine formation & dentine mineralisation

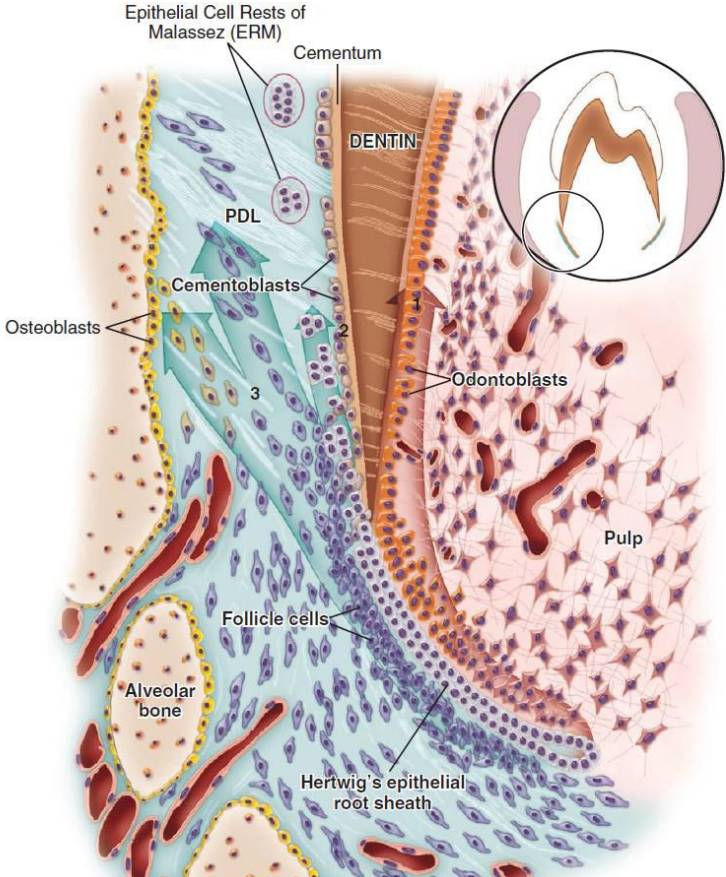
- Odontoblasts develops stubby processes and lay down organic matrix (Predentin)
- Appearance of matrix vesicles signals start of mineralisation
    - Predentine mineralizes to form mantle dentine
- Reciprocal induction occurs (mentioned in slide 10)
- Odontoblasts move towards center of dental papilla as they deposit dentine
- 2 patterns of dentine mineralisation - depends on rate of dentine formation
    - Globular - faster
    - Linear - slower



# Cementogenesis

# Cementogenesis

- Occurs during late bell stage & coincides with tooth eruption
- OEE and IEE converges into a cervical loop that proliferates apically > Hertwig's epithelial root sheath
- Onset of root dentinogenesis > formation root sheath fragments
    - Fragments form epithelial cell rests of malassez (ERM)
    - ERM may be involved in periodontal repair & regeneration
- Contact between dentine and inner follicle cells (due to fragmentation of root sheath) > follicle cells differentiate into cementoblasts



# Multirooted teeth

- Ingrowths determined by areas of low vascularity

**Some Key Molecules in the Periodontium**

| | SUGGESTED FUNCTION RELATED TO CEMENTOGENESIS |
|---|---|
| **Growth Factors** | |
| Transforming growth factor β superfamily (including bone morphogenetic proteins) | Reported to promote cell differentiation and subsequently cementogenesis during development and regeneration. |
| Platelet-derived growth factor and insulin-like growth factor | Existing data suggest that platelet-derived growth factor alone or in combination with insulin-like growth factor promotes cementum formation by altering cell cycle activities. |
| Fibroblast growth factors | Suggested roles for these factors are promoting cell proliferation and migration and also vasculogenesis—all key events for formation and regeneration of periodontal tissues. |
| **Adhesion Molecules** | |
| Bone sialoprotein<br>Osteopontin | These molecules may promote adhesion of selected cells to the newly forming root. Bone sialoprotein may be involved in promoting mineralization, whereas osteopontin may regulate the extent of crystal growth. |
| **Epithelial/Enamel Proteins** | Epithelial-mesenchymal interactions may be involved in promoting follicle cells along a cementoblast pathway.<br>Some epithelial molecules may promote periodontal repair directly or indirectly. |
| **Collagens** | Collagens, especially types I and III, play key roles in regulating periodontal tissues during development and regeneration.<br>In addition, type XII may assist in maintaining the periodontal ligament space versus continuous formation of cementum. |

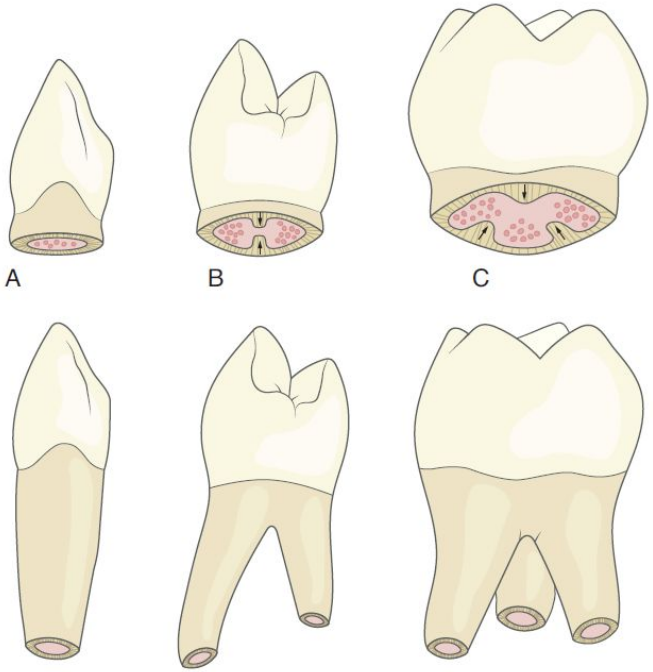
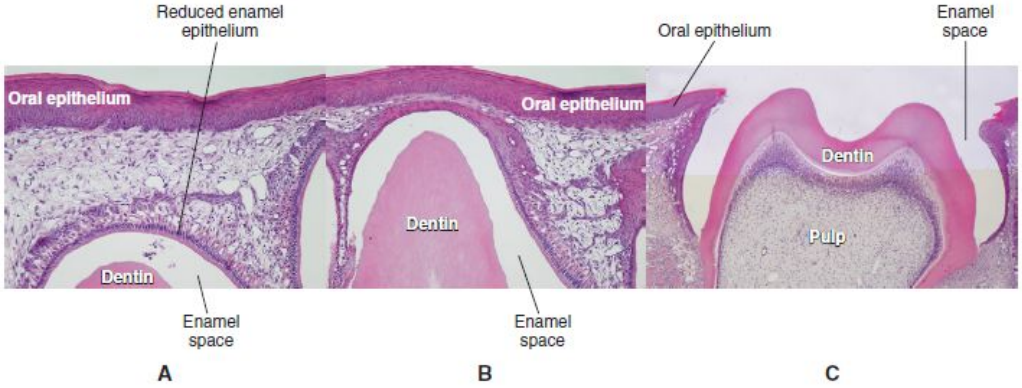



**Fig. 25.1** The formation of a single-rooted tooth (A), a two-rooted tooth (B) and a three-rooted tooth (C). Small red circles indicate vascular concentrations.

# Tooth eruption

1. Starts after initiation of root development
2. Formed enamel covered by layer of reduced enamel epithelium
3. Resorption of overlying bone
4. Crown passes through CT
5. Outer cells of reduced enamel epithelium proliferate
    a. Collagen degradation so crown can pass through CT
6. Degeneration of overlying fibroblasts within CT
7. Reduced enamel epithelium fuses with oral epithelium forming a mass of epithelium over the crown
    a. Central cells in the mass degenerate to form epithelial canal for tooth to erupt into oral cavity



# Dental Age
# &
# Timing of Development

# Calcifications (Crown)

## Primary Teeth Calcifications

- Central incisors - ¾ crown
- Lateral incisors - ½ crown
- Canines - ⅓ crown
- First molars - only cusps but united (calcified junctions between cusps)
- Second molars - only cusps, calcification not joined (isolated)

## Secondary Calcifications (Occurs postnatally) - Important

- 1 - 3 months
- 2 (Md) - 5 months
- 3 - 5 months
- 2 (Mx) - 1 year
- 4 - 1 ½ - 2 ¼
- 5 - 2 ½ - 3 ½
- 6 - Birth
- 7- 2 ½ - 3 ½
- 8 - 7 - 12

# Calcification (Root)

**Primary Root Formation**

Central incisors - 1.5 years

Lateral incisors - 2 years

Canines - 3 ⅓ years

First molars - 2.5 years

Second molars - 3.5 years

Terminology

Teeth emerge into the oral cavity when approximately 75% of the root has been formed

- Eruption = movement of tooth from the non-functional alveolar process to its final functional position in the occlusal plane
  Emergence = point at which the tooth has breached the oral mucosa (visually seen)

To complete calcification

- Crowns always take four years (except for the 6s)
- Incisor roots take 4-5 years
- Other tooth roots- canines, premolars, molars- take 7-8 years
- Apical closure takes 3 years after emergence
- 6s develop faster, 3 years for crown, 4 for root

# Tooth eruption times

There are variations of tooth eruption times between different textbooks but these are the ones we used. Can check with Dr Hughes for the exact times he wants.

**Tooth Eruption**

| | Primary Teeth | | | | |
|---|---|---|---|---|---|
| **Teeth** | *Central Incisor* | *Lateral Incisor* | *Canine* | *1st Molar* | *2nd Molar* |
| **Mx** | 10 months | 11 months | 1 year 6 months | 1 year 4 months | 2 years 5 months |
| **Md** | 8 months | 1 year 1 month | 1 year 8 months | | 2 year 3 months |

| | Permanent Teeth | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Teeth** | *Central Incisor* | *Lateral Incisor* | *Canine* | *1st Premolar* | *2nd Premolar* | *1st Molar* | *2nd Molar* | *3rd Molar* |
| **Mx** | 7-8 years | 8-9 years | 11-12 years | 10-11 years | 10-12 years | 6-7 years | 12-13 years | 17-21 years |
| **Md** | 6-7 years | 7-8 years | 9-10 years | 11-12 years | 11-12 years | | 11-13 years | |

Credit: Jessica Thai

# Calculating Dental Age + Timing of Dental Development

FORMULA:

Dental age = (% crown development x 3/4) + (%root development x 4-5/7-8) + time of initial calcification

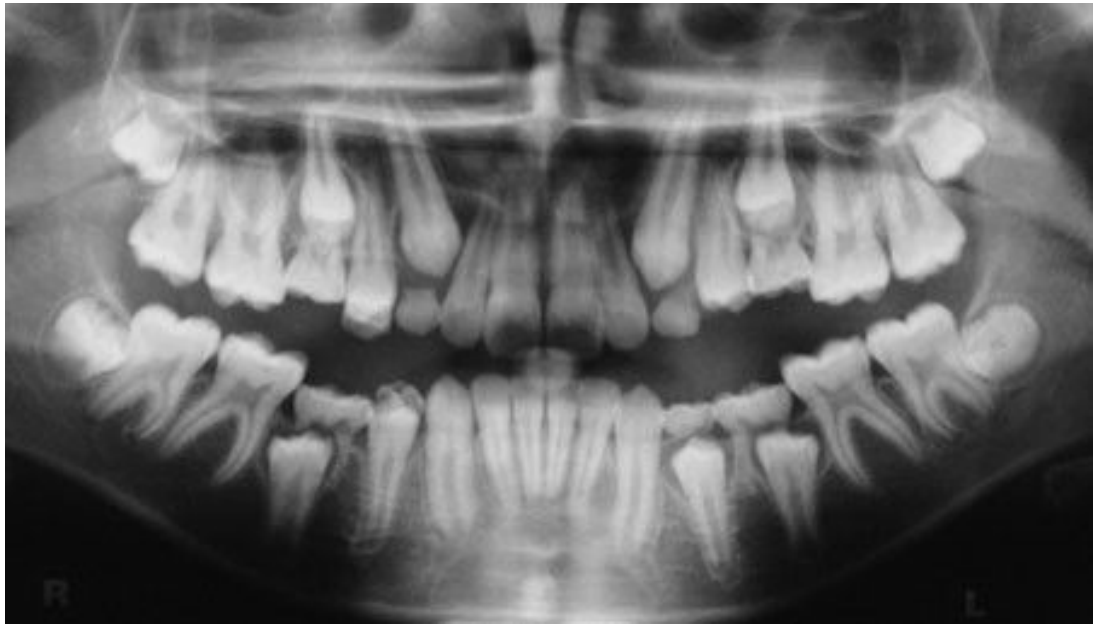
In COMBINATION WITH:

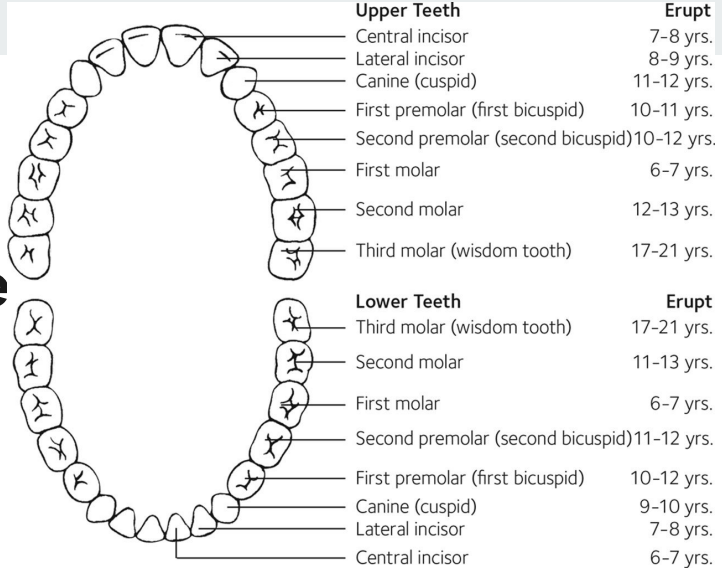
- Eruption times
- Give a range of ages (>7 years or 7-9 yo)
    - EG. 36 - fully developed crown and root = pt is over the age of 7
- Pick 2-3 teeth, calculate and then average to get more reliable result

FINAL STATEMENT:

- EG. Therefore, pt is approximately 12 years old

# Practice Question - Estimating De






Credit: Roberts et.al, 2008)

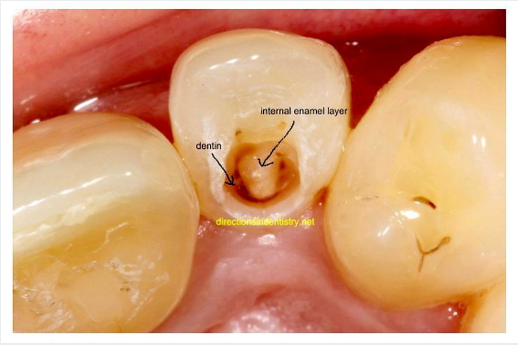
# Developmental abnormalities

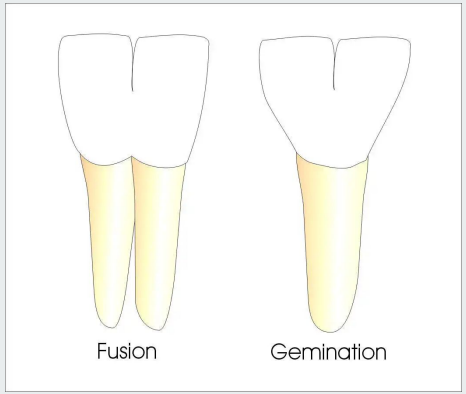
# Stages of odontogenesis & associated disturbances

The type of tooth defects are related to the stage of odontogenesis in which the disturbance has occurred.

| Stage of odontogenesis | Disturbance |
|---|---|
| Initiation (number of teeth) | Anodontia (absence of all teeth, rare)<br>Supernumerary teeth |
| Bud (size) | Microdontia<br>Macrodontia |
| Cap (shape of tooth) | Dens in dente<br>Germination<br>Fusion<br>Tubercle |
| Apposition & maturation | Amelogenesis & dentinogenesis imperfecta<br>Concrescence<br>Enamel Pearl |

# Cap stage anomalies




Dens in dente

- Literal meaning = tooth in a tooth
- Due to inward folding of the enamel organ into the dental papilla

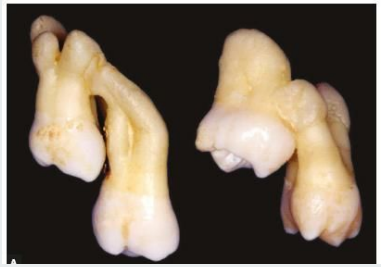
Germination

- Partial development of 2 teeth from a single tooth following incomplete division

Fusion

- Union between dentine &/or enamel of 2 or more separate developing teeth before calcification

# Concrescence, enamel pearl & taurodontism



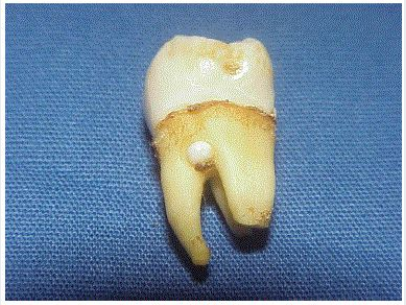
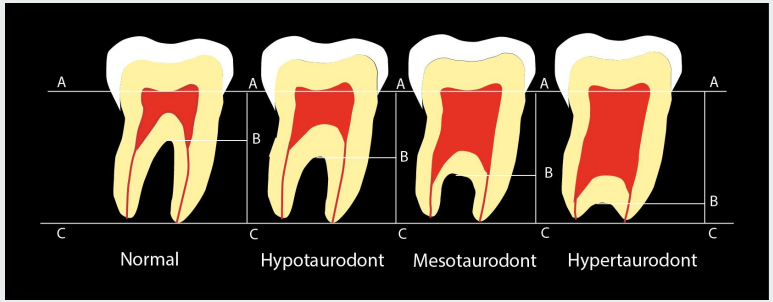


Fig. 1. Clinical appearance of spherical enamel pearl located in the furcation region of the root.




Concrescence

- Roots of one or more teeth united by cementum after formation of crowns (usually in 3rd molars)

Enamel pearl

- Localised formation of enamel on the root surface

Taurodontism

- Enlarged pulp chamber and apically displaced furcations
- Have different subtypes

# Causes of developmental defects

**Genetic/systemic causes (cause generalised disturbances)**

- Mutations in genes (e.g., ENAM, AMELX, MMP20, KLK4 with AI)
- Syndromes and multisystem disorders

**Environmental causes**

- Localised disturbances:
  - Localised infection of deciduous teeth
  - Irradiation→ can disturb development of teeth lying in path of the radiation beam (e.g., childhood cancer therapy)
  - Trauma to deciduous teeth (often Mx. incisors)
- Generalised disturbances
  - Malnutrition (e.g., Vit A deficiency)
  - Excessive ingestion of fluoride during permanent tooth development
  - Medical conditions/infectious diseases/fever/drugs
  - Antibiotics (e.g., tetracycline)
  - Low birth weight

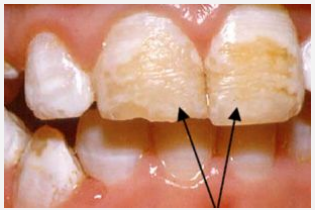
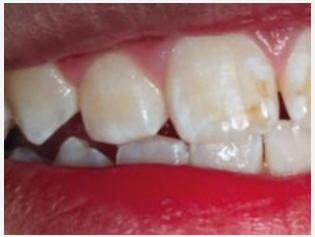
# Other causes

Just for reference.

**Table 2.3** List of etiological factors, reported in the literature, responsible for the formation of enamel defects in the permanent dentition

| | Systemic | | |
|---|---|---|---|
| Local | Perinatal and neonatal | Postnatal | Hereditary conditions |
| Trauma<br>Primary tooth<br>Surgery<br>Distraction osteogenesis<br>Tooth forceps | Neonatal hypocalcemia | Nutritional and gastrointestinal disturbances resulting in hypocalcemia and vitamin D deficiency | 22q11 deletion syndrome |
| Chronic periapical infection in a primary tooth | Severe perinatal and neonatal hypoxic injury | Bacterial and viral infections associated with high fever | Autoimmune polyendocrinopathy-candidiasis-ectodermal dystrophy |
| Cleft lip and palate | Prolonged delivery | Exanthematous diseases | Candidiasis endocrinopathy syndrome |
| Radiation | Prematurity | Juvenile hypothyroidism | Cleidocranial dysostosis |
| Burns | Low birth weight | Hypothyroidism | Celiac disease |
| Osteomyelitis | Twins | Hypogonadism | Congenital adrenal hyperplasia |
| Jaw fracture | Cerebral injury | Phenylketonuria | Congenital contractual arachnodactyly |
| | Neurological disorders | Alkaptonuria | Congenital unilateral facial hypoplasia |
| | Hyperbilirubinemia | Renal disorders | Ectodermal dysplasias |
| | Prolonged neonatal diarrhea and vomiting | Congenital heart disease | Ehlers-Danlos syndrome |
| | Severe neonatal infections | Congenital allergy | Epidermolysis bullosa |
| | High fever | Oxalosis | Focal dermal hypoplasia |
| | | Mercury poisoning (acrodynia) | Heimler's syndrome |
| | | Fluoride | Hypoparathyroidism |
| | | Prolonged use of medicines | Ichthyosis vulgaris |
| | | Prolonged diarrhea and vomiting | Lacrimo-auriculo-dento-digital syndrome |
| | | Radiation and cytotoxic therapy | Morquio syndrome |
| | | | Mucopolysaccharidosis |
| | | | Oculodentodigital dysplasia |
| | | | Orodigitofacial dysostosis |
| | | | Prader-Willi syndrome |
| | | | Pseudohypoparathyroidism |
| | | | Seckel syndrome |
| | | | Tricho-dento-osseous syndrome |
| | | | Tuberous sclerosis |
| | | | Vitamin D-resistant rickets |
| | | | William's syndrome |

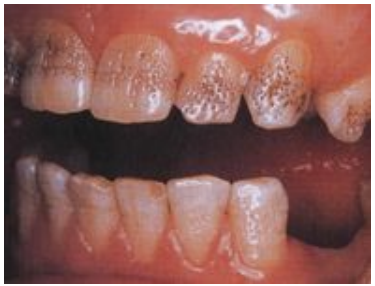
# Hypomineralisation and hypoplasia

| Developmental defect | Cause | Clinical appearance |
|---|---|---|
| Hypoplasia  | Quantitative defect in enamel caused by insufficient deposition of the enamel matrix. If related to a certain time period is called chronological hypoplasia. | Pits, grooves or bands on the tooth &/or thinner enamel. Can be localised or generalised, affecting the whole crown or parts of the crown. |
| Hypomineralisation  | Qualitative defect involving defective mineralisation of the tooth. Amount of enamel matrix deposition remains normal. | Presents as changes in colour & translucency due to spaces/pores in enamel which are filled with water/protein (changed reflective index). Shiny white or stained opaque patches, lines, spots, with distinct or indistinct boundaries. In severe cases, there is also pitting, grooves in the teeth and potential flaking. |

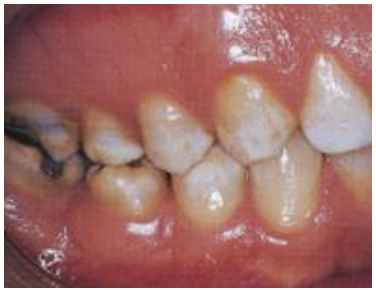
*If the hypomineralisation/hypoplasia is caused by excessive fluoride ingestion during permanent tooth development, this is called fluorosis (only affects permanent dentition).*

# Amelogenesis imperfecta

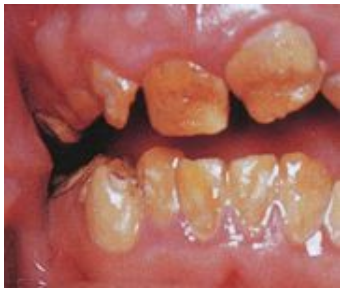
- Enamel defects caused by the mutation in genes encoding enamel matrix proteins
  - Autosomal types: ameloblastin, enamelin, tuftelin
  - X-linked: amelogenin
- Subtypes include: hypoplastic, hypomaturation and hypocalcified/hypomineralisation amelogenesis imperfecta
- Diagnosis includes: family history, clinical observation (should present at eruption affecting permanent and primary teeth), radiographs
- Clinical implications: tooth discoloration, tooth sensitivity, post-eruptive and pre-eruptive disintegration



*Hypoplastic AI*



*Hypomaturation AI*

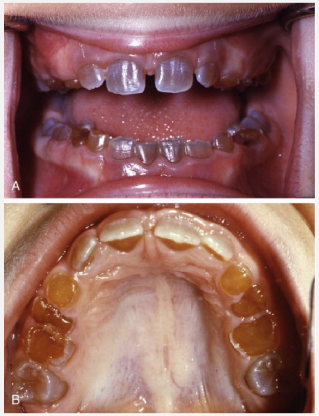


*Hypocalcified/hypomineralisation AI*

# Amelogenesis imperfecta subtypes

| Developmental defect | Cause | Clinical appearance |
|---|---|---|
| Hypoplastic AI | Hypoplasia = quantitative defect, usually resulting from abnormalities of proteins that form or degrade the enamel matrix | Thin enamel, surface pitting or grooving. |
| Hypomaturation AI | Qualitative defect due to defective maturation (defect in final growth of tissue with deposition of inorganic material and removal of organic material) | Opaque, white, brown-yellow, soft, vulnerable to attrition |
| Hypomineralisation/ hypocalcified AI | Qualitative defect due to defective mineralisation (defect in initial crystal growth and formation) | Enamel thickness normal at eruption, opaque, chalky appearance, stains and wears rapidly. |

# Dentine defects

| Developmental defect | Cause | Clinical presentation |
| --- | --- | --- |
| Dentinogenesis imperfecta  | An uncommon defect of dentine formation. Due to genetic mutations inherited in an autosomal dominant way (dentine sialoproteins affected). | Affects both dentitions. Normal contour at eruption but distinctive translucent opalescent or amber-like hue. Enamel is weakly attached to dentine, resulting in enamel being rapidly lost-> marked attrition (DEJ flat, not scalloped). Radiographically the teeth have short, blunt roots with partial or total obliteration of pulp chambers |

- Other dentine defects include: osteogenesis imperfecta with hereditary opalescent dentine, shell teeth, dentinal dysplasia
- Regional odontodysplasia (ghost teeth)- all dental tissues affected

# Differential diagnosis + onset & duration of disturbance

**Consider for differential diagnosis:**

- Localised vs. generalised
- Are the primary and/permanent teeth affected.
- Bilateral/symmetrical upper/lower.
- If family pattern is similar or not
- SHX & Mhx of prenatal mother and young child
- Caries risk and location of the lesion

How to calculate the onset and duration of an environmental disturbance:

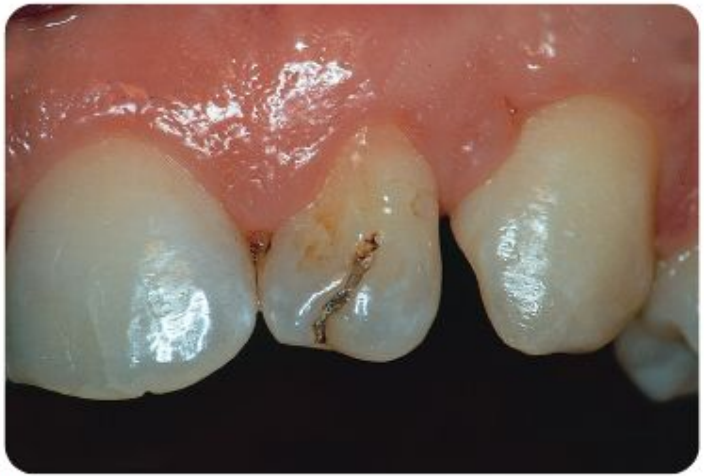
**Onset**: Age at which calcification begins for the tooth + (fraction where the disturbance starts **from the incisal edge/cusp tip**) x crown formation time (3 or 4yrs)

**Duration**: vertical width of the defect as a fraction x crown formation time (3 or 4yrs)

# Exam Style Questions

# Question 1

What are 2 possible causes of this developmental defect?



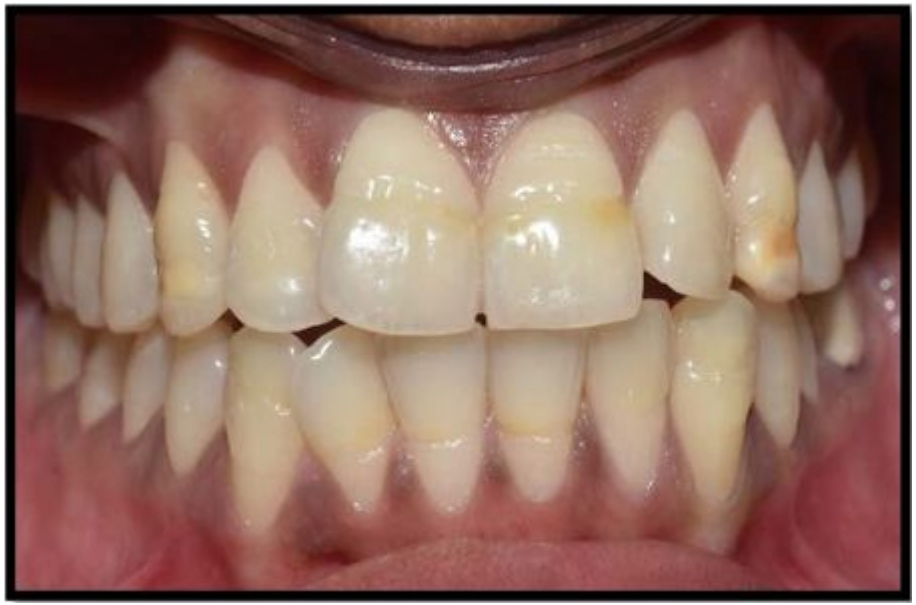
(B)

(Wright 2015)

Answer:

- In this image we can see a hypoplastic defect localised to the 22.
- Localised causes of defects include:
  - Localised infection of deciduous teeth
  - Irradiation→ can disturb development of teeth lying in path of the radiation beam (e.g., childhood cancer therapy)
  - Trauma to deciduous teeth (often Mx. incisors)
- Likely cause would be trauma or localised infection of the deciduous predecessor

# Question 2



(Bansode et at., 2019)

Sarah, a 16 year old girl has presented at your dental clinic with a complaint of ugly looking teeth. She says that all her adult teeth have looked scratched like this all her life but her baby teeth were normal. There was no family history of this defect.

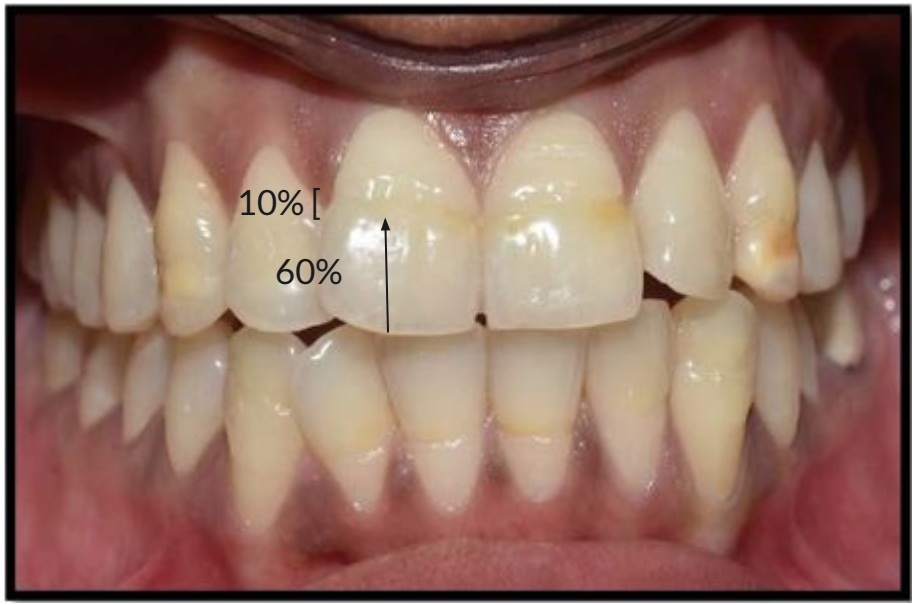
1. Briefly describe the tooth defect.

Generalised linear grooves on the buccal surfaces of all teeth. Localised brownish white shiny patches on the 13, 21, 23. (Can also go into more detail about the exact location on the buccal surfaces).

2. What is your differential diagnosis & why?

Chronological hypoplasia as there is a qualitative loss of enamel without a history of genetic disease.

# Question 2




(Bansode et at., 2019)

3. What are 2 possible causes of this defect?

Causes would be environmental disturbances causing generalised defects. 2 examples would be malnutrition and systemic disease during permanent tooth development.

4. What would the onset and duration of the disturbance be?

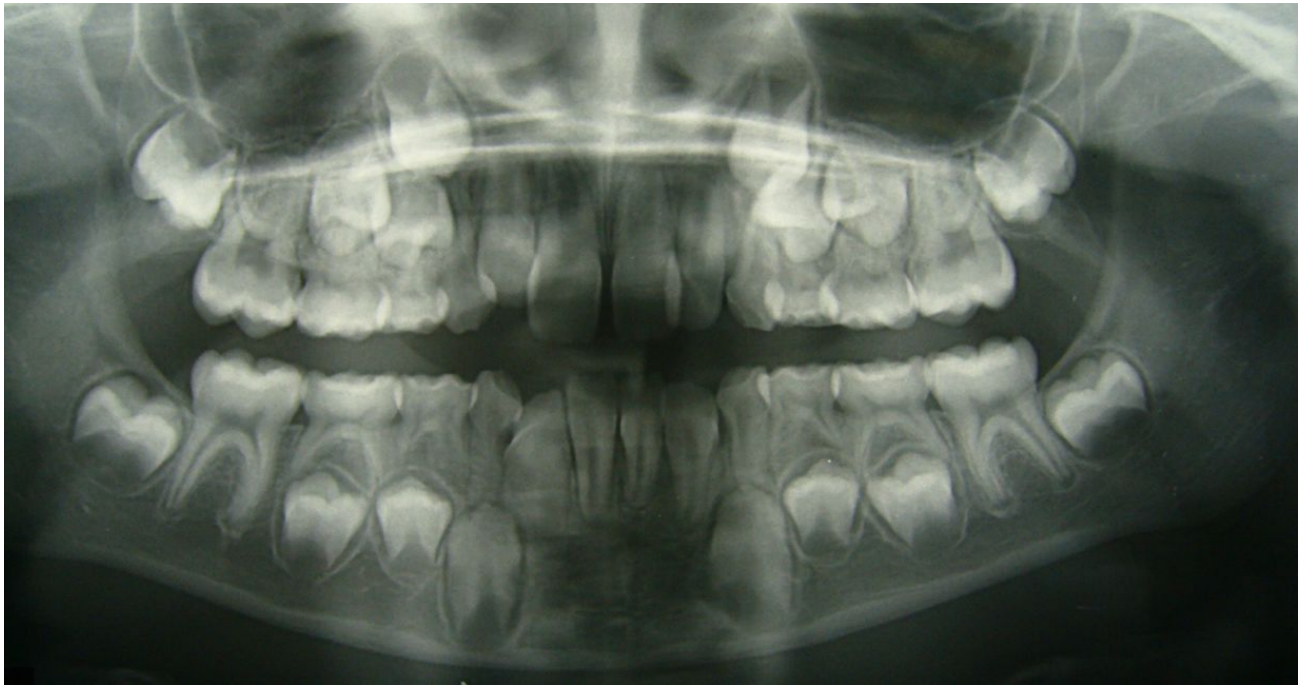
Onset: using the 11 & 21, the defects starts about 60% down from the incisal edge.

Onset = 3 months (calcification begins) + 0.6 (how far down the disturbance starts) x 4yrs (crown development) = about 2.5 years old

Duration: check how wide the defect is vertically

10% x 4 yrs = around 5 months

# Question 3: Calculate the dental age.



# Textbook recommendations

E-BOOK **Ten Cate's oral histology : development, structure, and function**

Nanci, Antonio,, Ten Cate, A. R., 8th ed., St. Louis, Missouri :, Elsevier, [2013], Total Pages 1 online resource (407 p.)

Text Book  Add tags to item

E-BOOK **Craniofacial and Dental Developmental Defects [electronic resource] : Diagnosis and Management**

Wright, J Timothy., 1st ed. 2015., Cham :, Imprint Springer; Springer International Publishing , 2015., Total Pages 1 online resource (131 p.)

Text Book  Add tags to item

View online

1

BOOK

**Pathology of the Hard Dental Tissues; 1. Aufl.**

Schuurs, Albert; 2012

*“ This is a seminal text uniquely dedicated to oral hard tissue pathology, presenting the growth of clinical knowledge and advancement in the field in recent years... “*

Online >