ODONTOGENESIS & tooth abnormalities.

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01

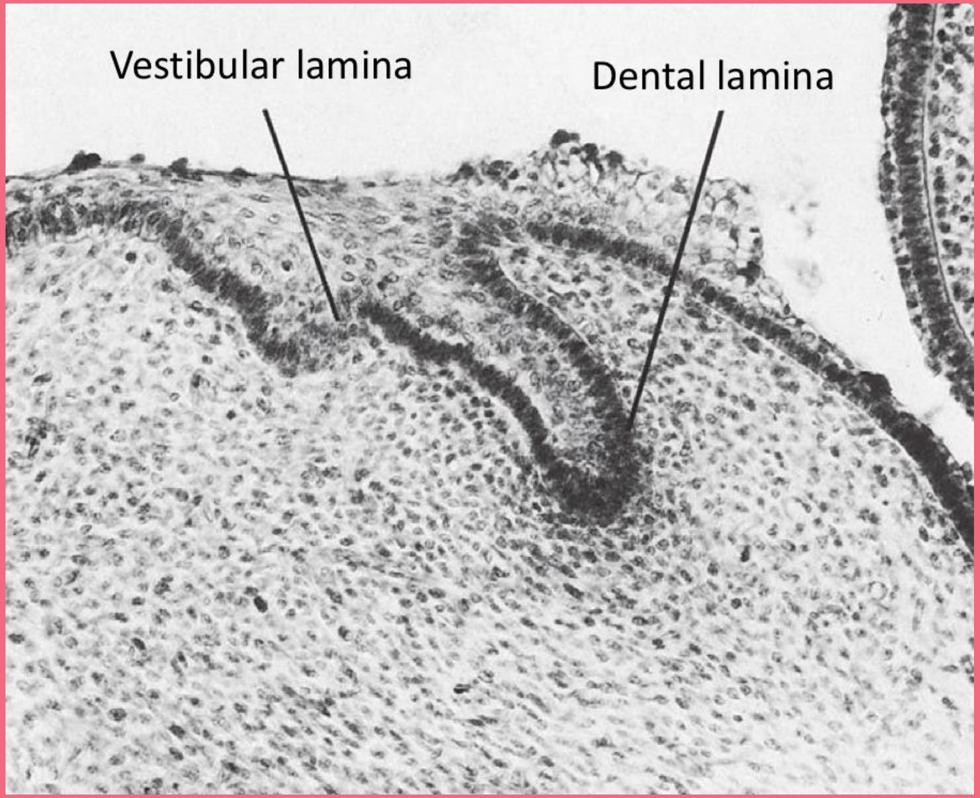
EARLY ODONTOGENESIS

WHAT DO YOU NEED TO KNOW?

- What occurs in initiation
- Three primary stages - bud, cap and bell (also apposition and maturation)
- How to recognise each stage in a histological slide
- What cells are present in each stage + functions
- What tissues are formed from the products of each stage
- Rough timelines of when each stage occurs
- What HOX genes are associated with each portion of the dentition

Early Odontogenesis – Primary Epithelial Band & Laminae

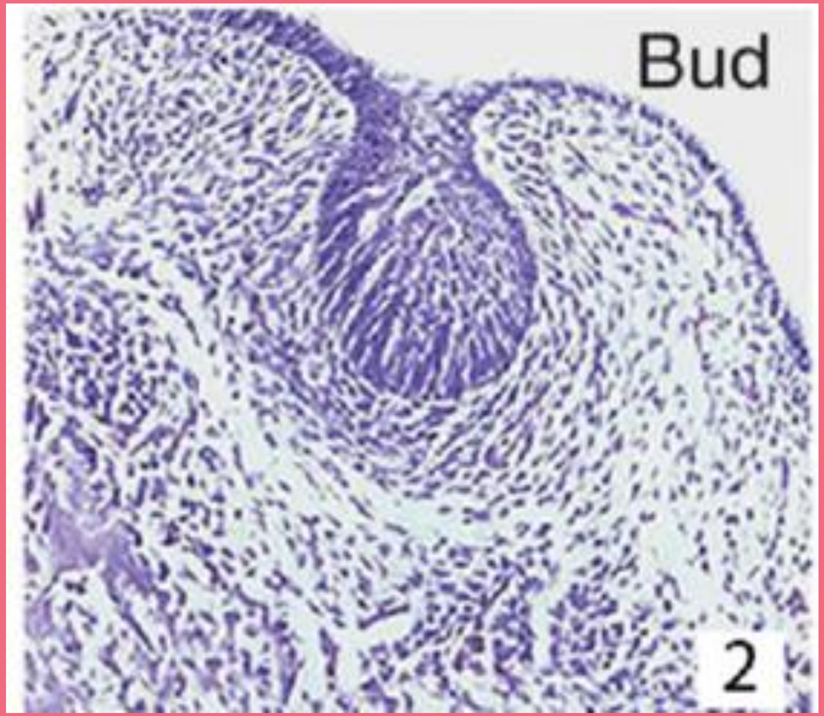
- Primary epithelial band forms in the primitive oral cavity in the **6th week**
- Forms the dental and vestibular lamina in the **7th week**
- During this week, the dental lamina grows down into the ectomesenchyme
- In the **8th week**, swellings form in the condensed ectomesenchyme - TG



Dental lamina is growing away from epithelial surface and has condensed ectomesenchyme (black spots) around it.

Early Odontogenesis - Bud Stage

- Formation of a small bud (hence the name) within the ectomesenchyme at **week 8-10**
- Continual condensation of ectomesenchyme
- Very minimal changes to cells - some histogenesis is all
- No morphology apparent as of yet



DL is the rough shape of a sphere/bud. Note the condensation of ectomesenchyme at the periphery and lack of recognisable features.

Early Odontogenesis - Cap Stage

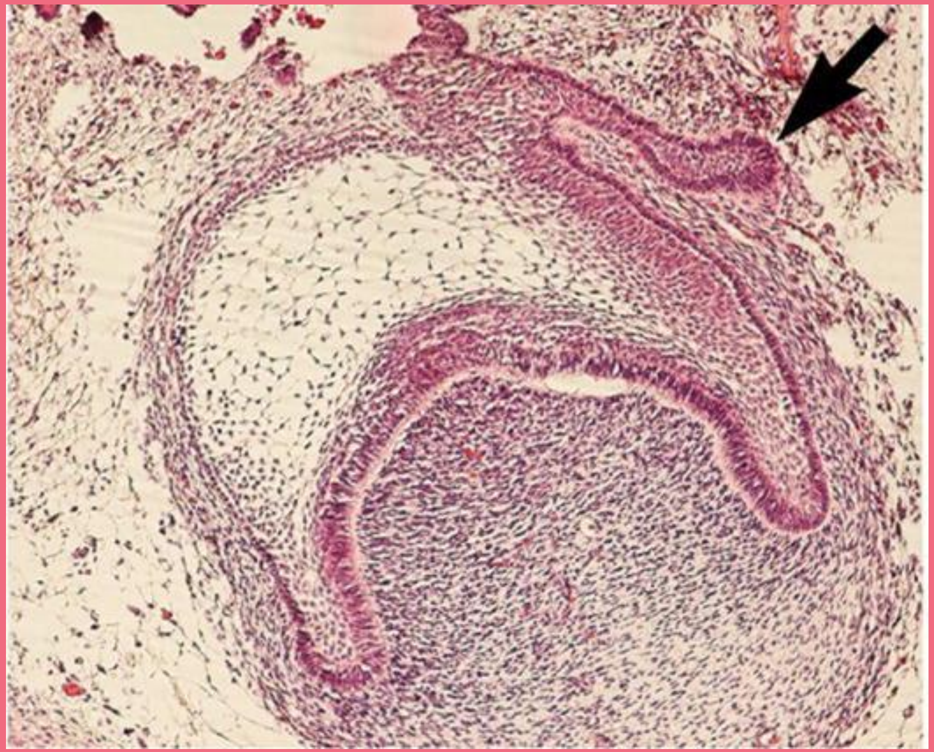
- Can be divided into early and late stages

Early stage (week 11):

- Enamel organ is recognisable above dental papilla and dental follicle/sac
- Cap shape is due to invagination of deepest portions of the bud
- This shaping is the first example of morphogenesis
- EO cells begin histodifferentiation - this process does not conclude until bell stage

Late Stage (week 12) :

- Enamel begins formation from EO
- Dentine and pulp begin formation from dental papilla
- PDL and cementum begin formation from dental sac

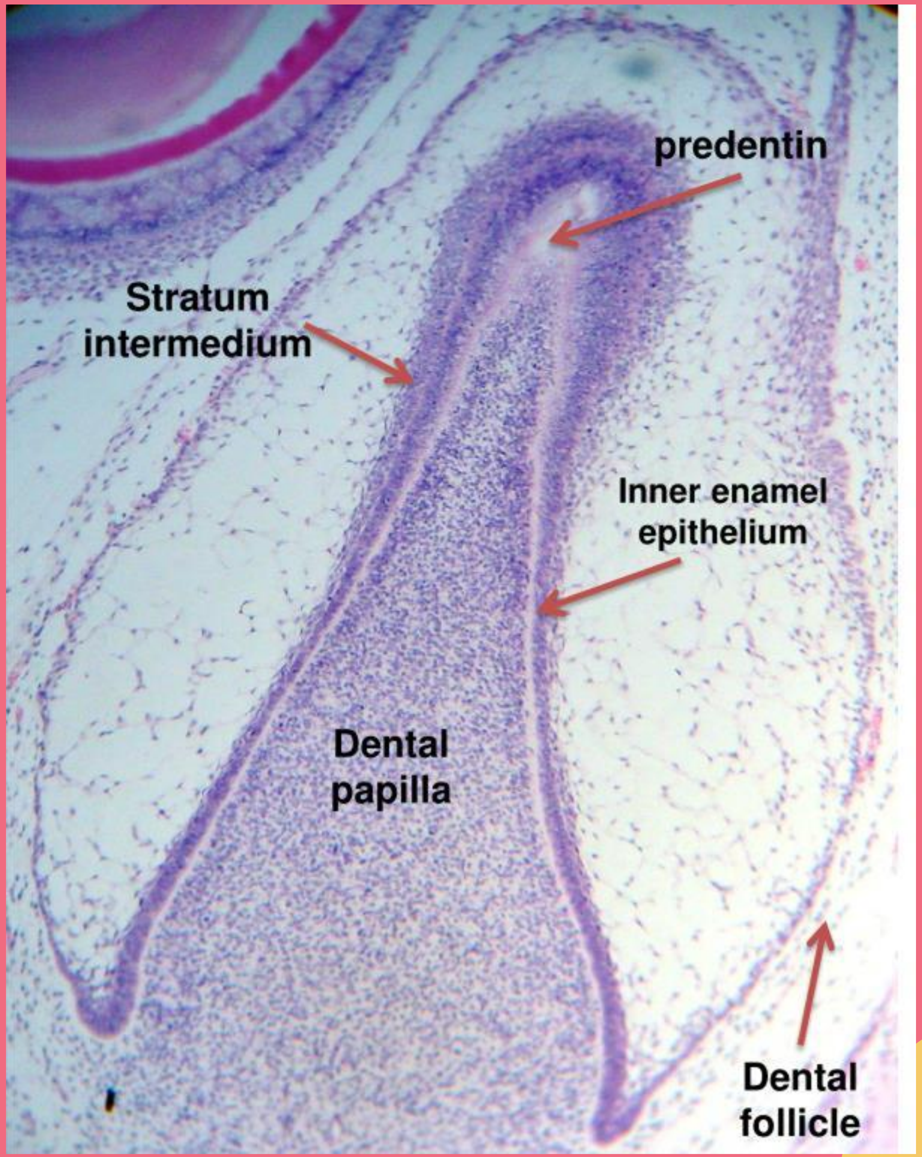


Early Odontogenesis - Bell Stage **(14 weeks)**

- Occlusal shape is formed (by IEE)
- 4 distinct cells of the EO now exist:

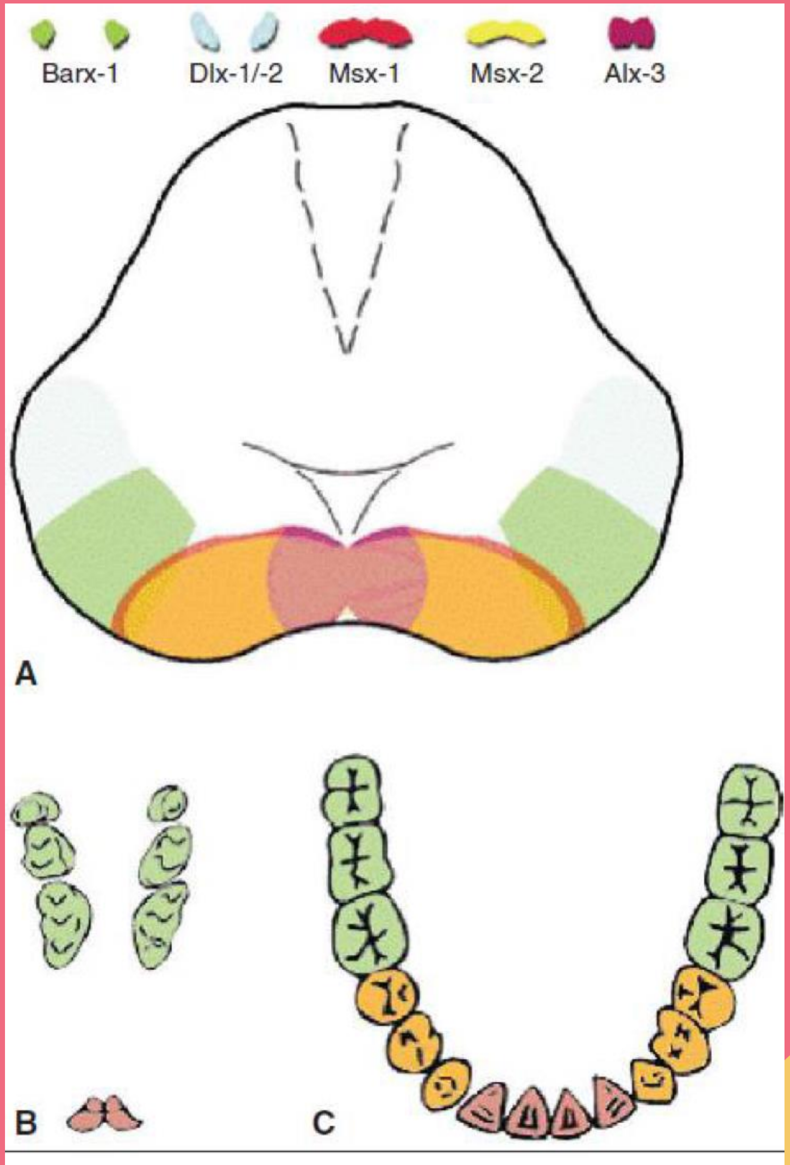
1. Stellate reticulum (star shaped): Produce GAGs to bring water into the EO and maintain shape and protect underlying components
2. Stratum intermedium (flat): Overlie IEE
3. Outer enamel epithelium (cuboidal): Assist in shape maintenance and nutrient exchange
4. Inner enamel epithelium (columnar): Precursor to ameloblasts

- Dental papilla and sac are composed of vascular and fibrous CT
- Connection to epithelium degrades and tooth germ is isolated in ectomesenchyme - rests of Serres



Early Odontogenesis - Epithelial Mesenchymal Interactions

- Proposed mechanism by which differentiation of adjacent epithelial and CT occurs
- Previously discussed for CL/P
- Dental papilla will determine if tooth germ becomes a tooth, not epithelium



02

AMELOGENESIS

WHAT DO YOU NEED TO KNOW?

- The stages of amelogenesis
- How ameloblasts interact with odontoblasts
- Where interrod and rod enamel are formed
- Proteins and genes responsible for the organic portion of enamel & what their functions are

AMELOGENSIS- STAGES

3 PRIMARY STAGES; SEPARATED INTO 7 SMALLER STAGES

PRE-SECRETORY

- Morphogenetic
- Histodifferential

SECRETORY

-Initial secretory

- Secretory

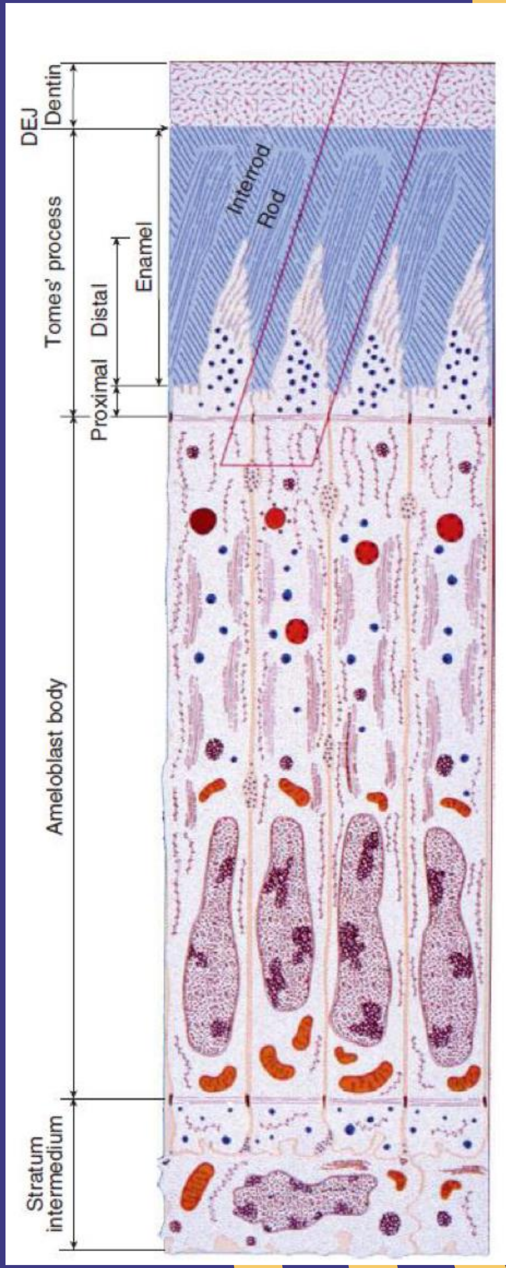
MATURATION

- Ruffle and smooth ended ameloblasts

PROTECTIVE STAGE

Amelogenesis- presecretory stage

- IEE begins with poor polarity or cytoplasmic development
- At the beginning of the differentiation phase:
- The IEE cells become columnar and become **preameloblasts**
- The nuclei move proximally (away from dentine)
- RER increase in number
- Golgi complex increase in number and move distally (towards dentin)
- **Reciprocal Induction** occurs when preameloblasts induce dental papilla cells -> odontoblasts
- Odontoblasts produce predentine, this induces preameloblasts -> ameloblasts
- Basal lamina between ameloblasts and predentin is degraded



Amelogenesis- secretory stage

- Enamel matrix acts as “scaffolding” on which HA crystals are placed
- Enamel is deposited from Tome’s process - protrusion at distal end of the ameloblast
- First layer of enamel matrix is deposited against mantle dentine - aprismatic
- Proximal surface = interrod enamel
- Distal surface - rod enamel
- Small space (rod sheath) lies between rod and interrod enamel, filled with organic material
- Ameloblasts shorten at the end of the process

Amelogenesis- maturative stage

Transitional Phase:

- 25% of ameloblasts die, reduction in height and volume of remaining ones

Modulation:

Alternation between:

Ruffle-ended ameloblasts - introducing inorganic material

-Ruffle end increases surface area, increasing rate of exchange

Smooth ended ameloblasts - removal water and organic material

Followed by dormant stage (protection & inactivity)

03

DENTINOGENESIS

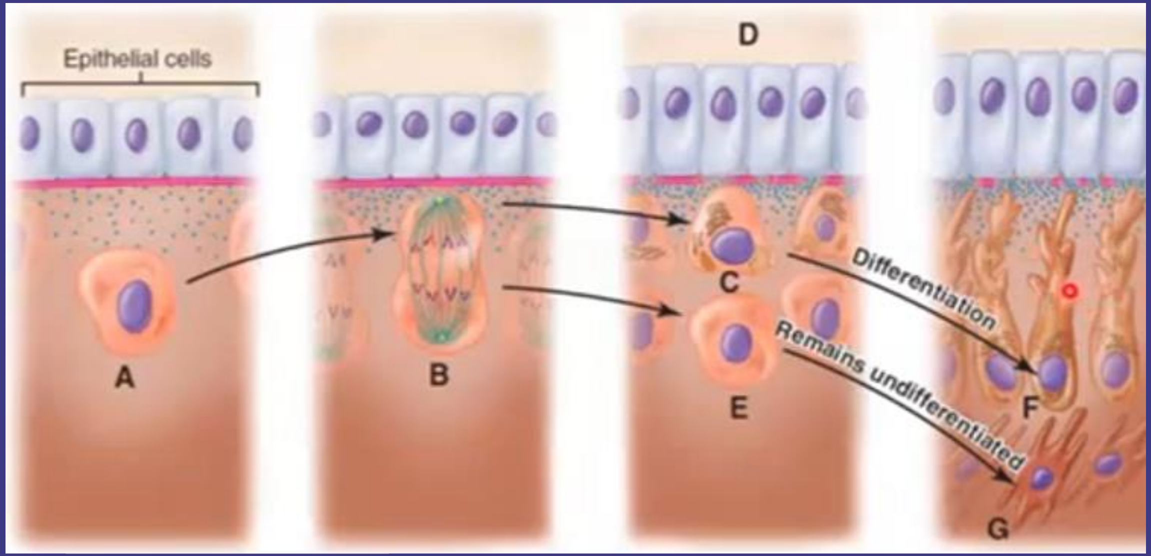
WHAT DO YOU NEED TO KNOW?

- Process of dentine formation and mineralisation
- The role of reciprocal induction and cellular communication

Dentinogenesis

Differentiation of Odontoblasts

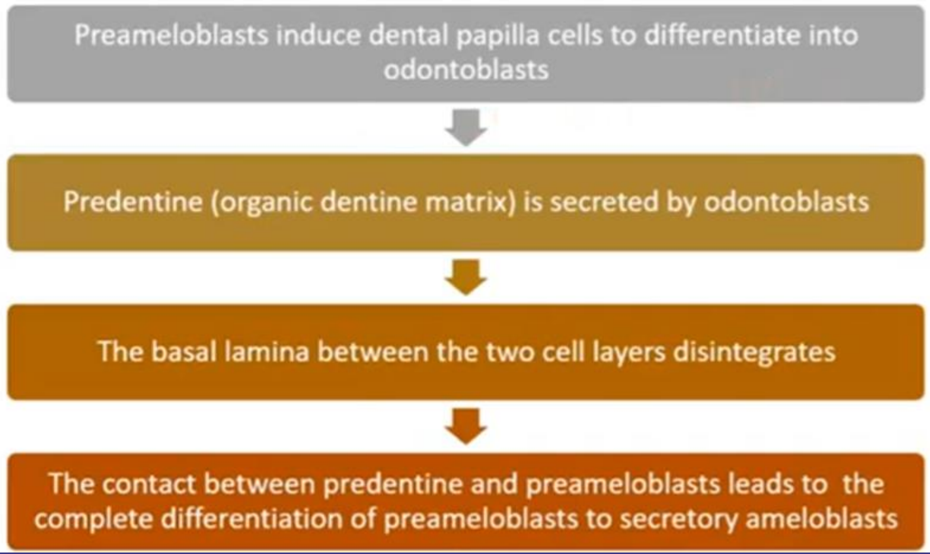
- Dental papilla cells -> preodontoblasts x 2 when induced by IEE
    - Formation begins from cusp tip to root
    - One preodontoblast terminally differentiates into odontoblasts
    - Other remains dormant - reservoir for damage

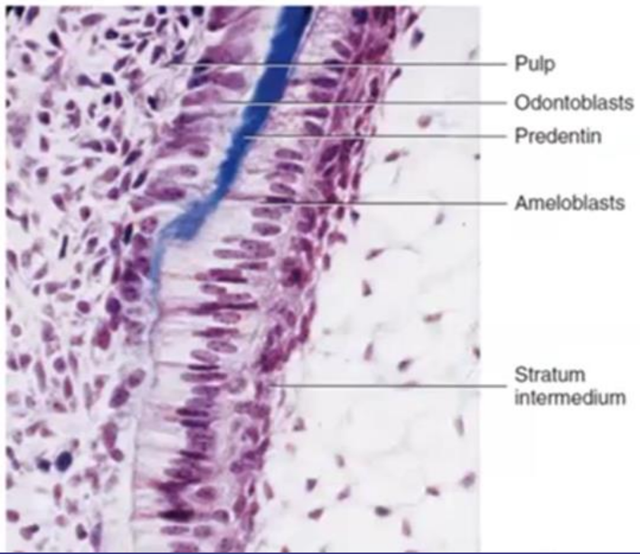


Dentinogenesis

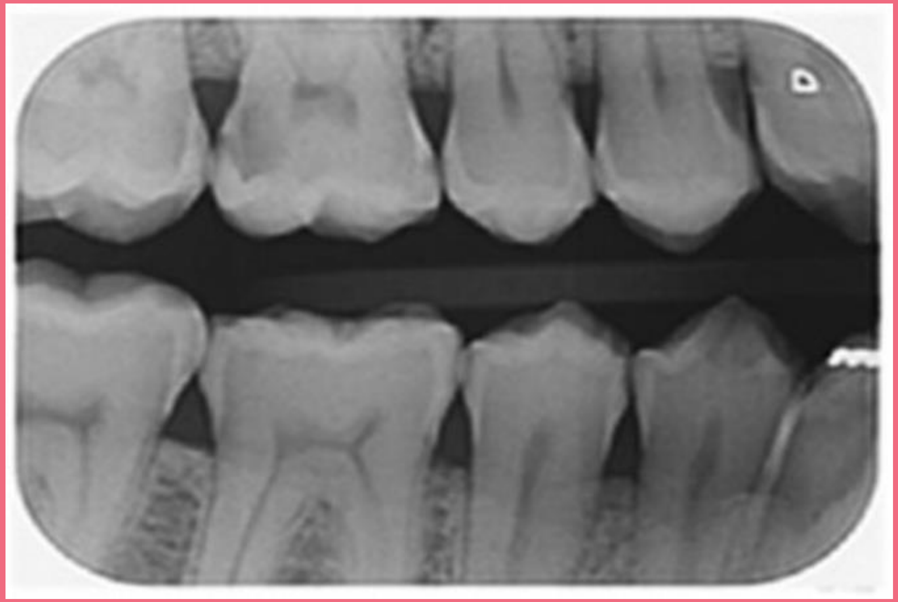
Mantle formation and mineralisation:

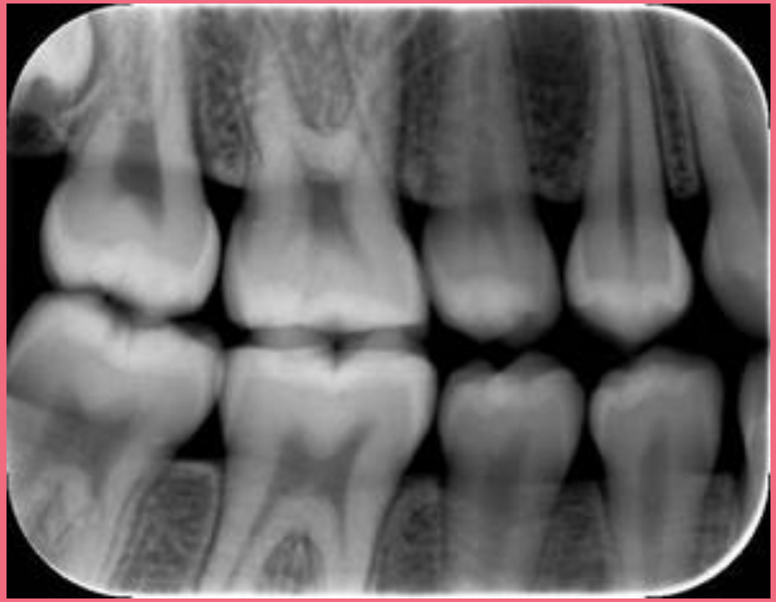
- Odontoblasts produce the initial organic matrix (predentine)
- Basal lamina between IEE and odontoblasts disintegrates
- Matrix vesicles form -> initial site of mineralisation
- Reciprocal Induction:





Case Scenario





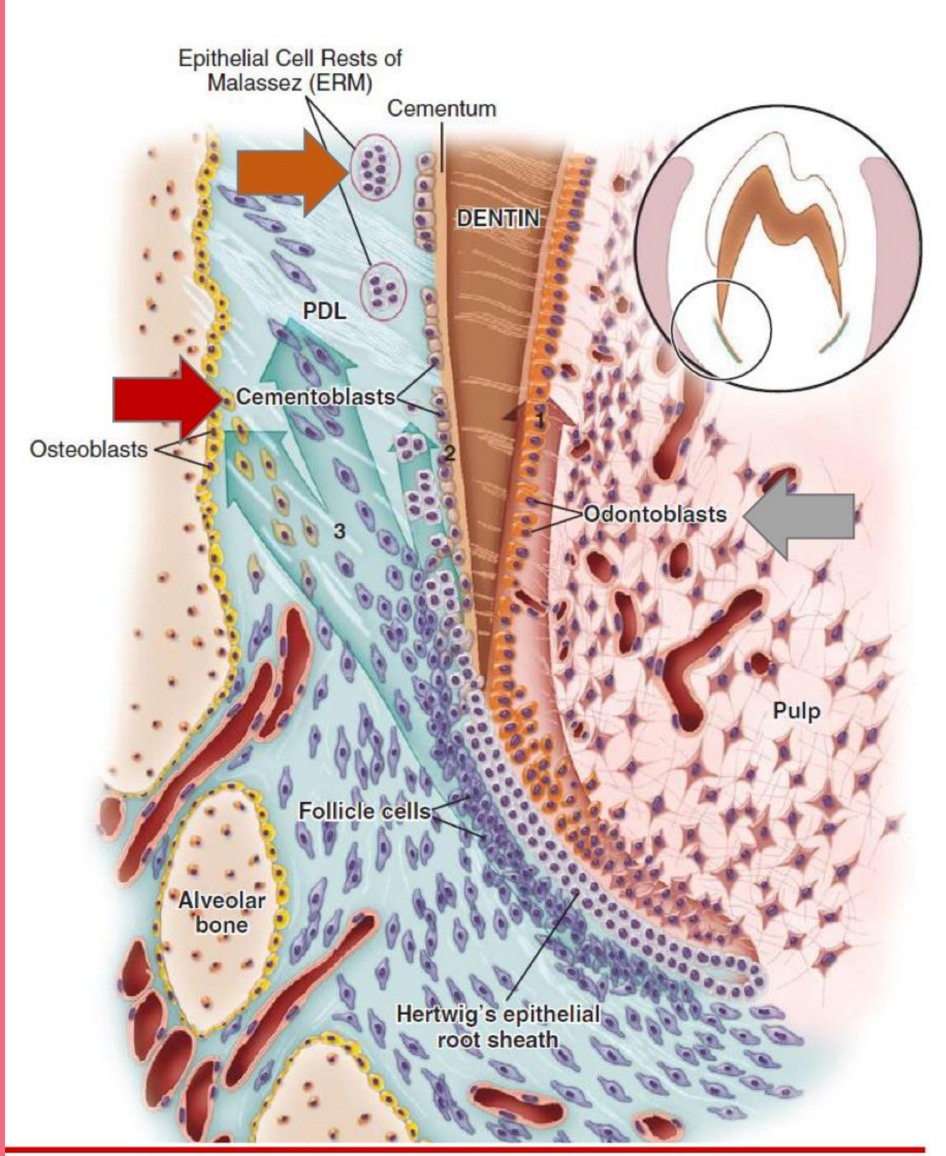
04 CEMENTOGENESIS

WHAT DO YOU NEED TO KNOW?

- Process of cementogenesis
- Terminology associated with landmarks
- What structures arise during cementogenesis

CEMENTOGENESIS

- Occurs during late bell stage, due to differentiation of dental follicle cells
- Contact between dentine and dental follicle cells -> cementoblasts
- Cementum is deposited alongside root
- During this process -> OEE and IEE unite & proliferate apically - form cervical loop (later becomes Hertwig's root sheath)
- Hertwig's Root sheath fragments also forms epithelial rest cells of Malassez (ERM cells) -> active role in PDL repair



CEMENTOGENESIS

Root formation

- In multirooted teeth, formation of ingrowths are determined by areas of low vascularity

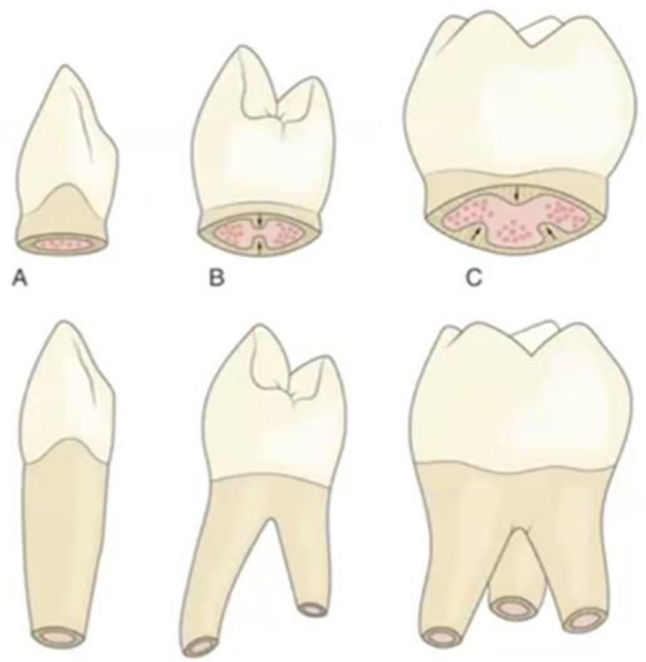


Fig. 25.1 The formation of a single-rooted tooth (A), a two-rooted tooth (B) and a three-rooted tooth (C). Small red circles indicate vascular concentrations.

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 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. 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. In addition, type XII may assist in maintaining the periodontal ligament space versus continuous formation of cementum.
Gla Proteins	
Matrix Gla protein/Bone Gla protein (osteocalcin)	These proteins contain γ-carboxyglutamic acid, hence the name Gla proteins. Osteocalcin is a marker for cells associated with mineralization—that is, osteoblasts, cementoblasts, and odontoblasts—and is considered to be a regulator of crystal growth. It has also been proposed to act as a hormone regulating energy metabolism through several synergistic functions favoring pancreatic β-cell proliferation, increasing insulin secretion (in pancreas) and sensitivity in peripheral tissues, promoting energy expenditure (in brown adipose tissue) and testosterone production by Leydig cells in testis. Matrix Gla protein appears to play a significant role in preventing abnormal ectopic calcification.
Transcription Factors	
Runt-related transcription factor 2 (Runx-2) Osterix	As for osteoblasts, these may be involved in cementoblast differentiation.
Signaling Molecules	
Osteoprotegerin Receptor-activated NF-κB ligand Receptor-activated NF-κB	These molecules mediate bone and root resorption by osteoclasts.
Cementum-specific Proteins	
Cementum protein 1 (Cementum-derived protein 23)	May play a role as a local regulator of cell differentiation and extracellular matrix mineralization.

Tooth Eruption

Starts soon after initiation of root development

↓

Formed enamel covered by a layer of reduced enamel epithelium

↓

Resorption of overlying bone

↓

Crown passes through connective tissue

↓

Outer cells of reduced enamel epithelium proliferate

- ?involved in collagen degradation

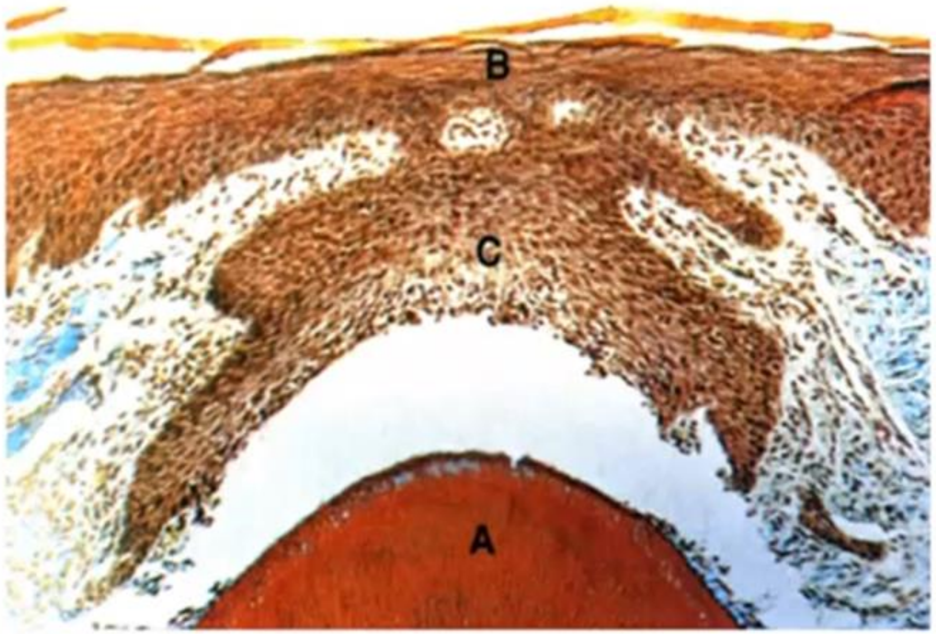
↓

Degeneration of overlying fibroblasts within the connective tissue

↓

Reduced enamel epithelium fuses with oral epithelium forming a "knot" of epithelium

- central cells degenerate to form an epithelial-lined pathway



05 DEVELOPMENTAL ANOMALIES

WHAT DO YOU NEED TO KNOW?

- Various types of developmental anomalies
- (For some types) the pathogenesis of the anomaly
- Be able to recognise different abnormalities
- Dental implications of abnormalities
- How the stage at which an anomaly occurs determines the type of anomaly

DEVELOPMENTAL ANOMALIES

STAGE	ABNORMALITY
INITIATION	Anodontia Supernumerary teeth
BUD	Microdontia/ Macrodontia
CAP	**Dens in Dente** **Gemination** **Fusion** Tubercle
APPOSITION & MATURATION	**Amelogenesis Imperfecta** Dentinogenesis Imperfecta **Concrescence** Enamel Pearl

Developmental anomalies

- Staging at which the anomaly occurs determines the type of anomaly
- Generally, it can be said that:

- An anomaly in initiation will lead to more or less teeth
- An anomaly during bud stage will lead to altered tooth sizing
- An anomaly during cap stage will affect tooth morphology *
- An anomaly during bell stage will affect a mineralised surface

Causes

Local/Environmental:

- Trauma
- Infectious agents
- Fluoride concentration
- Hormone concentration
- Antibiotics (e.g. tetracycline)

Systemic/Genetic:

- Gene mutations
- Syndromes and multi-system disorders

AMELOGENESIS IMPERFECTA

- AI = a series of genetic conditions causing change to normal enamel deposition
- Occurs due to mutation of enamel matrix proteins
- Results in hypoplastic, hypomineralised and/or hypocalcified enamel - subtypes classified on what
- Affects all teeth indiscriminately, deciduous and permanent
- Caused by mutations in the enamelin, ameloblastin, tuftelin and amelogenin genes

Symptoms and signs vary between subtypes - include discolouration, sensitivity, increased caries risk, disintegration

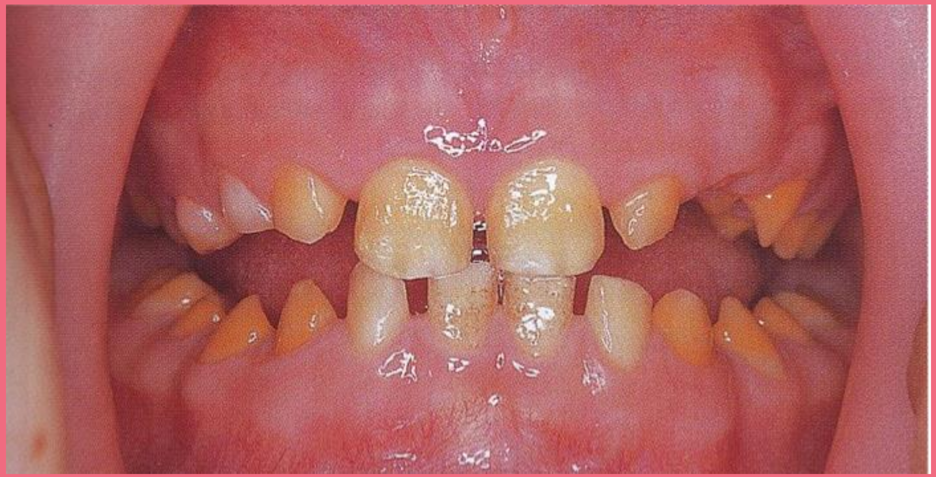
Amelogenesis Imperfecta Hypoplasia Type

- A **quantitative defect** (enamel quality is normal, but quantity is insufficient)
- Due to insufficient length of enamel matrix proteins
- (If pitting is into dentine) may cause sensitivity or harbour cariogenic bacteria

Note the pitting revealing the underlying dentine.

Amelogenesis Imperfecta Hypomineralisation Type

- A **qualitative defect** (enamel matrix quantity is normal, but quality is insufficient)
- Due to insufficient removal of organic material during amelogenesis, results in inability for mineralisation
- Can vary in colour from white to yellow to brown (in cases of mottling)
- Opacity may also vary
- **Teeth are highly susceptible to attrition**



Note the variation in opacity and colour.

Amelogenesis Imperfecta Hypocalcification Type

- Occurs due to inadequate calcification of the enamel matrix
- Enamel appears opaque, discoloured and chalky
- Stains and wears rapidly

Cap Stage Anomalies

Dens in Dente:

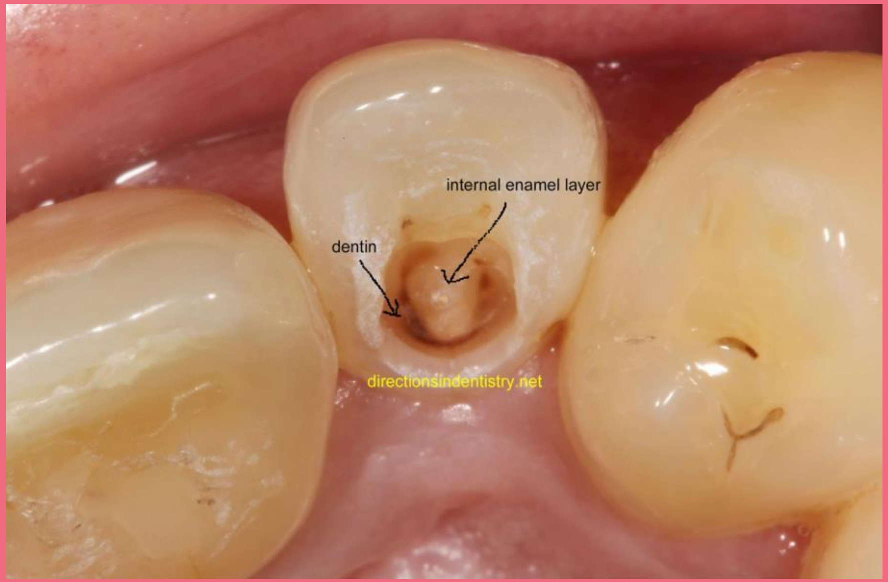
- Literally means 'tooth in a tooth'
- Refers to when a smaller 'tooth' exists within the larger tooth

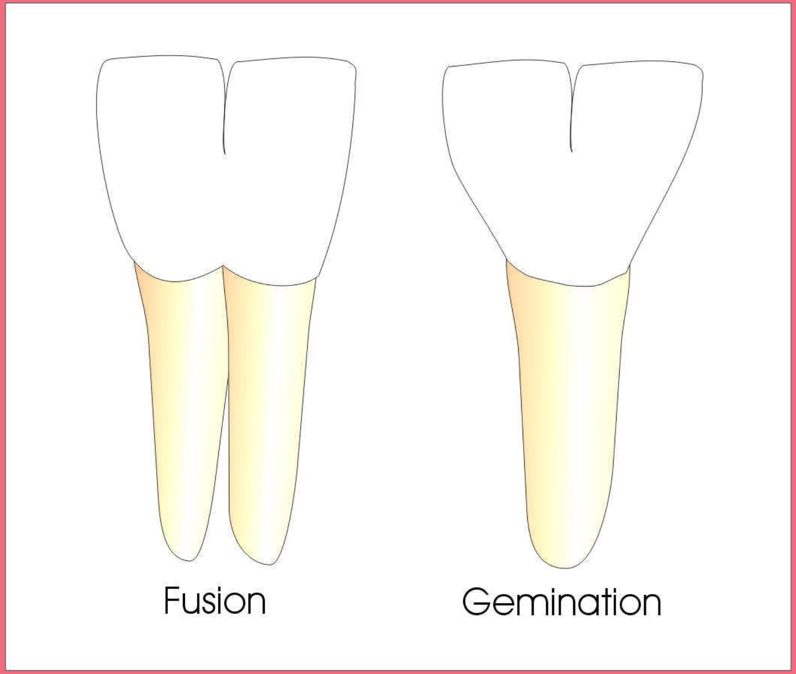
Gemination:

- The formation of two crowns from a single root

Fusion:

- The fusion of two individual crowns (has 2 roots)





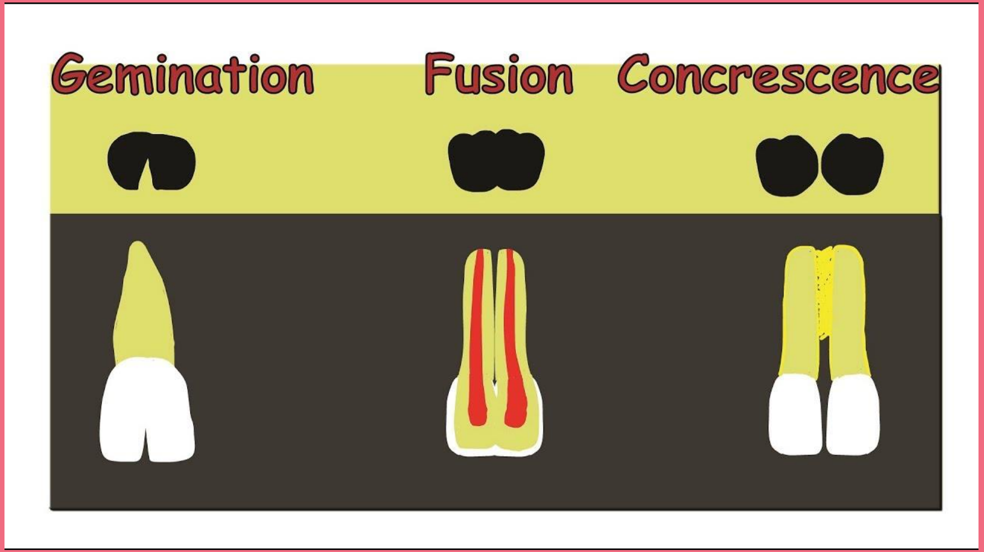
Concresence & Taurodontism

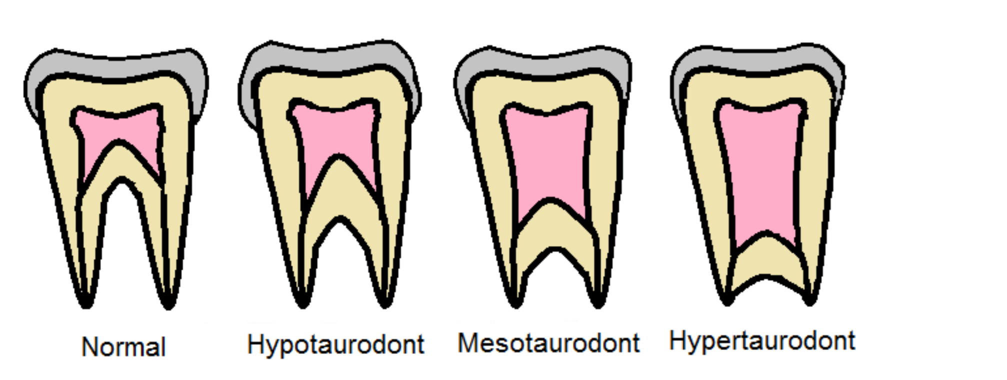
Concrescence:

- Refers to fusion of the roots due to shared cementum

Taurodontism:

- Enlarged pulp chamber and shortened roots
- Multiple subtypes





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06

DENTAL AGE & TIMING OF DEVELOPMENT

WHAT DO YOU NEED TO KNOW?

- Knowledge of tooth eruption, sequence, calcification timing and calcification sequence
- Given an OPG, be able to calculate the dental age of a patient
- The difference between eruption and emergence

Calculating Dental Age & Timing of Dental Development

Primary Tooth Calcification:

At birth the deciduous teeth are calcified to the following proportions:
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)

- All deciduous teeth are fully calcified within the first year after birth

Calculating Dental Age & Timing of Dental Development

Primary Root Formation:
Occurs in the following timespan:

Central incisors - 1.5 years
Lateral incisors - 2 years
Canines - 3 ⅓ years
First molars - 2.5 years
Second molars - 3.5 years

- Teeth emerge into the oral cavity when approximately 75% of the root has been formed
  Eruption = process of teeth moving to the occlusal plane
  Emergence = point at which the tooth has breached the oral mucosa

Calculating Dental Age & Timing of Dental Development

Secondary Calcification:
Begins:

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

- **Crowns always take 4 years to calcify**
- Incisor roots take **4-5** years, other take **7-8**

Calculating Dental Age & Timing of Dental Development

- Knowing these numbers we can create the following formula for calculating dental age:

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

Process for calculating dental age:

1) Identify 2-3 teeth that are erupting
2) Calculate dental age for each
3) Average to obtain a more reliable result

EXAMPLE

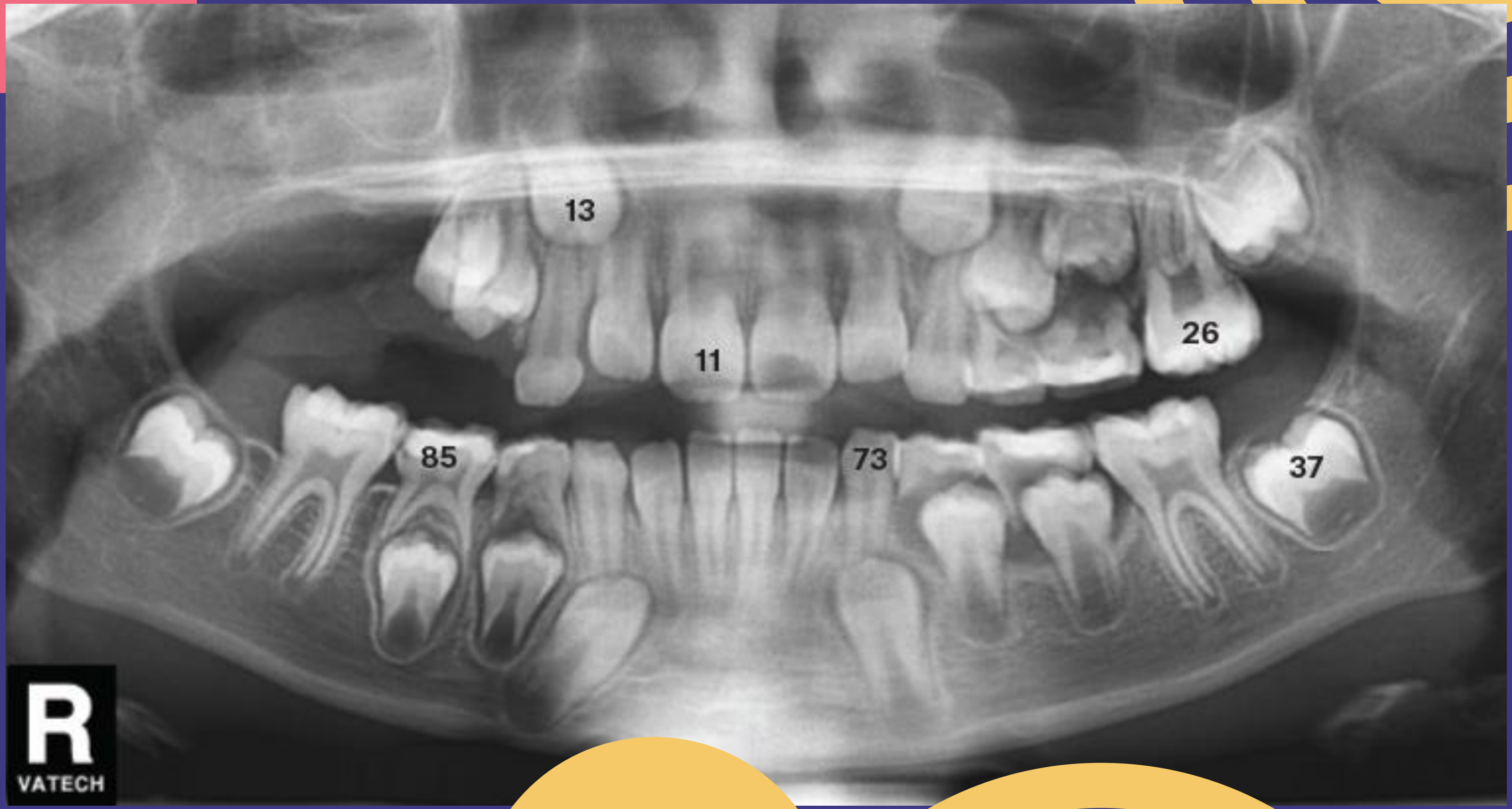
Example:

Let's take 37 & 33

37: (75% crown x 4) + (2.5-3.5) = 3 + 3 = 6

33: (100% crown x 4) + (75% x 7-8) + 5/12 = 4 + 5.625 + 5/12 = 10.04

Average = 8.02



GLOSSARY

Apposition: Deposition of hard dental structures into tissue matrices (HA crystals being put in the organic tissues)

Maturation: Removal of organic matrix to provide space for inorganic materials (organic tissues being taken out of enamel/dentin/cementum)

Morphogenesis: The formation of the morphological appearance of the tooth

Histogenesis: Alteration of histological appearance of cells for their role in the tooth germ

Histodifferentiation: Differentiation of the cells of the enamel organ into their subtypes (IEE, OEE, SI, SR)

Enamel knot: Middle portion of IEE that is non-dividing. Visible as the “middle of the cap” during cap and bell stages

Enamel niche: Secondary attachment between tooth germ and dental lamina

Enamel cord: Artefact that overlies the first cusp or incisal edge of tooth germ

Aprismatic: Enamel with no matrix, higher mineral content

Enamel Maturation: Process of eliminating organic material to be replaced replaced with inorganic HA

QUESTIONS