Histology & Physiology of the Dental Pulp

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The Pulp
- Innermost tissue within the tooth
- Vital – soft, pink mass, very vascular, tough & inelastic d/t collagen
- If exposed – sensitive to T° changes
- Appears less dense on radiographs
- Pulp ↔ Dentine – dependant on each other for survival

Functions of the Pulp
1. Formation of Dentine
2. Nutrition of the Tooth
3. Innervation of the Tooth
4. Defense

1. Formation of Dentine
- Mesodermal derivative
- Develops from dental papilla (like dentine)
- Ectoderm induces mesoderm to differentiate into odontoblasts (OB's) and initiate dentine formation
- Rapid until crown & root formation complete

2. Nutrition
- Via OB's & blood vessels (BV's) beneath
- Nutrients from capillaries – enter pulp – transferred to dentine through dentinal tubules

3. Innervation
- D/t fluid movement b/w tubules
- Peripheral receptors
- Sensory nerves of the pulp

4. Defense
- Response to irritants, rapid
- 2° & 3° dentine formation
- Intentional/accidental
- Prevent/delays caries penetration
- By existing or new OB’s
- Differs microscopically from N dentine
- Many names – osteodentine, reparative, etc
- Also via inflammation of pulp
Anatomy of the Pulp

- Confined in pulp chamber
- Conforms to shape of tooth – individualised
- 2 divisions: Coronal & Radicular

1. Coronal Pulp:
   - In crown
   - Extensions = pulp horns
   - Prominent in 1° teeth

2. Radicular Pulp:
   - Root / pulp canal
   - From cervical area to apex
   - Opens into PDL
   - May have accessory canals

Anatomy of the Pulp

- Accessory Canals:
  - Extra openings from pulp to PDL
  - Lateral canals
  - Formed when Hertwig’s Root Sheath encounters a blood vessel during root formation, root is formed around the vessel

Anatomy of the Pulp

- Apical Foramen:
  - Opening of pulp @ the apex
  - Surrounded by cementum
  - Arteries, veins & nerves enter & exit to PDL
  - Open, large & central when crown erupts
  - Becomes smaller & offset with age

Histology of the Pulp

4 Distinct Zones:
1. Odontoblastic zone – periphery
2. Cell-free zone of Weil – beneath the OB’s
3. Cell-rich zone - ↑ density of cells esp. fibroblasts
4. Pulp core – major vessels & nerves of pulp esp. fibroblasts + GS + collagen
Histology of the Pulp

Principal Cells
1. Odontoblasts
2. Fibroblasts
3. Undifferentiated mesenchymal cells
4. Macrophages
5. Immunocompetent cells
6. Other cells

1. Odontoblasts
- Defense cells
- Most distinct cell in pulp
- Easily recognisable - large body, pseudostratified columnar with processes extending into dentine
- No. of cells α on tooth type & location within pulp space
- B/w 59000 – 76000/mm² coronally
- Larger in crown, smaller in root

1. Odontoblasts
- Morphology α on functional state of cell
- Active – columnar with pear-shaped basal nucleus, basophilic cyto, prominent Golgi
- Resting – cuboidal with ↓ cyto, less prominent nucleus
- Can get intermediate type
- Fxn – glycoprotein synthesis & secretion
- Cell secretes matrix via vesicles – forms predentine - mineralised

1. Odontoblasts
- Palisaded / pseudostratified cells d/t cramming of cells at periphery of pulp chamber
- Radicular pulp – no compression – cells cuboidal
- Apex – cells squamous
- Cell body produces matrix, transported to & secreted by OBP that extends to the DEJ
- Extension – 2-3mm ??
1. Odontoblasts
- OB can modify dentine structure by producing peritubular dentine
- Hypermineralised tissue – can narrow tubule
-若 irritated – blockage of tubule – sclerotic dentine – seen esp. in teeth with cervical erosion

2. Fibroblasts
- Reserve cells
- Majority
- ↑ in coronal pulp
- In cell-rich zone
- Forms & maintains pulp matrix – GS & collagen
- Histo α final state

2. Fibroblasts
- Young pulp - ↑ organelles, activity, plump cyto, increased secretion
- Age - flattened spindle-shaped cells, dense nuclei
- Apoptosis – in cell-rich zone – turnover of cells
- Can ingest degrading collagen if stimulated
- Via lysozymal enzymes

3. Undifferentiated Mesenchymal Cells (Histiocytes)
- Pool of cells that can differentiate x on need of the pulp
- Can give rise to OB's / fibroblasts
- In cell-rich zone
- Near blood vessels
- Large, polyhedral cells – large nucleus, pale staining, lots of cyto with extensions
- ↓'s with age - ↓'s regeneration

4. Macrophages
- Throughout pulp
- Large oval/spindle-shaped cells
- Dark nucleus
- Eliminates dead cells – indicates turnover of pulp fibroblasts

5. Lymphocytes
- Mainly T-lymphocytes
- Immune fxn

6. Dendritic Cells
- From bone marrow
- Immunosurveillance
- Unerupted teeth - near OB layer
- Erupted teeth - beneath OB layer
- Near BV's & N's
- Captures & presents foreign antigen to T-cells
- ↑ed in caries
- > macrophages
7. Other Cells

1. Mast Cells:
   - Release histamine – near BV’s – vasodilation – increased vessel permeability – fluids & leukocytes escape

2. Polymorphonuclear leukocytes:
   - Can phagocytose bacteria/dead cells
   - Usually causes inflammatory area to widen

Matrix & Ground Substance

- Matrix – collagen fibres & GS
- Collagen – Type I & III – young pulps
- Fibre bundles form with age
- ↑test concentration of collagen in apical part of pulp
- GS = GAG’s, glycoproteins & water
- Supports cells
- Transports nutrients from BV’s to cells and metabolites from cells to BV’s

Vasculature

- Vessels enter & exit pulp thro’ apex & accessory foramina
- Usually assoc. with sensory & sympathetic nerve bundles
- Vessels exiting pulp assoc. with arterioles & nerve bundles entering pulp
- Diameter of lumen ↑ by ↓ing thickness of vessel wall
- Give off branches in subodontoblastic area
- More branches as they move coronally – ‘U’ loops

Vasculature

- Capillary bed below OB’s
- Pericytes cyto around capillaries – intermittent sheaths on endothelial wall
- Contracts lumen
- Arteriovenous anastamoses
- Drainage – smaller venules

Lymphatics

- Small, blind, thin-walled vessels in coronal pulp
- Exit via 1 / 2 large vessels thro’ apex
- No Rbc’s in lumina – not venules
- Discontinuities in vessel wall & BM’s

Nerves

- Rich
- Enter thro’ apex – NVB
- Follow arterioles
- Provides atleast 8 terminal branches
- Forms Subodontoblastic plexus in cell-free zone
- Sensory afferent N’s from CN V
- Sympathetic branches from superior cervical ganglion
- Closely related to OBP
- No synapses / junctions
- Fibrils within tubules - variable
Pulp Stones / Denticles
- Discrete calc. masses
- Similar to dentine
- Single/multiple
- Ofifice of pulp chamber or root canal
- Concentric layers around
  thrombosed/dead/dying
cells & coll. fibres
- Attached / free
- Impede debridement & enlargement during RCT

Age Changes
- ↓ vol. of pulp
- ↓ blood supply
- ↓ fibrous bundles
- ↓ sensitivity –
degeneration of axons
- Dystrophic calc.
- Sclerotic dentine
- ↑ brittleness & permeability
- Dead tracts – retracted
  OBP – filled with air

Pulpal Physiology
Pulpal Disturbances:
1. Trauma
2. Excessive force – e.g. orthodontic
3. Canes
4. Fractures
5. Abrasion
Disturbance = communication b/w pulp & oral cavity

Process Cycle
Irritation
↓
Inflammation
↓
Pulpal tissue destruction
Irreversible pulpitis
Progresses
Generalised effect

Dentine Structure
- Calcified CT
- Millions of tubules – 40000 to 70000 / mm²
- Diameter of tubules - 1μm @ DEJ, 3μm @ pulp
- Fluid content similar to ECF
- Any toxins in fluid permeate the pulp eventually & cause inflammation

Dentine Permeability
- Tubules converge from coronal part of DEJ to pulp chamber
- Concentration of toxins that enter pulp –
  ↓ by 50%
- Dentine less calcified & more permeable @ pulp
- Deep cavities, attrition & irritation contribute
  - Pulp roof easy to enlarge
Dentine Permeability

Increased permeability d/t:
- Open tubules – fracture / acid etch

Decreased permeability d/t:
- Closed tubules – anatomical / debris (smear layer)

Pulp Metabolism:
- Rate at which pulpal cells are metabolising
- Measured by rate of O₂ consumption or lactic acid production
- O₂ consumption led by ZOE, eugenol, calcium hydroxide, amalgam, procaine

Pulp Reaction to Permeating Substances

- No bacteria only by-products
- Rxn depends on concentration of toxin
- Ranges from no inflammation to abscess
- If pulpal BF normal, then microcirculation with remove toxins & prevent diffusion into pulp
- If pulpal BF reduced, the concentration of toxins increases & moves across into pulp

Reactions that Occur

1. Degranulation of mast cells
2. Histamine release
3. Substance P release
4. Bradykinin production
5. Plasma protein activation

Consequences of Inflammation

1. Arterioles vasodilate
2. Capillary hydrostatic pressure ↑
3. Plasma proteins leak into pulp interstitium
4. Ted pulpal tissue pressure ↓

Measurement of Pulp Pressure

- Normal pulp pressure = 10.4mm Hg
- Very low vs systemic pressure
- Blood flow – laser Doppler blood flowmeter
- BF ↑↓, pulp tissue pressure

Symptoms of Pulpal Inflammation

- Dull, aching, poorly-localised pain
- D/t pulp pressure and ↓ BF in certain areas
- Effect is spread to larger volume of pulp
- Sensitivity:
  - Sharp, brief, well-localised
  - D/t fluid movement within tubules
Dentine Sensitivity

3 Theories:
1. Direct Stimulation – nerves in dentine
2. OBP Excitable – 1/2 tubule length
3. Hydrodynamic Theory – Brannstrom
   - Fluid in dentinal tubules
   - Move in either direction
   - Stimulus moves the fluid which can stimulate sensory nerves in the pulp

Effect of Posture on Pulpal Pain

Lying down increases pulpal pain. Why??
1. Gravity:
   - Standing position - structures above $\downarrow$ BF – no pain
   - Lying down – effect disappears – $\uparrow$ BF – pain!
2. Baroreceptors:
   - In carotid sinus @ arch of aorta
   - Increased sympathetic stimulation
   - Standing – vasoconstriction - $\downarrow$ BF – no pain
   - Lying down – vasodilation – $\uparrow$ BF - pain

Systemic Distribution of Substances from Dentine & Pulp

- Proved that substances from dentine & pulp lead to blood stream & lymphatics
- Experiments with radioactive iodide, cortisone, tetracycline, lead, formocresol, gluteraldehyde, ZOE, etc

Histology of Periradicular Region

- Diseased pulp changes beyond the pulp – to PDL & periapical CT
- Periapex – continuum of CT of the root canal, foramen & periapical zone
- Pulpal problem – RCT
- Periradicular – aim @ periapical area
- RCT – confine prep & obturation to canal space – try not to instrument into PCT
- If disturbed – can heal spontaneously
- Substances in pulp will travel to PDL, alveolar & medullary bone & marginal gingiva

Histology of Periradicular Region

Periapex:
- Apical continuation of PDL
- Contents similar to root canal
- Attachment fibres at the apex ??
- NVB enters apex thro' a bony passage – don't confuse with inflammation – hanging drop appearance
- BV's & N's grouped & surrounded by CT sheath – inflammation – spread by the CT
Differences between Pulpal Tissue & PDL

PDL:
1. Acute tactile reception – proprioreceptors allow spatial differentiation – localise an inflamed PDL easier than inflamed pulp
2. Collateral blood supply – resolves inflammation
3. Communicates with medullary spaces of alveolar bone – allows diffusion of inflammation & pressure

Histology of PDL
- Collagen fibres b/w cementum & alveolar bone
- Interruption in bone & fibres where NVB passes thro’ pulp
- Epithelial cell rests of Malassez – cord of ectodermal cells of original root sheath – forms a tight network b/w tooth & bone
- Can proliferate during dxs & line apical cysts
- Cribriform bone on lateral walls of socket & periapex – blood vessels traverse it to marrow
- Marrow – reserve cells for repair of dxed pulp or after RCT