- PDL is a soft, specialized connective tissue situated between the cementum and bone forming the socket wall.
- Synonyms: Desmodont, Gomphosis, Pericementum, Dental periosteum, Alveolodental ligament & Periodontal membrane.
- Main function → support the teeth in their sockets & permit them to withstand forces of mastication.

Extent	• Coronally → to most apical part of the lamina propria of the gingival • Apically → to apical foramen, where it is continuous with the dental pulp
Width	• Thinnest around the middle third of the root → Hour glass appearance →fulcrum of physiologic tooth movement (fulcrum of rotation). • *Average thickness → 0.5 to 0.38 mm* ▪ In young adult (11 - 16 years of age) → 0.21mm ▪ In mature adult (32 - 52 years of age) → 0.18 mm ▪ In older adult (51 - 67 years of age) → 0.15 mm

- *Gomphosis* → Type of joint formed when PDL connects the tooth root to the alveolar bone.
- Periodontal space (width):
  - Space occupied by the periodontal ligament → its width on radiographs → 0.4 to 1.5 mm.
  - It is narrower in permanent teeth than those of primary teeth.
  - Decreased in non-functional & unerupted teeth, with aging.
  - Increased when teeth are subjected to heavy occlusal stress.

DEVELOPMENT

- Periodontal ligament → develops from dental sac (dental follicle)

Begins with root formation prior to tooth eruption.
↓
After the formation of crown, HERS develops & grows apically separating dental papilla from dental follicle.
↓
Dental follicle cells → two subpopulations → mesenchymal cells of the dental follicle proper & perifollicular mesenchyme. As the root formation continues:

- Innermost cells of the dental follicle adjacent to forming root → differentiate as cementoblasts → lay down cementum.
- Outermost cells → differentiate as osteoblasts → furnish the lining of bony socket.
- Centrally located cells (Perifollicular cells) → differentiate as fibroblasts → synthesize and deposit collagen fibrils and glycoproteins in the developing periodontal ligament.
- Cementoblasts, osteoblasts, fibroblasts → differentiates from dental follicle.

↓
At first → all developing fibres of PDL → run obliquely in a coronal direction from tooth to bone.
↓
With positioning of CEJ coronal to alveolar crest → final positioning of the principal fibres of PDL takes place.
↓
First collagen fibre bundles of PDL → precursors of *Alveolar crest fibre* bundle group → appear immediately before tooth eruption.
↓
Upon eruption of tooth into oral cavity → only fibres discernible histologically → *Alveolar crest fibres.*
↓
By the time of first occlusal contact of the tooth → *Horizontal fibres* → completely developed, *Oblique fibres* are still being formed.
↓
The PDL fibres become embedded in newly developed cementum and alveolar bone.

STRUCTURE

PDL consists of

1. Fibres
2. Cellular elements
3. Ground substance
4. Interstitial tissue

FIBRES

- Connective tissue fibres of PDL
  - Mainly collagen (over 90%)
  - Small amounts of Oxytalan, Elastin & Reticulin

1. Collagen fibres

- Collagen fibres → predominant fibres of PDL

Type I collagen	more than 70%
Type III collagen	20%
Type V and VI	Small amounts
Type IV & VII	Traces
Type XII	Found only when the PDL is fully functional

- Collagen fibres → *synthesized & degraded by fibroblasts*.
- Collagen fibres → form bundles → 5µm in diameter → PRINCIPAL FIBRES of PDL → run from cementum to alveolar bone.
- Each bundle resembles a spliced rope.
- Subunits of collagen bundle → collagen fibrils.
- Principal fibres → follow a wavy course which straighten out under load.
- A specific type of waviness seen in collagenous tissues (including PDL) →crimping → best seen under polarizing microscope.
- Principal fibres → more numerous, but smaller at their attachment to cementum than at the alveolar bone.
- Principal fibres (Fig 6.1) show different orientations in different regions of PDL. Based on this, fibres of PDL are arranged into 5 groups
  1. Alveolar crest fibres
  2. Horizontal fibres
  3. Oblique fibres
  4. Apical fibres
  5. Inter radicular fibres

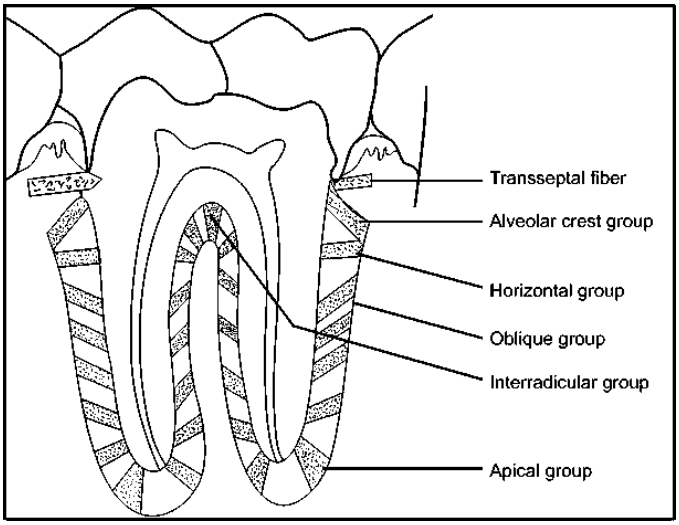

Fig 6.1 Principal fibers of Periodontal ligament

Principal fibres	Location of attachment	Function
Alveolar crest fibres	Cervical cementum to alveolar crest.	Resist tilting, extrusive, intrusive, rotational forces & lateral tooth movements.
Horizontal fibres	▪ Run at right angles to the tooth from cementum in the Mid-root region to adjacent alveolar bone proper. ▪ Occupies 1/4th of PDL space	Resist horizontal& tipping forces Maintains the mesiodistal width of tooth
Oblique fibres	▪ Extend obliquely in a coronal direction from the cementum in the apical 1/3rd of root to the alveolar bone proper. ▪ Most numerous ▪ Occupies 2/3rd of ligament	Resist vertical masticatory forces
Apical fibres	▪ Apex of the root to fundus of bony socket. ▪ Not seen in incompletely formed roots.	Resist luxation & tipping forces.
Inter radicular fibres	▪ Found only between roots of multi rooted teeth running from cementum to alveolar bone proper. ▪ Runs from cementum of one root to another root across inter radicular alveolar bone septum.	Resist vertical & torquing forces.

Transseptal fibers

- Extend interproximally over the alveolar bone crest and embed in the cementum of adjacent teeth
- Also called *interdental ligament*
- Can be regenerated after damage
- They are **considered as gingival fibers** due to lack of osseous attachment

Sharpey's fibres (Fig 6.2)

- Collagen fibres that are embedded into cementum on one side of the periodontal space and into alveolar bone on the other → *Sharpey's fibres* → *subjected to tensional forces*
- The embedded fibres calcify to a certain degree and are associated with non-collagenous proteins like osteopontin and bone sialoprotein

- The fibres in the primary acellular cementum → completely mineralized, in the cellular cementum and bone → partially mineralized

Transalveolar fibres

- Few fibres pass uninterrupted through the bone of the alveolar process and continues as principal fibres of the adjacent periodontal ligament
- Pass through alveolar process only when the process consists of compact bone entirely without Haversian systems.

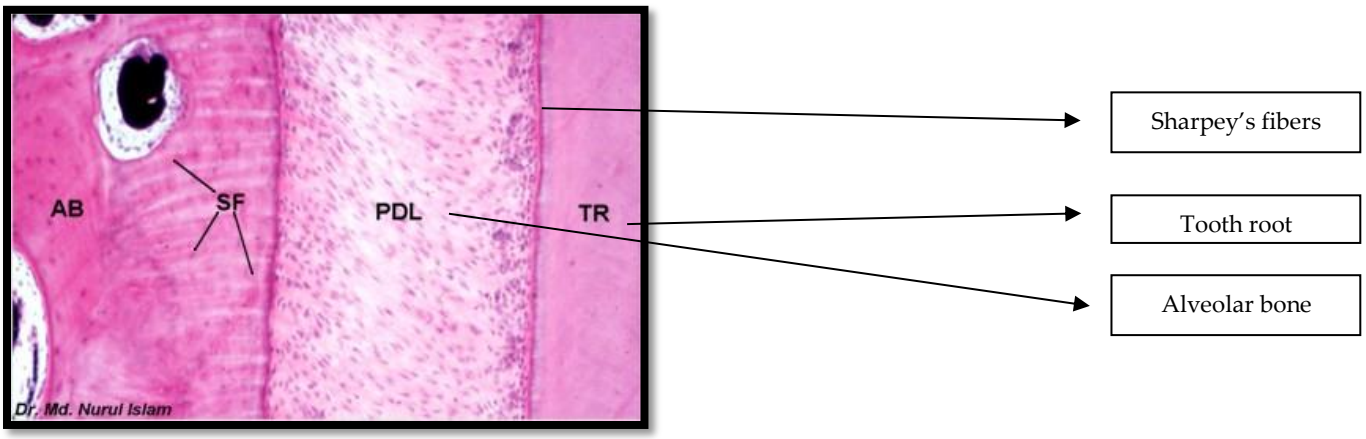

Fig 6.2 Sharpey's Fibers

Intermediate plexus

- The principal fibres of the periodontal ligament follows a wavy course from the cementum to alveolar bone and are joined in the mid region of the periodontal space, giving rise to a distinct appearance → *Intermediate plexus*
- Considered to be an area of high metabolic activity, in which splicing and unsplicing of fibres might occur.
- Recent research suggests
  - No such plexus exists → an artifact
  - Areas of highest activity → fibre terminals → near cementum or bone, not in middle

Non-collagenous proteins

- Osteopontin
- Bone sialoprotein
- Functions
  1. Help in the regulation of mineralization
  2. Tissue cohesion in areas of increased biomechanical strain

2. Elastic Fibres

1. ***Mature elastic fibres /Elastin fibres:*** Seen only in the walls of afferent blood vessels
2. ***Elaunin fibres***: Found within the fibres of gingival ligament
3. ***Oxytalan fibres***
   - Only elastic fibres present in PDL
   - These are *immature elastic fibres* →0.5 μm to 2.5 μm in diameter
   - Run in an *axial direction*, running from bone or cementum to the wall of a blood vessel.
   - More numerous and dense → in the cervical region of the ligament.
   - Thicker & more numerous oxytalan fibres
     - Teeth subjected high loads
     - abutment teeth for bridges & orthodontically moved teeth
   - Function

- Exactly not known
- But may play a role in supporting the blood vessels of PDL and regulate blood flow in relation to tooth function.

3. Secondary fibres

- Newly formed collagen elements
- Not yet incorporated into principal fibres
- Traverse the PDL space coronoapically
- Associated with blood vessels & nerves

Indifferent fibre plexus

- Small collagen fibres → associated with large principal fibres → running in all directions → forming a plexus → Indifferent fibre plexus.
- Seen under scanning electron microscope, but not under transmission electron microscope → so, some consider them as artefact

2. CELLULAR ELEMENTS

- Principal cells of the healthy, functional periodontal ligament → involved in synthesis and resorption of alveolar bone and fibrous connective tissue of the PDL and cementum.

Synthetic cells

- Osteoblasts
- Fibroblasts
- Cementoblasts

Resorptive cells

- Resorbing fibroblasts
- Osteoclasts
- Cementoclasts

Progenitor cells / Undifferentiated cells

Epithelial rests of Malassez

Defense cells

- Mast cells
- Macrophages
- Eosinophils

1. Synthetic Cells

- Common cytologic criteria that is seen in all cells actively synthesizing proteins.

Electron microscopic features	**Light microscopic features**
Increased transcription of RNA & production of ribosomes	Large open-faced nucleus (vesicular nucleus) with prominent nucleolus
Increased numbers of Rough Endoplasmic Reticulum & Ribosomes	On H&E staining → Hematoxyphilia of the cytoplasm
Prominent Golgi apparatus	Not stained by acid hematein → appear as unstained area in Hematoxyphilic cytoplasm
Increased numbers of mitochondria	To accommodate all the increased cell organelles → increased cytoplasmic area

Synthetic Cells of Periodontal ligament

Cell	*Appearance*	*Location*	*Functions*
Osteoblasts	▪ Cuboidal in shape, with basally located prominent round nucleus.	Periodontal surface of alveolar bone.	▪ Formation of bone
Fibroblasts *predominant cells of PDL*	▪ Active synthesizing cell → Fusiform shaped cell with well-developed cell organelles & extensive processes. ▪ Long axis → parallel to the collagen fibrils. Fibroblasts of PDL have cilia.	Throughout the periodontal ligament.	▪ Formation and maintenance of collagen and elastin fibres ▪ Formation of glycoproteins and glycosaminoglycans ▪ They help in the eruption of tooth by their contractile property (PDL traction theory)
Cementoblasts	▪ plump and round or cuboidal with well-developed cell organelles & cytoplasmic processes. ▪ Difficult to distinguish from periodontal fibroblasts	Adjacent to cementum	▪ Formation of cementum

2. Resorptive cells

Cell	*Appearance*	*Location*	*Functions*
Resorbing Fibroblasts	▪ Same as collagen forming fibroblasts ▪ Mononuclear cells exhibiting lysosomes	Throughout the periodontal ligament	Degradation of collagen → by extracellular & intracellular event. ▪ Extracellular event → involving the activity of the enzyme collagenase ▪ Intracellular event → intracellular organelles in fibroblast → by Enzyme hydrolysis → intracellular collagen profiles
Osteoclasts	▪ Arise from blood cells of macrophage type ▪ May be mononuclear small cells or multinucleated giant cells ▪ Actively resorbing cells → plasma membrane exhibits Ruffled or Striated or Brush border → adjacent to resorbing bone	Occupy bays in bone → Howship's lacunae.	▪ Resorption of bone
Cementoclasts	▪ Rarely seen ▪ Arise from blood cells of macrophage type. ▪ Mononucleated cells or multinucleated giant cells.	Occupy bays in cementum → Howship's lacunae.	▪ Resorption of cementum

3. Progenitor Cells (Undifferentiated Mesenchymal Cells)

- These cells undergo mitotic division → replace the dying differentiated cells.
- These cells have a small, close-faced nucleus and scant cytoplasm.
- Location → perivascular area.

4. Epithelial Cell Rests of Malassez

- Remnants of the Hertwig's epithelial root sheath → *Cell Rests of Malassez*
- First discovered by Malassez in 1884.
- Location → about 25 μm from the cementum surface.

Age	Location
1st & 2nd decades	Apical zone
3rd to 7th decade	Cervically in the gingiva above the alveolar crest

- Appearance → cluster-like or duct-like. Cells within the cluster show prominent nucleus, scant cytoplasm & prominent basal lamina separating them from surrounding connective tissue.
- More numerous
  - In children
  - In the apical and cervical areas
- Less numerous → in older individuals.
- More abundant → in the furcation area
- Contain Keratinocyte growth factors
- Shows positivity for tyrosine kinase-A neurotrophin receptor
- Physiological role in PDL → unknown, could be involved in periodontal repair and regeneration.
- Pathological role:
  - On appropriate stimulus → ex: chronic inflammation → Cell rests of Malassez proliferates → forms cysts or tumors
  - Also, Cell rests of Malassez → undergo calcification → form Cementicles

5. Defense cells

Cell	*Appearance*	*Location*	*Functions*
Mast cells	▪ Small round or oval cells, 12-15 μm in diameter having a granular cytoplasm and a round nucleus.	Associated with blood vessels.	▪ Production of histamine, heparin & factors associated with anaphylaxis. ▪ May regulate endothelial and fibroblast cell population.
Macrophages	▪ Oval or spindle shaped cells with granular cytoplasm, horse shoe or kidney shaped nucleus & short blunt processes. ▪ Make up about 4% of PDL cell population.	Adjacent to blood vessels.	▪ Phagocytosing dead cells & invading organisms ▪ Secreting interferon (antiviral factor), prostaglandin & growth factors that regulate the proliferation of adjacent fibroblasts
Eosinophils	▪ Granulocyte with bilobed nucleus. ▪ Rarely seen in the normal PDL.	Associated with blood vessels.	▪ Phagocytosis

3. GROUND SUBSTANCE

- The space between cells, fibres, blood vessels and nerves in the periodontal space → occupied by ground substance
- It helps in transportation of anabolites and catabolites among the cells.
- Composition
  - 70%water
  - Glycosaminoglycans (Hyaluronan)
  - Proteoglycans (fibromodulin, perlecan)
  - Glycoproteins (fibronectin, laminin)
- High water content (70%) → thought to have a significant effect on the tooth's ability to withstand stress loads.

- Tissue fluid pressure in PDL → high → 10mm Hg above atmospheric pressure → implicated in tooth support & eruptive mechanisms.

4. INTERSTITIAL TISSUE

- Loose connective tissue surrounding blood vessels, lymphatics and nerves of PDL → *Interstitial Tissue.*

A. Blood vessels

- The rich blood supply to PDL is derived from:
  - Inferior & Superior alveolar arteries.
  - Arteries from gingiva (lingual & palatine arteries)
- This dual supply → allows the PDL to function following removal of root apex because of various endodontic treatments.
- Perforating arteries
  - Inferior & Superior alveolar arteries → run intraosteal course → gives interalveolar branches → enter the PDL space → *perforating arteries*
  - Abundant in PDL of posterior teeth than PDL of anterior teeth
  - Abundant in maxillary teeth than mandibular teeth
- Diameter of arterioles in PDL → range from a 15-50 µm with an average diameter of 20 µm.
- Specialized features of vasculature of PDL:
  - Presence of large number of fenestrations in the capillaries & Crevicular plexus of capillary loops.
  - Fenestrated capillaries →increase the diffusion & filtration capacity → related to high metabolic requirements of PDL.
  - Crevicular plexus of capillary loops → may allow rapid redistribution of blood under varying occlusal loads.
- Blood supply of PDL
  - Increases from incisors to molars.
  - In single rooted teeth → more in gingival 3rd, followed by apical 3rd, least in middle 3rd.
  - In molars → greatest at gingival 3rd, equal in apical & middle 3rd.
- The arterioles & capillaries → ramify in the PDL → form a rich network of arcades → *more evident in the half of the periodontal space adjacent to bone than that adjacent to cementum.*
- Venous channels → large diameter of 28 µm → receive blood from the capillary network and specialized shunts called *glomera* in the PDL

B. Lymphatics

- Lymph from PDL → drains into lymph nodes of head & neck.

Area	Draining lymph node
Mandibular incisors	Submental lymph nodes
Mandibular premolars, 1st & 2nd molars	Submandibular lymph nodes
Mandibular 3rd molars	Jugulodigastric lymph nodes
Maxillary palatal area	Deep cervical lymph node
Maxillary Buccal area	Submandibular lymph nodes

C. Nerves

- Nerve fibres entering PDL are derived from 2 sources:
  - Some bundles enter near the root apex & pass up through the PDL.
  - Finer branches enter the middle & cervical portions of PDL through openings in the alveolar walls.
- Nerve fibres supplying PDL are functionally of 2 types:
  - *Sensory fibres* → associated with nociception and mechanoception→ touch, pressure, pain and taste sensations.

- *Autonomic fibres* → associated with PDL vessels.

- PDL nerve fibres → myelinated & non-myelinated.
- Myelinated fibres → 5-15 µm in diameter → sensory fibres.
- Unmyelinated fibres → 0.5 µm in diameter → both sensory & autonomic.
- Apical region of PDL → contains more nerve endings than elsewhere (exception is upper incisors, which shows dense innervation than molars & more nerve endings both coronally & apically).

FUNCTIONS

<table>
<tr><td>Supportive</td><td>

Supports the teeth in their sockets
Attaches the cementum to alveolar bone
Transmits masticatory forces to the bone
Helps in tooth eruption
Maintains the functional position of tooth

</td></tr>
<tr><td>Sensory</td><td>

PDL → through its mechanoreceptors → involved in the neurological control of mastication
<u>Transmit</u>:
- Tactile
- Pressure
- Pain sensations } Trigeminal pathways

4 types of neural terminations. They are:

<table>
<tr><th>Type of nerve terminal</th><th>Features</th></tr>
<tr><td>Free endings</td><td>• Tree like configuration
• Pain sensation</td></tr>
<tr><td>Ruffini like end organs</td><td>• Mechanoreceptors
• Primarily located – apical area</td></tr>
<tr><td>Meissner's corpuscles</td><td>• Coiled, Mechanoreceptors
• Mainly – mid root region</td></tr>
<tr><td>Spindle like</td><td>• Pressure & vibration endings
• Surrounded by a fibrous capsule
• Located mainly in the apex.</td></tr>
</table>
</td></tr>
<tr><td>Nutritive</td><td>

Blood vessels of PDL → nourishes the PDL cells
Occlusion of blood vessels → necrosis of cells in the affected parts of the ligament

</td></tr>
<tr><td>Formative / Resorptive</td><td>

PDL cells → form, maintain & repair collagen, cementum & alveolar bone

</td></tr>
<tr><td>Homeostatic</td><td>

Cells of PDL → Synthesise & resorb connective tissue of PDL, cementum & alveolar bone → continuous process, with varying intensity throughout the life of tooth → Homeostasis
If this homeostasis is lost → loss of PDL → loss of attachment between bone & tooth → loss of tooth

</td></tr>
<tr><td>Protective</td><td>

PDL → resilient to masticatory forces → acts as a shock absorber
Protection of blood vessels and nerve from mechanical forces
Restricts movement of teeth to masticatory forces

</td></tr>
</table>

Shock absorption – 2 theories

1. *Tensional theory*
   - The principal fibers of the PDL has a major responsibility in supporting the tooth and transmitting forces to the bone.

Forces when applied to the crown
↓
Principal fibers 1st unfold & straighten
↓
Transmit forces to the alveolar bone
↓
Elastic deformation of bony socket
↓
Alveolar bone exceeds its limit
↓
Load transmitted to basal bone

2. *Viscoelastic theory*
   - The displacement of the tooth largely controlled by fluid movements with fibers having a secondary role.

PERIODONTAL LIGAMENT – A Specialized Connective Tissue

These features of PDL differentiate it from other soft, fibrous connective tissue and make it a specialized tissue:

- Presence of different types of collagen (Type I, III, V, VI, XII) and collagen cross links
- These collagen fibres have characteristic orientation
- Very high turnover rate
- Highly cellular and rich in ground substance
- High tissue hydrostatic pressure
- Cells of PDL are involved in formation of dental tissues
- Presence of PG1, a specific proteoglycan for PDL
- PDL fibroblasts:
  - Attach to adjacent cells → adherence type of junction.
  - Attach to extracellular matrix & collagen → fibronexus, a specialized junction.
  - *Have intracellular actin → connects to extracellular fibrils → via fibronectin (a sticky glycoprotein that can stick to extracellular components, including collagen) & transmembrane proteins (vinculin, talin, α-actin & integrin).*
- Rich blood and nerve supply
- Presence of Fenestrated capillaries

AGE CHANGES

- With aging, following changes are seen in the periodontium
  - Decrease in the cell number & cell activity
  - Bone & cementum appears scalloped. PDL fibres attach to the peaks of these scallops than over the entire surface as seen in younger periodontium
  - Normal functional stimulation of PDL is diminished
  - Gingival & Periodontal diseases → reduction in the height of gingiva → destructive changes in PDL
  - *Cementicles*
    - Calcified bodies seen in PDL → diameter of individual cementicles rarely exceeds 0.2 mm
    - Nidus for their calcification → dead cells associated with the epithelial rests of Malassez or mineralized Sharpey's fibres
- Free Cementicles (Fig 6.3) → Cementicles that remain free in connective tissue
- Attached cementicles (Fig 6.3) → Cementicles joined with the cementum
- Excementosis → forms when cementicles adhere to cementum

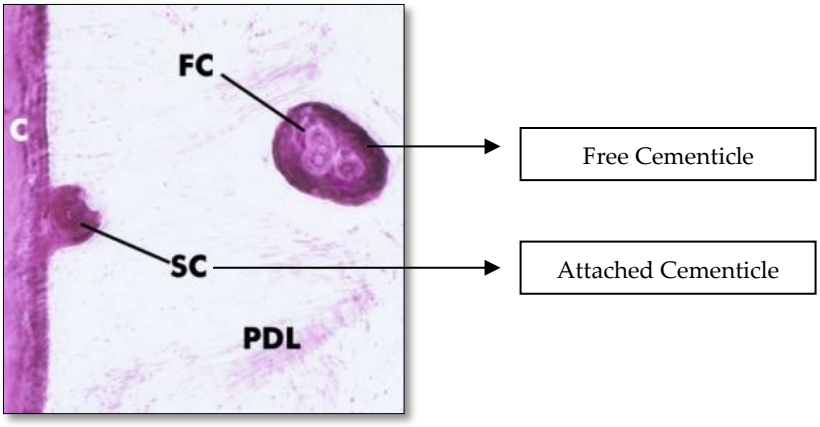

Fig 6.3 Free and Attached Cementicles

CLINICAL CONSIDERATIONS

- Thickness of PDL
  - Maintained by the functional movements of the tooth.
  - Thin → nonfunctional and unerupted teeth.
  - Wide → teeth under excessive occlusal stresses
- Acute trauma to the PDL, accidental blows or rapid mechanical separation → may produce pathologic changes → fractures, resorption of cementum, tearing of fibre bundles, haemorrhage & necrosis.
- Inflammatory disease of pulp → progresses to apical PDL → Periapical granuloma/ Dental granuloma → Periapical cyst.
- Progression of periodontal disease →tooth mobility → loss of tooth.
- Localization of pain in a tooth when a dentist "percusses" the tooth → is through the PDL.
- Pathological conditions showing widening of PDL space → osteogenic sarcoma and scleroderma.
- *Ankylosis* → direct union between cementum and alveolar bone without an intervening PDL.