Periodontal ligaments
The periodontium is defined as those supporting the tooth and it consists of four principal components namely:

- **Gingiva**
- **Periodontal ligament (PDL)**
- **Cementum**
- **Alveolar bone**;

These tissues form a specialized fibrous joint and are thought to be of ectomesenchymal origin.
Periodontal ligaments

- The periodontal ligament is a fibrous connective tissue between the alveolar bone and the cementum covering the root;
- This ligament covers the root and connects with the tissue of the gingiva;
- The periodontal ligaments occupy the periodontal space and is composed of:
  - Fibers;
  - Cells;
  - And intercellular substance.
Periodontal ligament

- Cells of dental follicle differentiate into collagen-forming cells of the ligament and of cementoblasts, which lay cementum on the tooth roots;
- Some cells of the ligament invade the tooth root sheath as it breaks apart;
- Other cells of the ligament area form delicate fibers, which appear along the forming roots near the cervical region of the crown.
Periodontal ligaments

- The thickness of the PDL varies from tooth to tooth and its position in relation to root;
- The thinnest portion of the PDL is near the middle of the root;
- The width of PDL shows a progressive decrease with age.
The PDL has a heterogeneous population of mesenchymal cells that when induced differentiate into fibroblasts, cementoblasts and osteoblasts;

The fibroblasts also have the capacity to form PDL, cementum and alveolar bone any time in health;

The factors secreted by PDL fibroblasts inhibit mineralization and prevent ankylosis of the tooth.
Development of PDL

- During the initial stage of root formation the follicular cells show increased proliferation;
- The innermost cells of the follicle near the forming root differentiate into cementoblasts and the outer most cells differentiate into osteoblasts;
- The centrally located cells differentiate into fibroblasts.
Formation of the periodontal fibers

Initially, the fibers (PDL) are oriented parallel to the root;

At this stage, almost no or only a thin layer of cement was postponed over (D).
Fibroblasts produce the periodontal ligament fibers; They get embedded in the developing cementum and alveolar bone; At first, all the developing fibers of the periodontal ligament run obliquely in a coronal direction from tooth to bone; This changes as the tooth erupts; The part of PDL fibers present in the cementum and alveolar bone are called Sharpey`s fibers.
Formation of the periodontal space

Formation of the first group of fibers - towards a cementum:

- Under the influence of the Hertwig’s root sheath mesenchymal cells group are differentiated in fibroblasts;
- They are arranged under cementoblasts;
- Produce thick fibers primary arranged in parallel to the root;
- Fibers are converge towards the cement.
FIGURE 1 - On the root surface the cementum is covered by cementoblasts (white arrows). Collagen fibers—called Sharpey’s fibers—penetrate amid these cells and attach themselves to the cementum (C). In the periodontal ligament (green arrow) epithelial cell islands and cords can be observed (red arrows) which form a three-dimensional network around the root, like a basketball hoop. This epithelial component of the periodontal ligament, called Epithelial Rests of Malassez (red arrows), constantly releases Epithelial (or Epidermal) Growth Factor (EGF), whose molecules diffuse through the cells in the extracellular matrix and stimulate osteoclastia on the periodontal bone surface, thereby promoting the maintenance of periodontal space (D = dentin; F = fibroblasts; V = blood vessels. HE; X25).
The cementum matrix has specific matrix molecules that attract fibers;

Attachment of the fibers is done by adhesins and specific receptors on the fibers;

Driven thus the fibers are inserted into the cementum matrix perpendicular to the dentin.

Sharpei's fibers embedded in cementum
Sharpei`s fibers hanging in the periodontal space

- After attachment of the fibers to the dentin, they are coated with a cementitious matrix;
- Remain switched on in cement as external or extrinsic fibers;
- They are called Sharpei`s fibers;
- Their ends remain freely suspended in the periodontal space.
Sharpey's fibers

- The Sharpey's fibers are the mineralized continuation of the thick fiber bundles (marked with an *) that originate in the periodontal ligament and help anchor the tooth to the bone;

- In this section the mineralized bone, that includes the Sharpey's fibers, appears light blue as compared to the purple color of the non-mineralized portions of the fibers.
Sharpey's fibers in

- Note the short Sharpey's fibers (SP) imbedded in the new osteoid seam (OS) secreted by osteoblasts (OB) in the periodontal ligament;
- OC, osteocytes; RL, reversal line.
Formation of the alveolar bone

Under the influence of Hertwig`s sheath cells of the outermost part of the dental follicle differentiate into osteoblasts;

Osteoblasts begin the secretion of bone matrix and its mineralization;

In parallel with the generation of the root wall is formed corresponding zone of the bone socket.
Intermediate fiber groups - almost perpendicular to the other

Fibroblasts, which are located below the osteoblasts produce fibers that are inserted into the bone socket.

Their edges remain free in the periodontal space.
Formation of the third group of fibers

They are formed from fibroblasts in the periodontal space between the developing alveolar bone and cementum.

These fibers are arranged in groups at a different angle to the fibers in the cementum and in the bone;

They form a network in periodontal space, but not participate in the ligaments.
Connection of the periodontal fibers

During tooth eruption the fibers remain unassembled;

They are joined by the action of masticatory forces after tooth eruption;

Linkage between the two groups of fibers become by growth, branching and continually remodeling.
Increasing the fibers

From the socket go out fewer, but thicker bundles;

From cementum go out a greater number, but thinner bundles;

Fibers branching as a brush;

Fibers are growing and approaching;

They are interconnected by adhesins of tissue fluid and peripheral receptors on the fibers;

They are grouped together in the periodontal ligaments.
This is a diagrammatic illustration of the remodeling process in the dental follicle that leads to the formation of the mature periodontal ligament.

The earliest remodeling takes place along the tooth (T) and the alveolar bone (AB) side of the dental follicle (Figs. A and B).

- Small bundles of collagen align themselves perpendicularly to the tooth and bone surface.
- They gradually grow thicker and longer, with the fibers on the bone side becoming wider than those on the tooth side.
- On the tooth side, the fiber bundles become incorporated into the developing cementum layer and on the bone side into new bone.
The first stage in the formation of periodontal ligaments:

- Short and numerous bundles coming out of cement;
- They branch out as a brush;
- From alveolar bone leaving smaller but thicker bundles;
- Among them have an axial fibers;
- The majority of the periodontal space is occupied by loose fibers.
The root surface at onset of cementogenesis and genesis of periodontal ligaments.

- **Legends:**
  - D, root dentin
  - DF, dental follicle (immature periodontal ligament)
  - EF, extrinsic fibers
  - F, fibroblasts
Second Stage

Anchored fibrils grow in length;

Branching;

¾ of periodontal space remains engaged with free fibrils;
Both groups anchored fibrils are growing. They are approaching to the central zone of the periodontal space; in this way they are pushing the free fibrils.
Overlap of the fibers

Continue to increase in thickness;

Now they look continuous, although overlapped;

Carry out the continuous remodeling of the fibers resulting from the masticatory forces
Intermediate plexus

Incompletely remodeled ligament or sections through neurovascular channels have been erroneously described in the dental literature as a so-called "intermediate plexus", a zone believed to allow for mechanical "slippage" between cemental and osseous fibers during rapid eruption.

It is recognized today that rapid tooth movement takes place because of continuous remodeling of the structural elements of the ligament at the molecular level, and not by mechanical accommodation of the fibrous elements.
Parallel formation of cement and periodontium
Periodontium during tooth eruption

- Crown of the tooth is ready, but the root is not;
- Dental follicle around the root has become a thin capsule that will remodeling periodontal ligaments (PDL);
- Some of pluripotent cells of the follicle producing cementoblasts, osteoblasts and fibroblasts, remain as undifferentiated cells;
- Usually they are perivascular, remodeling ligaments of the enamel-cement bond, pull it up apically.
Histology of PDL

- PDL like any other connective tissue is composed of cells and extracellular components;

- Cells
  - Fibroblasts;
  - Cementoblasts;
  - Osteoblasts;
  - Osteoclasts;
  - Undifferentiated mesenchymal cells;
  - Epithelial cell rests of Malassez.
Extracellular components

- Collagenous fibers;
- Elastic fibers;
- Ground substance;
- Nerves;
- Blood vessels;

- The main fibers are the principal fibers and additional fibers are oxytalan fibers.
Morphology of PDL
Principal fibers of the periodontal ligament

1. transseptal fibers
2. oblique
3. apical
4. interradicular
5. horizontal
6. alveolar crest
7. dento-gingival (free gingival)
8. alveolar-gingival
9. circular
10. dento-periosteal
The fibre bundles that exit the cementum and alveolar bone from the periodontal ligament are called principal fibers;

According to the location of those fibers they can be dentoalveolar fibers or gingival fibers.
The periodontal fibers of the periodontal ligament are primarily composed of bundles of type I collagen fibrils. They have been classified into several groups on the basis of their anatomic location. The following constitute the **principal fiber groups** of the periodontal ligament:

1. Alveolar crest fibers;
2. Horizontal fibers;
3. Oblique fibers;
4. Periapical fibers;
5. Interradicular fibers.
- **Alveolar crest group** – near the cervical region. They extend obliquely from the cementum just beneath the junctional epithelium to the alveolar crest.

- **Horizontal fiber group** – near the middle part of the root. They attach to the cementum apical to the alveolar crest fibers and run perpendicularly from the root of the tooth to the alveolar bone;

- **Interradicular group** – are only found between the roots of multi-rooted teeth, such as molars. They also attach from the cementum and insert to the nearby alveolar bone.
Oblique fiber group – immediately above the apical group. They are the most numerous fibers in the periodontal ligament, running from cementum in an oblique direction to insert into bone coronally;

Apical fiber group – near the apical area of the root - these fibers prevent the extrusion of the tooth and resist lateral tooth movements. They are radiating from cementum around the apex of the root to the bone, forming the base of the socket.
Interradicular group – are only found between the roots of multi-rooted teeth, such as molars. They also attach from the cementum and insert to the nearby alveolar bone.
Gingival group

The main fibers of this group are divided into 8 subgroups:

1. **Cement-gingival group.** This attached to the cement consists of two types – (1) free gingival fibers, fixed at one end to the cement, and the other ends freely in the neck; (2) Attached gingival fibers. They are attached to the cement in the neck of the tooth and end in the attached gingiva.

2. **Alveoli-gingival fibers.** They attach to the alveolar ridge and end freely in the gingiva.
3. **Dento-periostal fibers.** They emerge from the cervical cement and end in the alveolar ridge.

4. **Circular gingival fibers.** Long fibers that circulate around the cervix. They form eights around adjacent teeth.

5. **Transgingival fibers.** They emerge from the proximal root surface, pass to the adjacent teeth and merge with other vestibular and orally arranged octoid fibers.
6. **Semicircular fibers.** They emerge from the medial and distal approximate area, circumvent the oral and vestibular surfaces and attach to the opposite approximate zone.

7. **Transseptal fibers.** They emerge cervical from one crown, pass over the alveolar ridge between two teeth without attaching there, and terminate in the cervical zone of the adjacent tooth.

8. **Intergingival fibers.** They run parallel to the dental row of the vestibular and oral.
Dentoalveolar fibre group
They are five groups:

1. **Alveolar-ridge group.** It is located cervical, but below the dento-periostal fibers of the gingival group. They emerge from the cement and head toward the alveolar ridge. They are opposed to vertical and intrusive forces.

2. **Horizontal group.** These are horizontal fibers perpendicular to the longitudinal axis of the tooth. They have a radial incision and connect the cement to the bone. They are located below the alveolar-ridges and sometimes reach the middle of the root. They resist the transversal forces of the chewing act, as well as against the rocking of the tooth.
3. **Oblique fibers.** They start below the horizontal, gradually becoming shorter at the end of the root. The high lobes are to the alveolar bone and the low to the cement. They are the largest part of all fibers. They neutralize the most powerful axial forces of the chewing act, preventing the alveoli from clogging.

4. **Apical group of longitudinal fibers.** They are located in the apical area. Their direction is an extension of the longitudinal axis of the tooth. They are trapped perpendicular to the apex, clinging to the bottom of the alveoli. They resist the extrusive forces by preventing tooth extraction.
5. ** Interradicular group of fibers.** It is located between the roots of the multi-rooted teeth. They are also perpendicular to the alveolar base and the furcation and are parallel to the longitudinal axis of the tooth. They are opposed to both vertical and lateral horizontal forces.
Gingival fibre group

- Dentogingival group – these fibres are the most numerous, extending from the cervical cementum to the lamina propria of the gingiva.
- Alveologingival group – these fibres extend from the alveolar crest to the lamina propria of the gingiva.
- Circular of Circumferential fibres – continuous around the neck of the tooth.
- Transseptal fibres – these fibers extend from the cervical cementum of one tooth to the cervical cementum of the other.

Dentogingival group and alveologingival group fibers embed in attached gingiva and free gingiva, hence, also called attached gingival group and free gingival group fibers.
Cementum-alveolar fibers
Alveolar crest fibers - extend obliquely from the cementum just beneath the junctional epithelium to the alveolar crest.

- These fibers prevent the extrusion of the tooth and resist lateral tooth movements.
Transseptal fibers

- Transseptal fibers (H): extend interproximally over the alveolar bone crest and are embedded in the cementum of adjacent teeth;
- They form an interdental ligament;
- These fibers keep all the teeth aligned;
- These fibers may be considered as belonging to the gingiva because they DO NOT have osseous attachment.
Transseptal fibers

Starting from cementum to one tooth - over interdental septum - to cementum to the adjacent tooth.
Horizontal fibers

- Horizontal fibers (J): attach to the cementum apical to the alveolar crest fibers and run perpendicularly from the root of the tooth to the alveolar bone.
Oblique fibers (K): are the most numerous fibers in the periodontal ligament, running from cementum in an oblique direction to insert into bone coronally.
Oblique fibers
Apical fibers

- Radiating from cementum around the apex of the root to the bone, forming base of the socket
Interradicular fibers are only found between the roots of multi-rooted teeth, such as molars. They also attach from the cementum and insert to the nearby alveolar bone.
Scheme of the periodontal ligament

Ligamentum circularae

Ligamentum oblique
The periodontal ligament is composed of collagen fibers that originate as fibers of different diameters at the mineralized surfaces where the fibers are continuous with their mineralized portion (Sharpey's fibers);
These fibers are of a wider diameter on the bone side than the cementum side.
Whether they originate from bone or cementum, they unravel into smaller fibers, which join up with those of adjacent fibers to produce a meshwork of interconnected fibers oriented between bone and cementum;

Thus, the periodontal fibers do not stretch cable-like from cementum to bone, but form a meshwork of interconnected fibers.
Elastic fibres

- Apart from principal fibres additional fine fibres appear in the periodontal ligament that are called oxytalan fibres.

- These fibres support the principal fibres system and are considered to be part of the indifferent fibre plexus.

- They are elastic-like and appear around the vessel walls.

- Other elastic fibers are elastin and elaunin fibers.
The periodontal ligament contains a unique assortment of cells that are capable of generating and maintaining three distinct tissues, namely the ligament itself as well as the mineralized tissues on either side of it, i.e. the cementum and the alveolar bone.

The major cell types of the periodontal ligament include fibroblasts, macrophages, undifferentiated ectomesenchymal cells, cell rests of Malassez.
Fibroblasts

These cells are responsible not only for the synthesis of collagen and its assembly into collagen fibers, but also for the removal of collagen fibers during the continuous remodeling that takes place in the ligament. Collagen fibrils are removed, in part, through intracellular degradation by fibroblasts in digestive vacuoles. ICC, intracellular collagen in a digestive vacuole.
The main mass of the periodontium is the fibers. Spaces called interstitial spaces are formed between each strand of fibers. These are not empty spaces, but filled with vessels, lymph, and nerves. They counteract the dynamic effects of chewing forces. In addition, they have a fine network of thin fibers, chaotically interconnected. They are the support of terminal blood vessels and nerves.
Blood supply

- The periodontal ligaments are rich in blood supply. with a.a. alveolaris superior and inferior knobs, as well as a. Facialis of a. Carotis Externa.

- The blood supply is provided in three directions - (1) *apical vessels* - these are the branches of the central artery before entering the pulp.

- They enter the periodontal space and branch out to a powerful network from the apex to the cervical area;

- (2) *penetrating vessels* - branches of vessels in the alveolar bone;

- (3) *anastomosing vessels* - branches of the gingival urethra in the cervical zone. Branches form a capillary plexus.

- There are anastomoses between them. The arteries and veins pass through the entire periodontal space and end with a powerful capillary network around the fibers. This is due to the high load of periodontal ligaments.
Innervation of the periodontium

- The innervation scheme is similar to the blood supply. The nerves move in parallel with the blood vessels. The large nerves extend over the entire periodontal space, and their terminal branches are around the fibers. They end up with encapsulated proprioceptors or pressure-responsive acinar receptors.
Lymphatic vessels in the periodontal space

- They are collector vessels draining lymph from the gingiva and periodontium.
- In the apical area, the fine lymphatic vessels of the pulp also join them, and together they head to the cervical lymphatic nodes.
Essential substance in the periodontal space

- It is formed by glycoproteins, proteoglycans, electrolytes, colloids, and water.
- Proteins and polysaccharides supply cells with essential products coming from the capillaries.
- Unnecessary waste is discharged through veins.
Vascular and Nerve supply

- There are spaces between the fibre bundles called the **interstitial spaces**.

- The interstitial spaces contain blood vessels, lymph channels, and nerves.

- These structures help maintain the vitality of the periodontal ligament.
Connective tissue in periodontium

Blood vessels are growing:
- There are branches of the apical artery;
- There are branches of the bone arteries;
- And gingival arteries;

Nerves grow under the same scheme;

There are also lymphatic vessels;

There are also tissue fluid.
Construction of the periodontal ligament:

- Bundles of densely packed collagen fibers;
- Thicker 100 - 150μm;
- Have longitudinally oriented vessels.
Collagen molecule

It is a rod with a width of 1.5nm in diameter and a length 300nm;

It consists of three helical polypeptide chains - α1, 2 and 3.

The most common collagen in humans is type-1.
Collagen type I

Molecules aggregate into fibrils with transverse striation of 70nm;

This is the smallest microscopically recognizable unit;

Their width is 3-4μm in diameter and striation of 640Å.
Collagen fibers form a network:

- Form complexes with wavy motion;
- They are interconnected to form a network;
- They go around the blood vessels;
- Among the strands are flattened fibroblasts with foliate appendage;
- In the center forms a plexus called "concluded fingers."
Histological cross-section through a periodontal ligament on the distal surface of a single-rooted tooth.

The periodontal ligament fibers (F) originate from relatively thin fibers (*) inserted into the cementum.

After they unravel and become intermeshed with adjacent fibers, they form thicker fiber bundles that insert into bundle bone (BB), so named because it contains numerous Sharpey's fibers (SF).

Because of **mesial drift**, the tooth is slowly displaced mesially (to the left).

This requires continuous remodeling of the ligament and deposition of new bone on the distal alveolar surface in order to maintain the width of the ligament constant.

Neurovascular channels (NV) that house blood vessels, lymphatics and nerves in a loose connective tissue sheath course throughout the periodontal ligament.

The ligament also contains **cell rests of Malassez** (M).
Histological cross-section through a periodontal ligament on the mesial surface of a single-rooted tooth.

- Mesial drift of the tooth results in cyclical episodes of alveolar bone (AB) resorption, followed by resting periods and short cycles of bone deposition.
- A distinct reversal line (RL) indicates the location where the last cycle of bone resorption was followed by bone deposition.
- The latter resulted from the production by osteoblasts (OB) of a thin seam of new bone in which very short Sharpey's fibers (SF) are imbedded. Note the thin fibers of the periodontal ligament (PDL) inserting into the cementum (C) laye
Inervation of Mandibular Teeth. Innervation of the gingiva and periodontium is via the mandibular nerve.
Cells, vessels and nerves of the periodontal ligament

- The periodontal ligament contains a unique assortment of cells that are capable of generating and maintaining three distinct tissues, namely the ligament itself as well as the mineralized tissues on either side of it, i.e. the cementum and the alveolar bone.

- The major cell types of the periodontal ligament include the following:
  - Fibroblasts, macrophages and undifferentiated ectomesenchymal cells.
  - Cementoblasts and cementoclasts.
  - Osteoblasts and osteoclasts.
  - Cell rests of Malassez.
  - Vascular and neural elements.
These cells are responsible not only for the synthesis of collagen and its assembly into collagen fibers (CF), but also for the removal of collagen fibers during the continuous remodeling that takes place in the ligament.

Collagen fibrils are removed, in part, through intracellular degradation by fibroblasts in digestive vacuoles.

ICC, intracellular collagen in digestive vacuole.
Dysfunctional periodontium

In the absence of the function of the tooth periodontal ligament, it loses organization;

It becomes narrower;

The fibers lose their specific direction.
Cementum, periodontal ligament, alveolar bone
E. Clinical considerations

1. The thickness of the periodontal ligament varies from 0.1 to 0.4 mm with a mean of around 0.2 mm.

2. The ligament is thicker in functioning than in non-functioning teeth, and in areas of tension than in areas of compression.

3. The ligament cells are capable of remodeling the ligament and adjacent bone when functional forces are altered or the ligament is damaged.

4. The periodontal ligament plays a key role in protecting the tooth from being resorbed by the normal remodelling process that affects the adjacent alveolar bone.
5. Excessive forces can cause localized necrosis (cell death) of the ligament by cutting off the normal blood supply to the cells.

This situation immediately results in stoppage of remodeling at the affected site.

Therefore, orthodontic tooth movement is no longer possible.

Repair occurs via emigration of cells from adjoining vital periodontal ligament.

In the event the ligament continuity is not restored, localized resorption and ankylosis may occur.
6. Accidentally exfoliated teeth can be replanted.

Complications include external root resorption and ankylosis if portions of the ligament are permanently damaged.

These can be minimized by avoiding excessive handling of the torn ligament prior to replantation.

7. Appropriate therapy can halt progressive destruction of the periodontal ligament by periodontal disease and can result in repair of periodontal defects.
8. The periodontal ligament is unique among the periodontal tissues, in that it contains precursor cells for the production of the entire attachment apparatus of the tooth, i.e. cementum, periodontal ligament and bone.

By using biologically compatible barriers, the therapist is able to promote the ingrowth of these cells into damaged sites where a new periodontal attachment is needed. This therapeutic principle is known as guided tissue regeneration.

9. Current research on growth factors and cytokines is aimed at promoting the ingrowth of specific cell types into a wound, while keeping out undesirable cell types.
The PDL are always in a state of remodelling

- Functions of PDL:
  - Formative;
  - Supportive;
  - Protective;
  - Sensory;
  - Nutritive.
Formative function

The periodontal ligaments are in continuous modeling and remodeling, which is supported by fibroblasts, macrophages, and undifferentiated mesenchymal cells.
The most important function of periodontal ligaments is to attach the root of the tooth to the alveoli and maintain it throughout its life. Any mistake in this function results in tooth loss. It provides complex tooth movements during chewing act and protects tissues from chewing forces.
Abundant periodontal ligament receptors capture pressure, and nerves send signals to the brain. It informs the chewing apparatus of determining the strength and mode of chewing. Such signals are sent to the maxillary joint and the chewing muscles. This is how the chewing act is controlled.
Nutritive function

The blood supply provides the periodontal ligaments with the necessary products to perform their functions. It nourishes its own structures, the cement, the surface of the alveolar bone. It feeds on all cellular elements.
It helps the tooth movement

When forces are exerted on the tooth (orthodontic treatment or occlusal problems), the ligaments are under pressure and the blood vessels are compressed. This results in the interruption of some of them and insufficient nutrition of the plot. The cells shrink and ischemia occurs. The tissue becomes transparent and is described as "hyalinized". Longer-acting pressures result in osteoclasts and loss of alveolar bone. This creates a space where the root can move and new blood vessels sprout.
It protects its own elements and fibers, as well as cement and alveolar bone from overload. It protects the entire periodontium from invading external elements and agents through saliva, mainly microorganisms. The protection is accomplished with the function of each element in the periodontal space.
Recovery function

The healing function of damaged structures is provided. This is done by contacting the cells with the surrounding intercellular fluid. This is how they respond to disability and are stimulated to recover. Fibroblasts, together with the newly formed fibers, are the emergency brigade of the periodontium with damaged fibers. They repair in situ, but also protect the cement and alveolar bone from damage.