Sri Aurobindo College of Dentistry

Indore, Madhya Pradesh

INDIA

Module plan

- Topic : Biology of Orthodontic Tooth movement
- Subject: Orthodontics
- Target Group: Undergraduate Dentistry
- Mode: Powerpoint – Webinar
- Platform: Institutional LMS
- Presenter: **Dr. Ashish Garg**

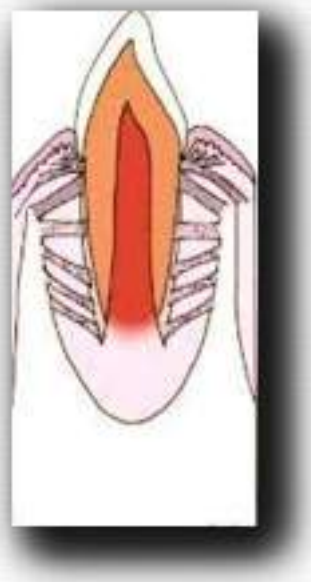
Physiologic Tooth Movement

It is the naturally occurring tooth movements that take place during and after tooth eruption.

1. Tooth eruption
2. Migration or drift of teeth
3. Changes tooth position during mastication

Tooth Eruption

Axial or occlusal movement of the tooth from its developmental position within the jaw to its functional position in the occlusal plane.



Theories Of Tooth Eruption

- Vascular pressure theory
- Root formation
- Hammock ligament
- Periodontal ligament traction

Vascular pressure theory:-

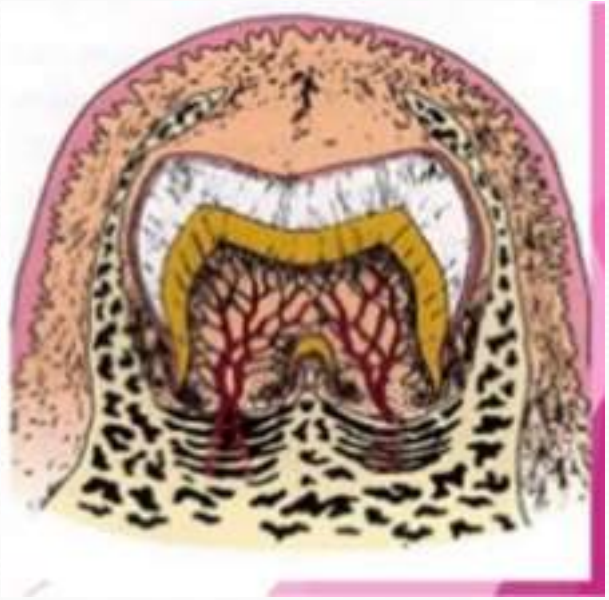
Tissues around developing end of root is highly vascular which causes axial movement of teeth.

Root growth theory:-

Apical growth of roots results in an axially directed force that brings about eruption of teeth.

Hammock ligament:-

- A band of fibrous tissue exist below the root apex spanning from one side of alveolar wall to the other.
- The developing root forces itself against this band of tissue, which in turn applies an occlusally directed force on the tooth.



Periodontal ligament traction:-

- This theory states that the periodontal ligament is rich in fibroblasts that contain contractile tissue.
- The contraction of these periodontal fibers (mainly the oblique group) result in tooth eruption.

Migration Or Drift Of Teeth

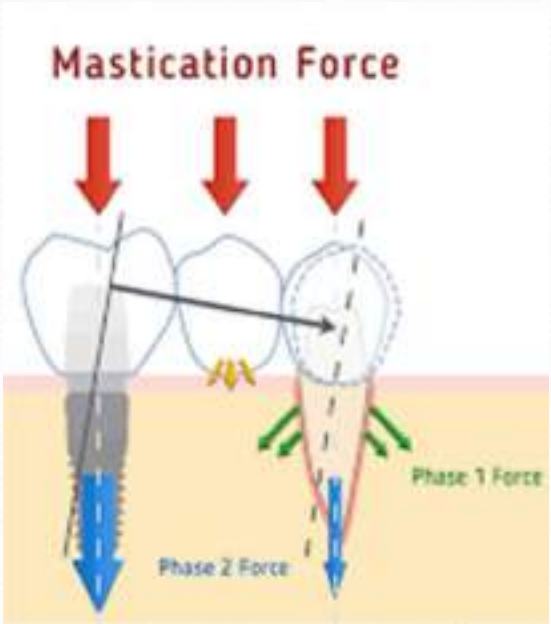
- Teeth have the ability to drift through the alveolar bone.
- Human teeth have a tendency to migrate in mesial or occlusal direction.
- This maintains the inter-proximal and occlusal contact.
- Aided by bone resorption and deposition by osteoclasts and osteoblasts respectively.

- **Mesial** - due to proximal caries (loss of tooth structure)

- **Occlusal** - Due to premature exfoliation or absence of opposing tooth (supra-eruption)

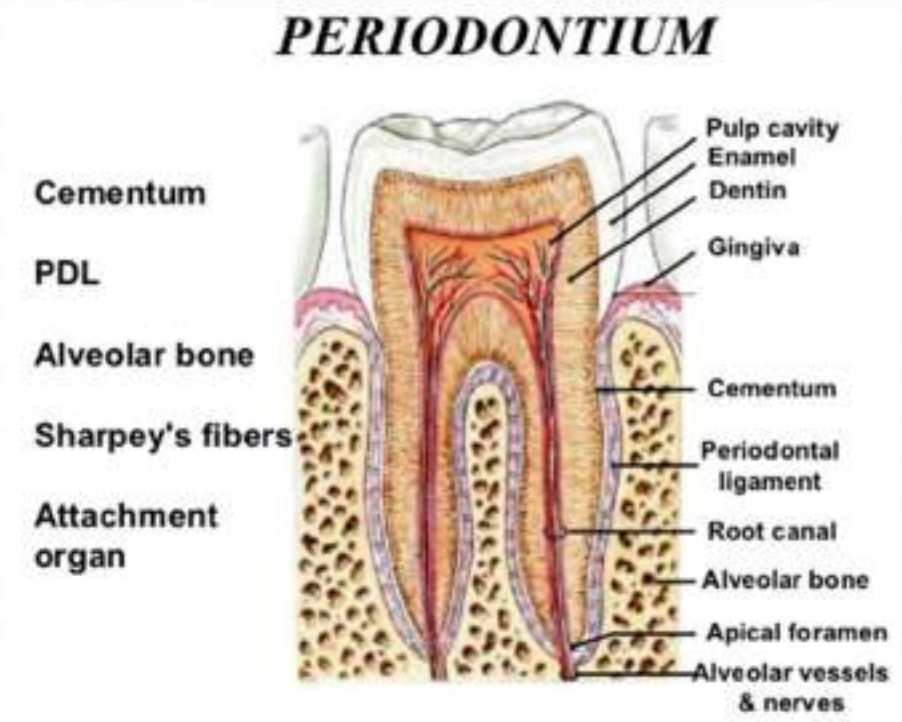
Tooth Movement During Mastication

- Normal force of mastication -1 to 50 kg.
- It occurs in cycles of 1 second duration.
- Teeth exhibit slight movement within the socket and return to their original position on withdrawal of the force.
- Whenever the force is sustained for more than 1 second, periodontal fluid is squeezed out & pain is felt as the tooth is displaced within the periodontal space.



Periodontium

Tooth is attached to alveolar bone by periodontal ligament which occupies about 0.5 mm width all around tooth root.

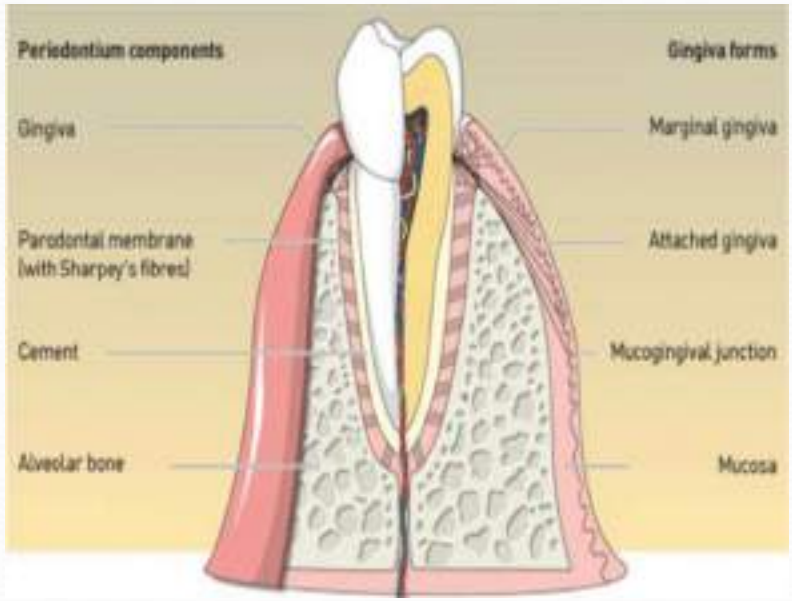


Components Of Periodontium

a) Network of parallel Collagenous Fibers .

b) Cellular Elements - undifferentiated mesenchymal cells and their progeny.

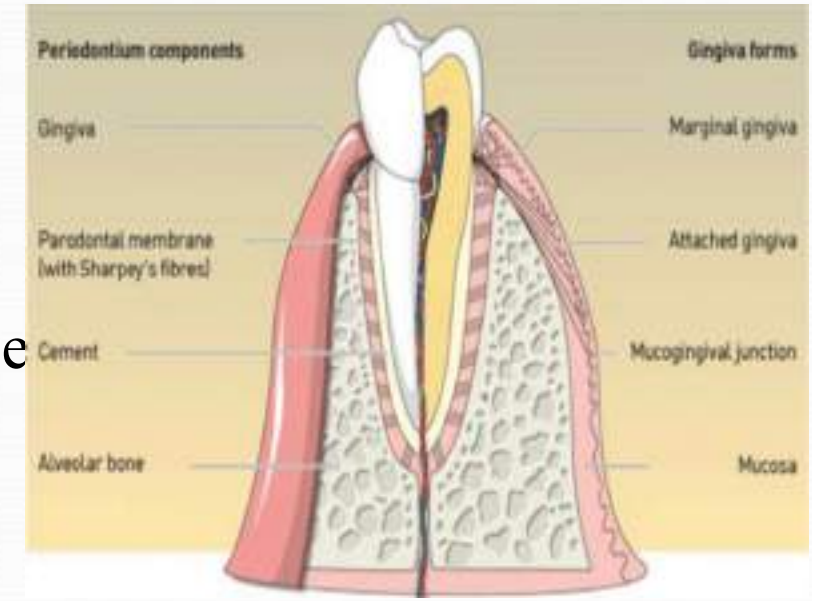
eg.fibroblasts/fibroclasts,osteoblasts/osteoclasts, cementoblasts /cementoclasts .



c) Vascular Elements -Blood vessels and cells derived from vascular system.

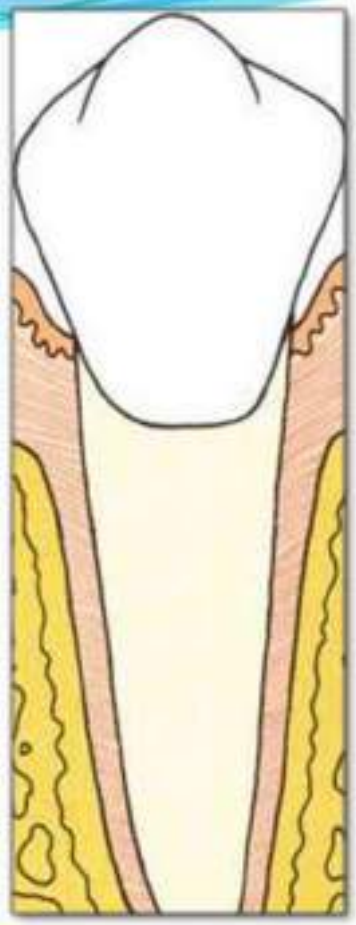
d) Nervous Elements -Unmyelinated free nerve endings (pain perception)
Complex Receptors(proprioception).

e) Tissue Fluids derived from the vascular system



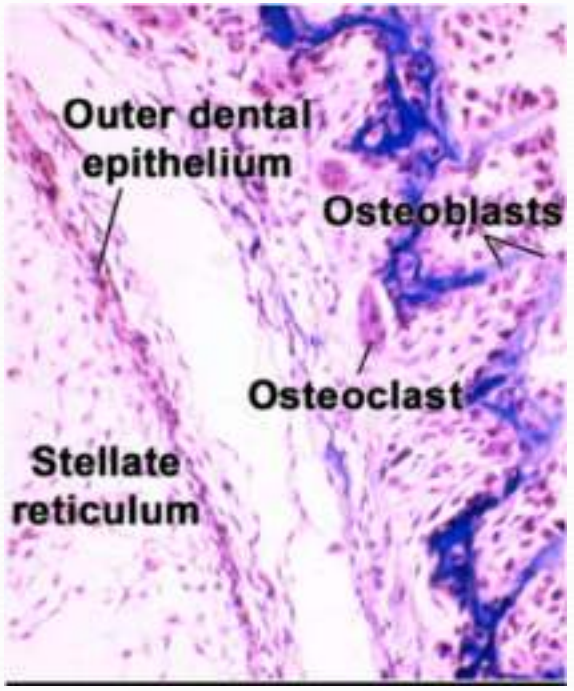
Collagenous Fibres

- Collagenous fibres of PDL connects the cementum and lamina dura.
- The fibers run at an angle attaching farther apically on the tooth than on the adjacent alveolar bone.
- PDL space is filled with fluid derived from vascular system.



Cellular Elements in the PDL

- Fibroblasts – produce and destroys collagen fibers.
- Osteoblasts –produce new bone.
- Osteoclasts – aids in bone resorption.
- Cementoblasts – forms new cementum.
- Cementoclasts – removes cementum.
- PDL is vascular and contains nerve endings which aid in proprioception.

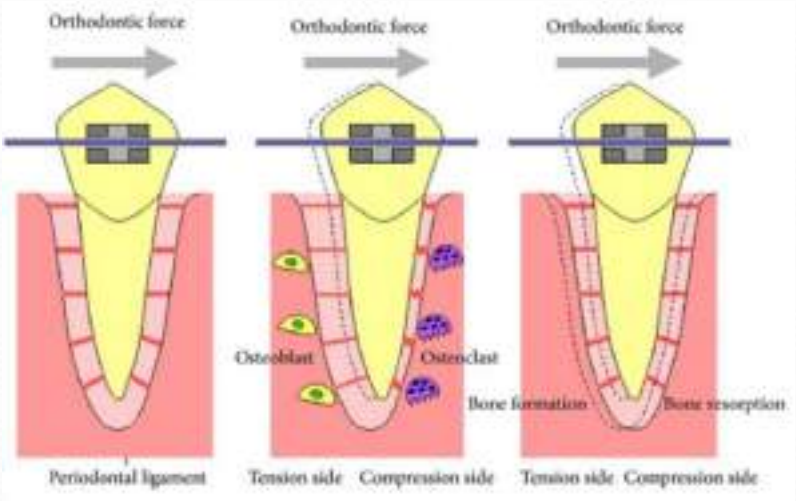


ORTHODONTIC TOOTH MOVEMENT

- It is a pathological process from which the tissue recovers.

Histology of tooth movement:-

- Orthodontic movement bring about areas of pressure and tension around the tooth. The histologic changes seen during tooth movement vary according to the amount & duration of force applied.



Response to Continuous Pressure

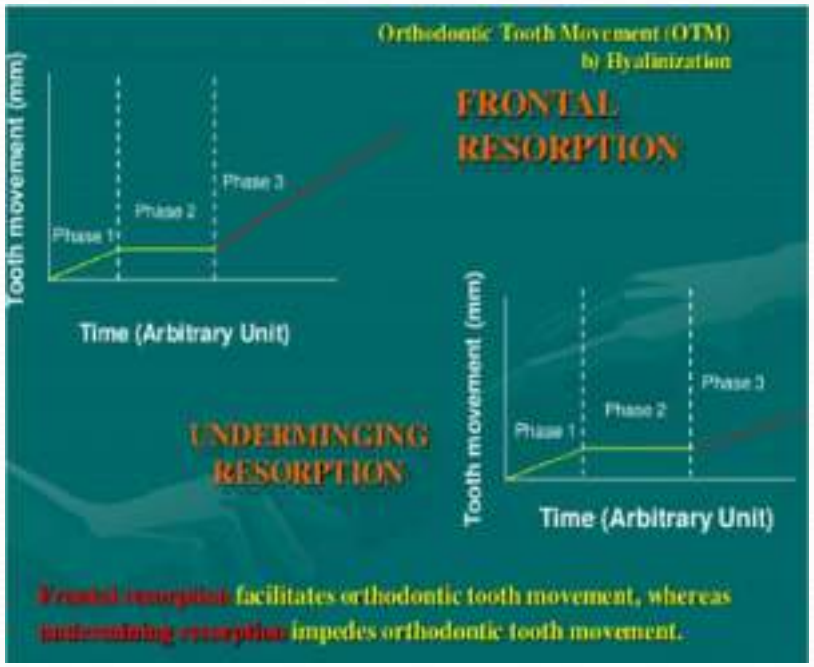
- **< 1 second:** Fluid in the PDL is incompressible.
- **1 – 2 seconds:** PDL fluid expressed, Tooth moves within PDL space.
- **3 – 5 seconds:** PDL fluid squeezed out, Tissue compressed and immediate pain is felt if force is heavy.

Force for Orthodontic Tooth Movement

- Forces that bring about orthodontic tooth movement are continuous and should have a minimum magnitude (threshold).
- Below this threshold limit, the PDL has the ability to stabilize the tooth by active metabolism.
- The minimum pressure required is 5 to 10 gm/cm^2 (current concept).

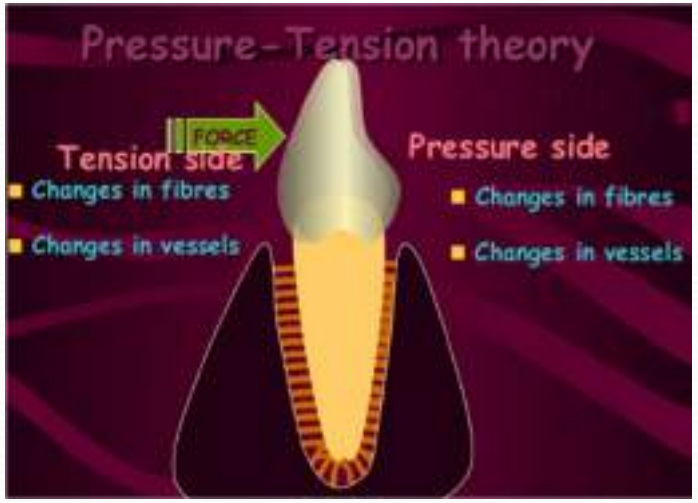
Types of Orthodonic Forces

- LIGHT FORCE – Frontal resorption
- HEAVY FORCE – undermining resorption



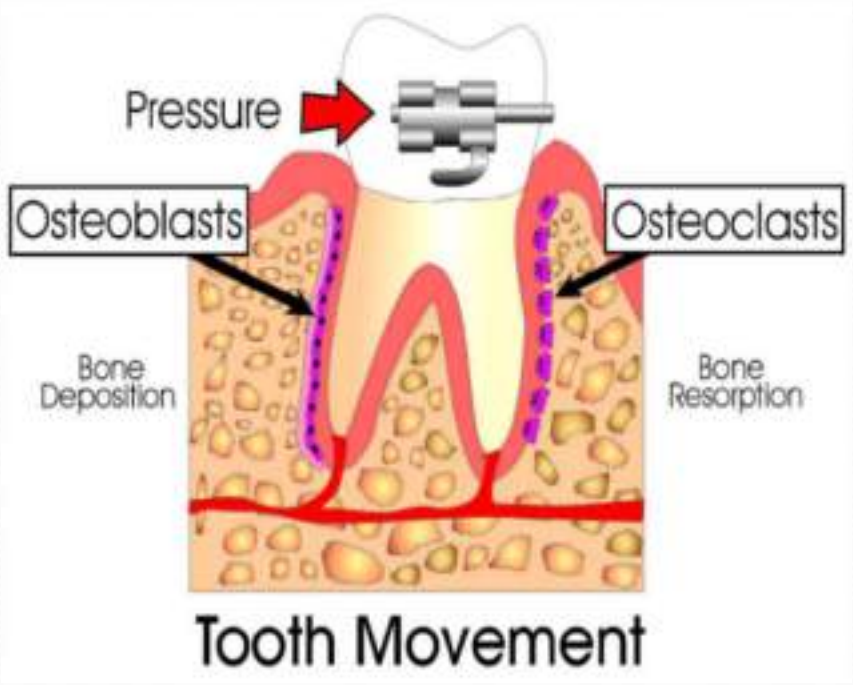
The Pressure – Tension Theory

- When force is applied on the tooth, PDL is compressed on one side and stretched on the other side.
- Blood flow is decreased on the pressure side where PDL is compressed.
- Blood flow is increased on the tension side where PDL is stretched.



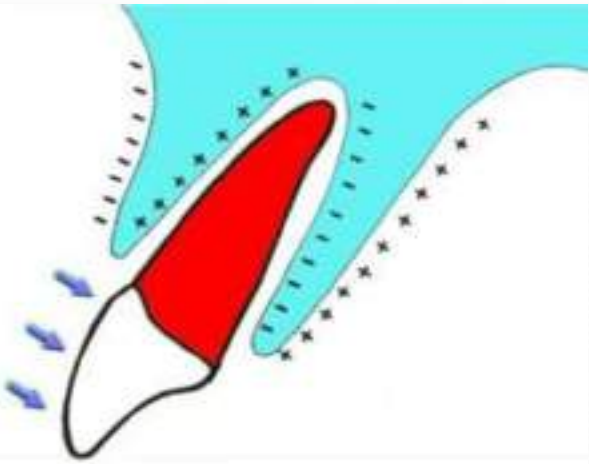
The process of initiation of tooth movement has 3 stages:-

1. Alternation of blood flow associated with pressure within the PDL.
2. The formation and release of chemical messenger.
3. Activation of cells which causes deposition and resorption of bone.



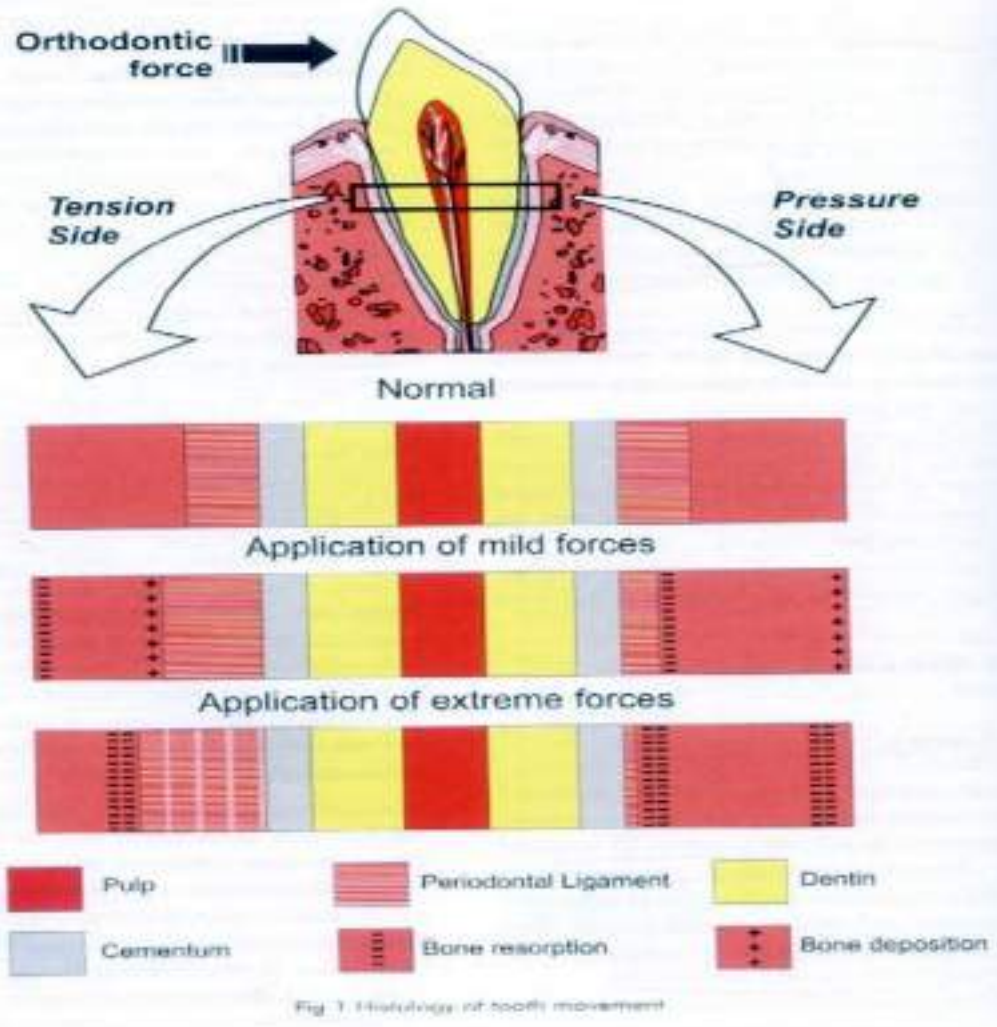
- BONE RESORPTION (osteoclastic activity) takes place at the side of the PDL where there is PRESSURE.

- BONE FORMATION (osteoblastic activity) takes place at the side where there is TENSION.



Maintenance of Thickness of Alveolar Bone

- In an ideal treatment, the attachment level is maintained.
- Resorption and deposition of bone maintains its thickness in the facial and lingual side irrespective of the type of movement the tooth has undergone on the alveolar bone.

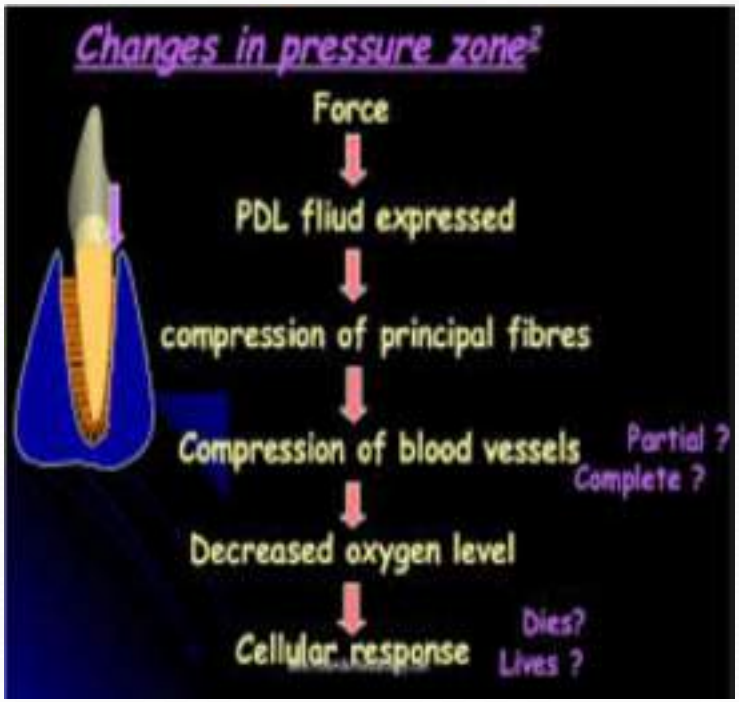

Orthodontic force
Tension Side
Pressure Side
Normal
Application of mild forces
Application of extreme forces
Pulp
Periodontal Ligament
Dentin
Cementum
Bone resorption
Bone deposition

Changes following application of light force

Classically the movement of teeth has been explained via the pressure-tension hypothesis in which PDL tissues in pressure side results in bone resorption , while placing the PDL tissues under tensile force lead to bone deposition.

Changes on pressure side

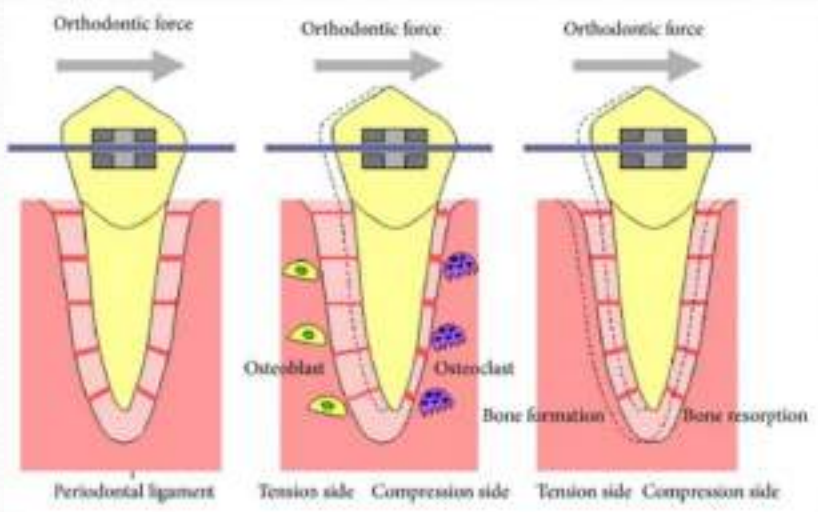
- The PDL in direction of tooth movement gets compressed to almost 1/3rd of it's original thickness.
- A marked increase in the vascularity of PDL on this side is observed due to increase in capillary blood supply.
- This increase in blood supply helps in mobilization of cells such as fibroblasts and osteoclasts.



- Osteoclasts are bone resorbing cells that lie in Howship's lacunae .
- When forces applied are within physiologic limits, the resorption is seen in alveolar plate immediately adjacent to the ligament. This kind of resorption is called frontal resorption.

Changes on tension side

- PDL stretched.
- Distance between alveolar process & tooth is widened.
- Increased vascularity.
- Mobilization of fibroblasts & osteoblasts.



- Osteoid is laid down by osteoblast in PDL immediately adjacent to lamina dura.
- Lightly calcified bone mature to form woven bone.

Secondary remodeling changes:-

- Bony changes also takes place elsewhere to maintain the width or thickness of alveolar bone. These changes are called secondary remodeling changes.
  - For eg:-If a tooth is being moved in a lingual direction there is compensatory deposition of new bone on the outer side of the lingual alveolar bony plate and also a compensatory resorption on the labial side of the labial alveolar bone.
  - This is to maintain the thickness of the supporting alveolar process .

Changes following application of extreme forces

On the pressure side :-

- Root closely approximates the lamina dura .
- Compresses the PDL and leads to occlusion of blood vessels.
- The PDL is hence deprived of its nutritional supply leading to regressive changes called hyalinization .
- Undermining/ Rearward resorption occurs in the adjacent marrow spaces and alveolar plate below, behind & above the hyalinized zone.

On Tension Side

- Over stretched PDL .
- Tearing of blood vessels & ischaemia.
- Extreme forces applied net increase in osteoclastic activity and tooth loosened in socket.

Optimum Orthodontic Force

- Is one which moves teeth most rapidly in the desired direction with the least possible damage to tissue and with minimum patient discomfort.

- ***Schwarz*** proposed the classic concept of the optimal force.

- Defined optimal continuous force as the force leading to a change in tissue pressure ,that approximated the capillary vessel & blood pressure. Thus preventing their occlusion in the compressed PDL.

- Below the optimal level cause no reaction in PDL.

- Forces exceeding optimal level would lead to areas of tissue necrosis, preventing frontal bone resorption.

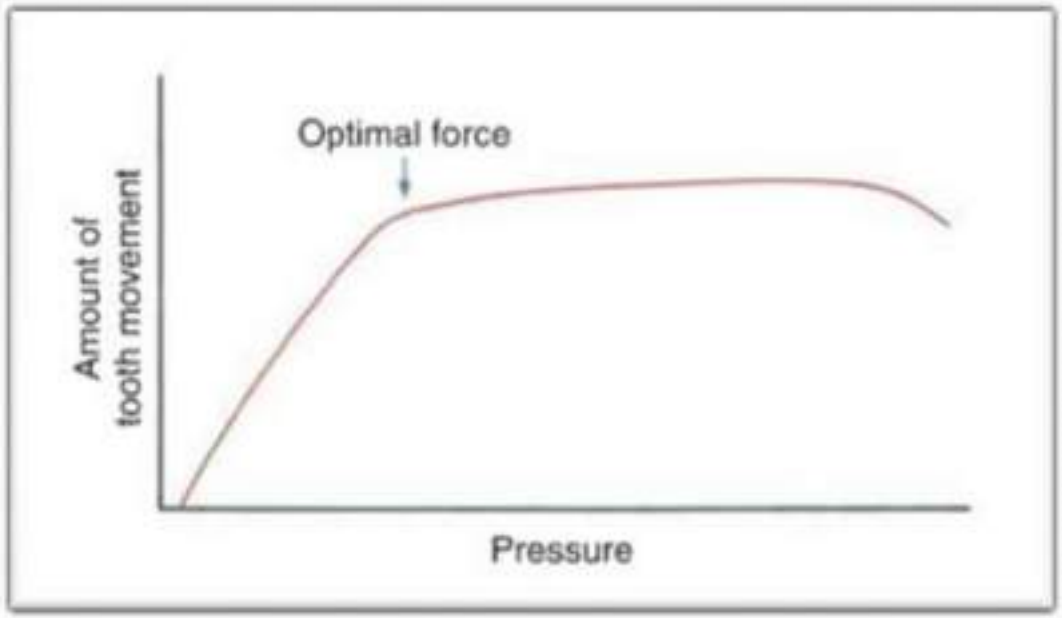
From a clinical point of view, Optimum orthodontic force has the following characteristics:

- Produce rapid tooth movement.
- Minimal patient discomfort.
- The lag phase of tooth movement is minimal.
- No marked mobility of the teeth being moved.

From a histological point of view the use of optimum force has the following characteristics:-

- The vitality of the tooth and supporting PDL is maintained.
- Initiates maximum cellular response.
- Produces direct or frontal resorption.

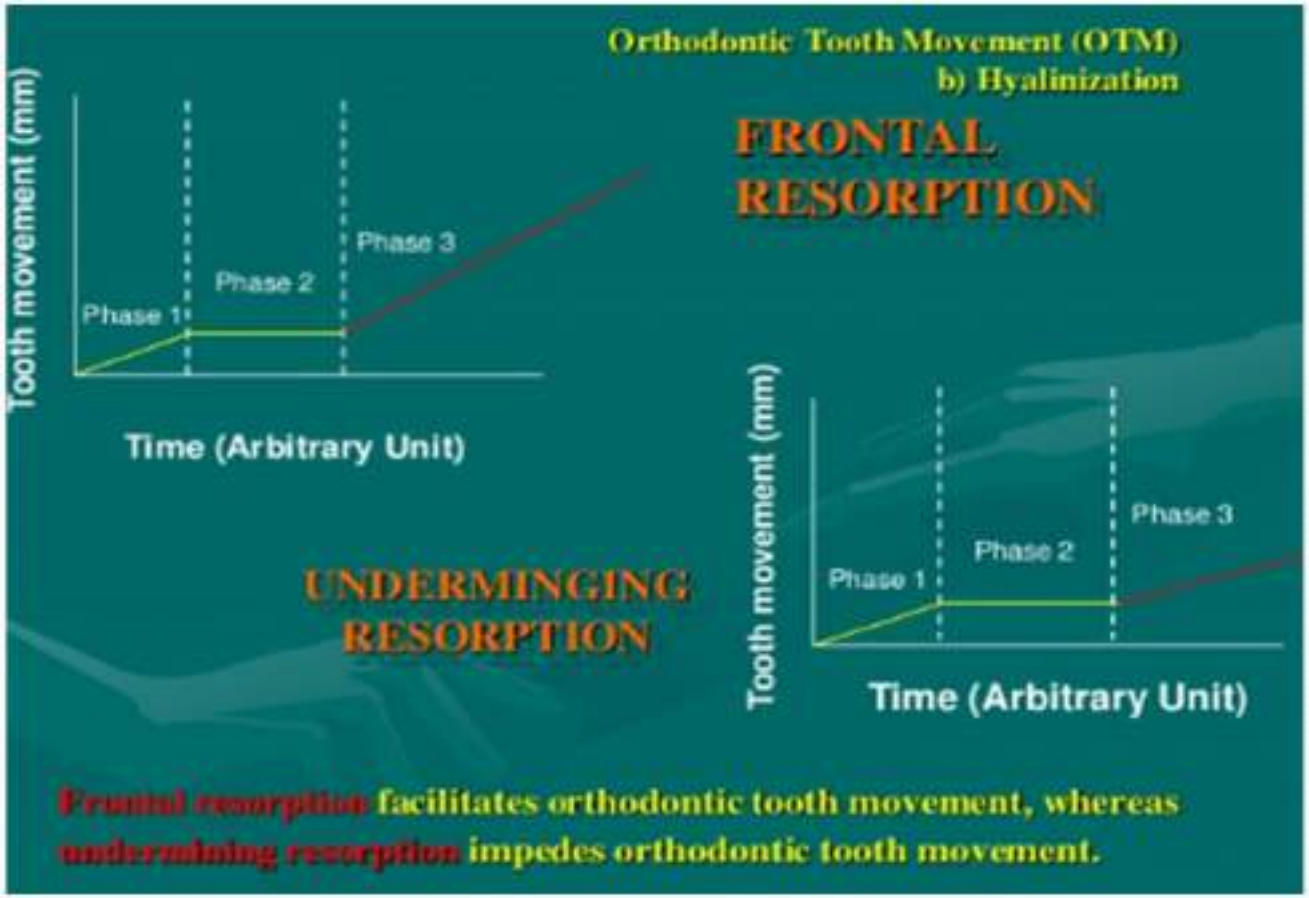
Magnitude of Force VS Tooth Movement



Modes of Orthodontic Tooth Movement

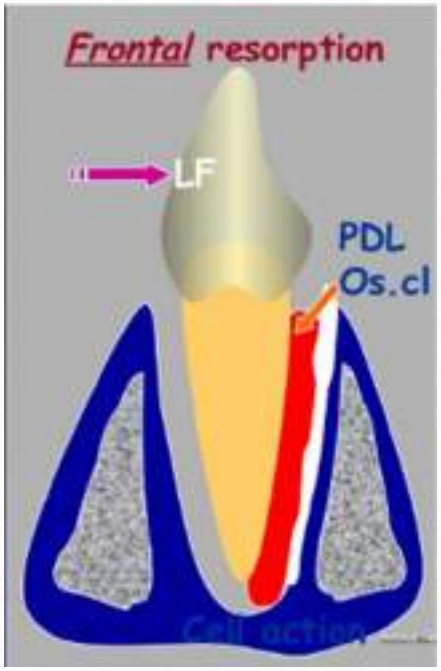
Forces created by orthodontic appliances bring about tooth movement by 2 mechanisms.

- FRONTAL Resorption
- UNDERMINING Resorption


Orthodontic Tooth Movement (OTM)
b) Hyalinization
FRONTAL RESORPTION
Tooth movement (mm)
Phase 1
Phase 2
Phase 3
Time (Arbitrary Unit)
UNDERMINGING RESORPTION
Tooth movement (mm)
Phase 1
Phase 2
Phase 3
Time (Arbitrary Unit)
Frontal resorption facilitates orthodontic tooth movement, whereas undermining resorption impedes orthodontic tooth movement.

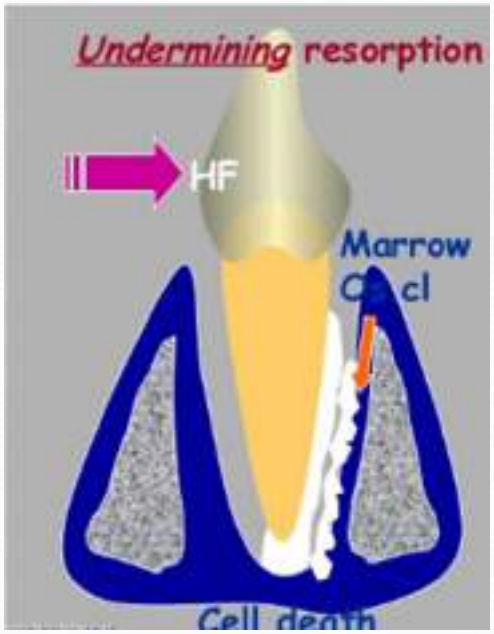
Frontal Resorption

- Accomplished by Light Orthodontic forces.
- Least painful.
- Least harmful to the periodontium.
- Most desirable.



Undermining Resorption

- Caused by Heavy Orthodontic Forces.
- Painful.
- More harmful to the periodontium.
- Occurs in a small scale even in the most careful orthodontic treatment.
- The dentist should always try to minimize this.

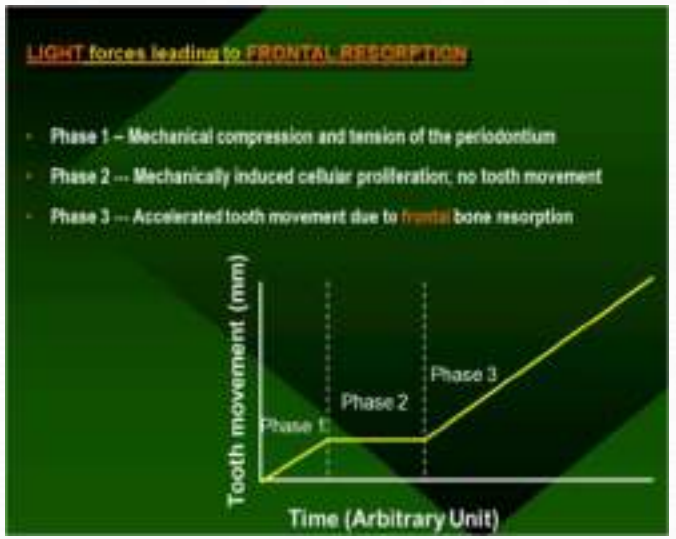


Result of Continuous Light Force

- Osteoclasts initiates resorption of lamina dura from the side of PDL.
- The osteoclasts arrive in 2 waves

  1st wave derived from the PDL itself

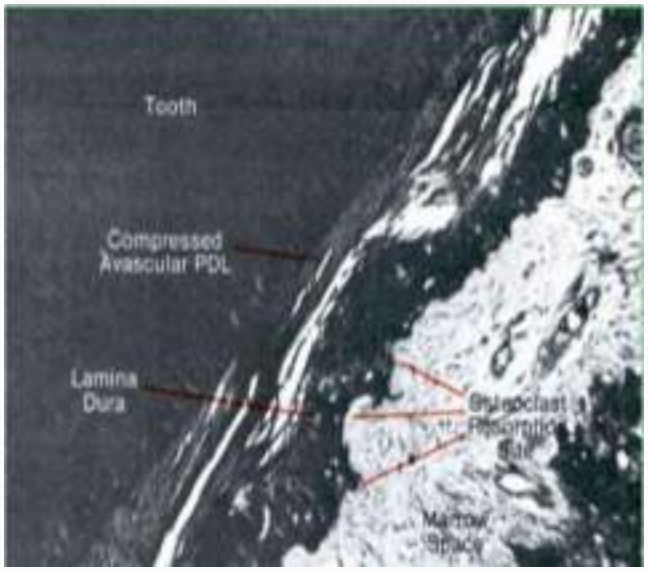
  2nd wave (larger) from distant areas via blood flow.



- All these events lead to FRONTAL RESORPTION.

Application of Continuous Heavy Force

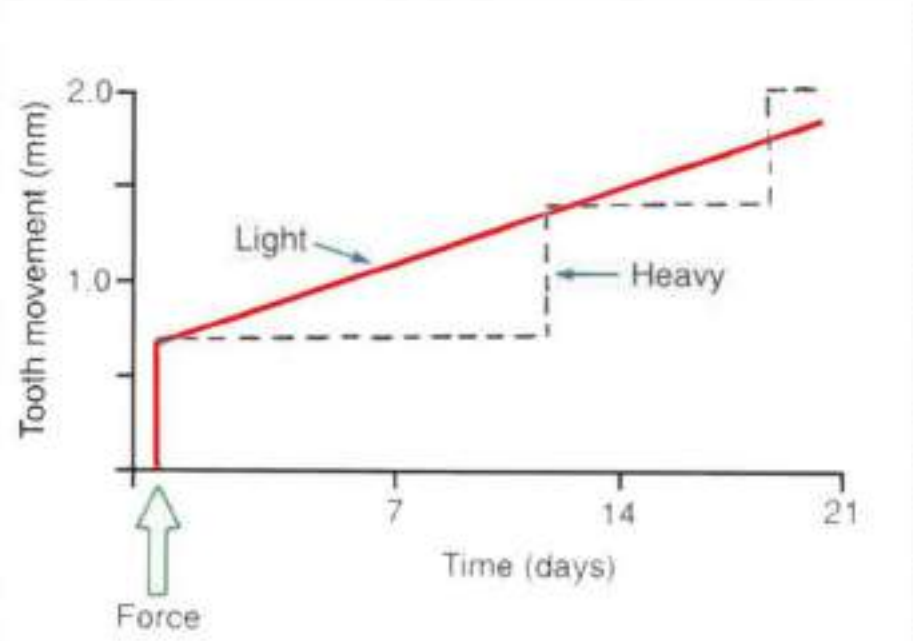
- **< 1 second:** PDL fluid is incompressible, alveolar bone bends, piezoelectric signal generated.



- **1 – 3 seconds:** PDL fluid expressed & tooth moves within the socket
- **3 – 5 seconds:** Blood vessels with in PDL occlude on the pressure side

- **Minutes:** Blood flow gets cut off to compressed PDL area.
- **Hours:** Cell death in compressed area.
- **3 to 5 days:** Cell differentiation in adjacent marrow spaces; undermining resorption begins.
- **7 to 14 days:** Undermining resorption removes lamina dura adjacent to compressed PDL & tooth movement occurs.

Frontal Resorption VS Undermining Resorption



Cellular Changes

- Loss of blood flow causes sterile necrosis of the PDL.
- A “Hyalinized” area devoid of cells and vasculature develops.
- Osteoclasts appear within the adjacent bone marrow spaces and begins an attack on the underside of the bone immediately adjacent to the necrotic PDL area.
- An initial delay in tooth movement occurs.

This delay is due to 2 reasons:-

- The delay in stimulating differentiation of cells within the marrow space.
- A considerable thickness of bone has to be removed from the underside before any tooth movement can take place.

Hyalanization

- Form of tissue degeneration characterized by formation of a clear, eosinophilic homogenous substances.
- Denotes a compressed and locally degenerated PDL.
- Reversible process.
- Occurs in almost all forms of orthodontic tooth movement but the areas are wider when the force applied is extreme.

Changes observed during formation of hyalinized zone are:

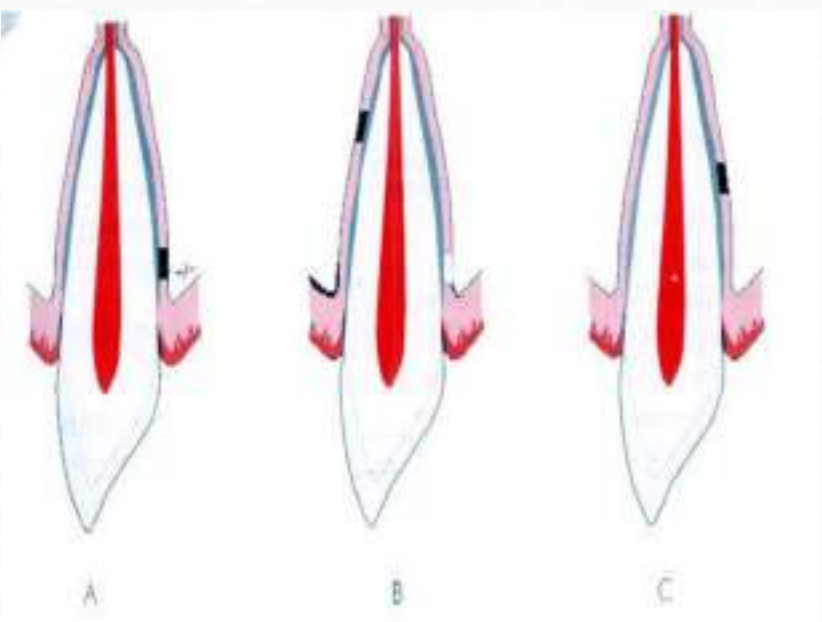
- Gradual shrinkage of PDL fibres.
- Cellular structures become indistinct.
- Collagenous tissues gradually unite into a more or less cell free mass.

- Changes also occur in the ground substance.
- Break down of blood vessel walls leading to spilling of their contents.
- Osteoclasts are formed after a period of 20-30hrs.

Forces & Hyalinization

- Greater the forces wider is the area of hyalinization. Thus larger areas of the ligament becomes functionless ,thereby showing larger areas of rearward resorption.
- If lighter forces are used, the hyalinised zone is smaller and a larger area of functioning ligament is available and frontal resorption predominates.
- The location and extend of hyalinised tissue largely depends on nature of tooth movement.

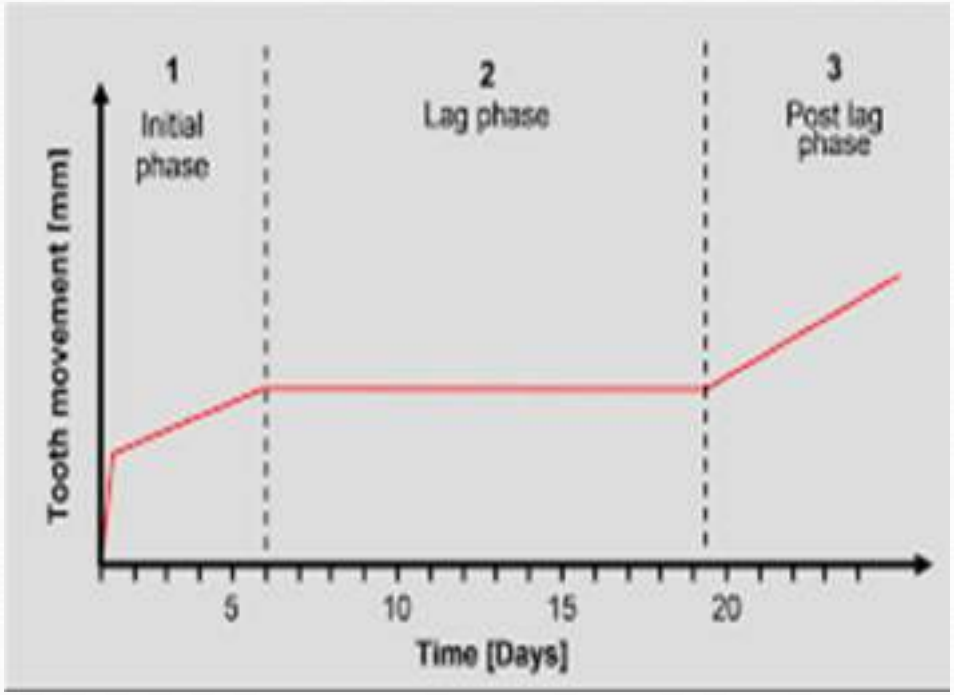
- A-Tipping –close to alveolar crest
- B-Excessive force during tipping-two areas,one on apical region and other in marginal area.
- C-Bodily-closer to middle portion of root



Phases Of Tooth Movement

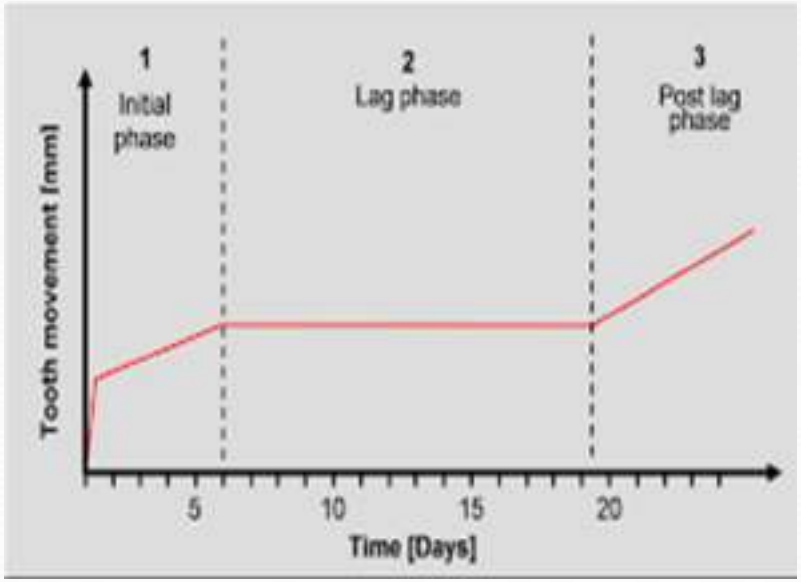
Burstone categorize the stages as:-

- Initial phase
- Lag phase
- Post lag phase



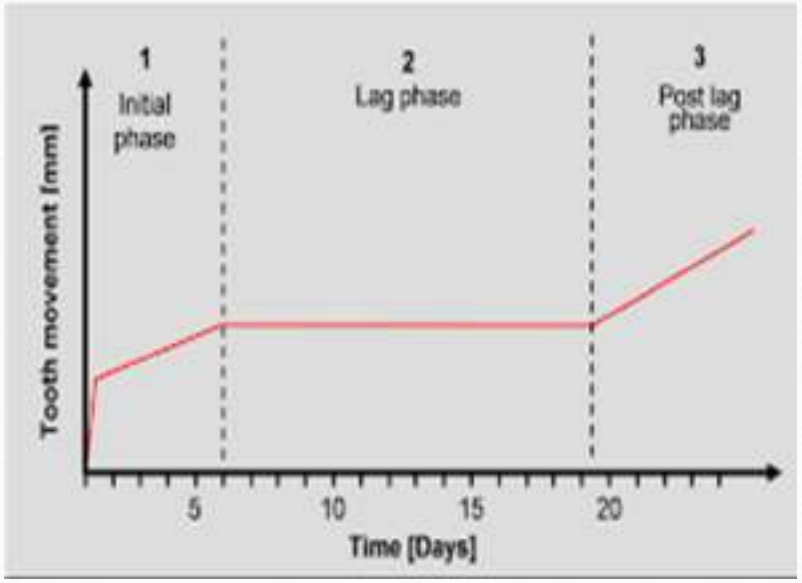
Initial Phase

- Rapid tooth movement is observed over a short distance which than stops.
- Represents displacement of tooth in PDL membrane space and probably bending of alveolar bone .
- Both light and heavy forces displace the tooth to same extend.



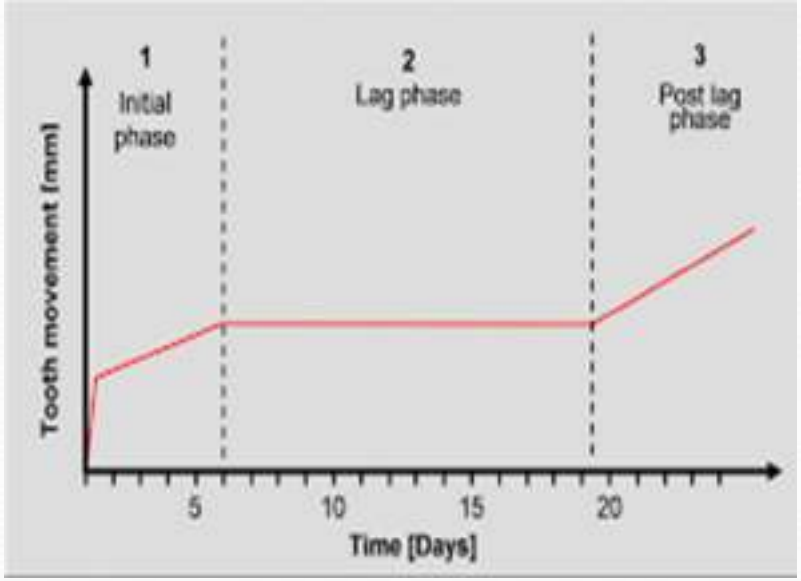
Lag Phase

- Little or no tooth movement occurs
- Formation of hyalinized tissue .
- Extent upto 2-3 weeks .



Post Lag Phase

- Tooth movement progresses rapidly as the hyalinized zone is removed and bone undergoes resorption .
- Osteoclasts are found over a larger surface area .

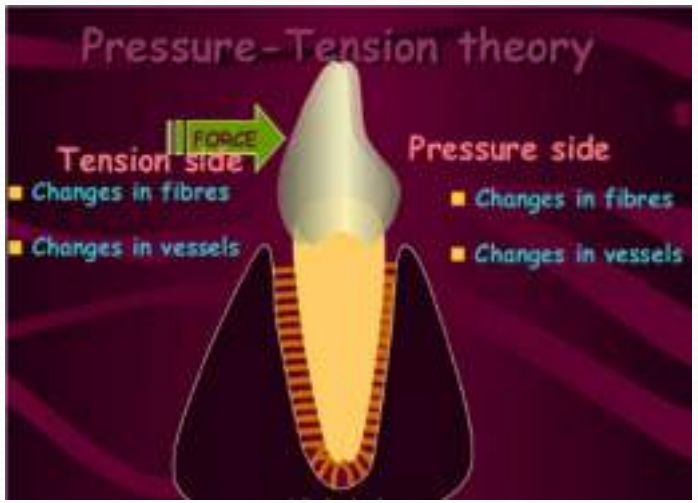


Theories Of Tooth Eruption

1. Pressure tension theory by Schwarz(classic theory)
2. Fluid dynamic theory by Bien/ blood flow theory
3. Bone bending & piezoelectric theory

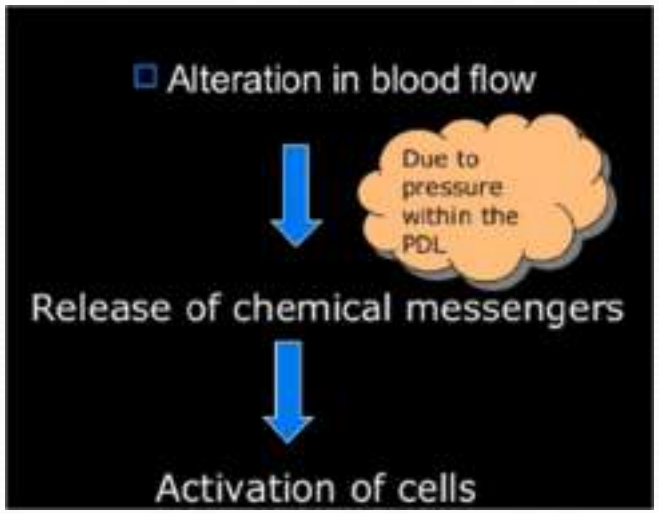
Pressure Tension Theory

- Schwarz(1932) - author of this theory .
- According to him ,whenever a tooth is subjected to an orthodontic force it results in areas of pressure and tension .
- Areas of pressure show bone resorption while areas of tension show bone deposition.



Blood Flow Theory

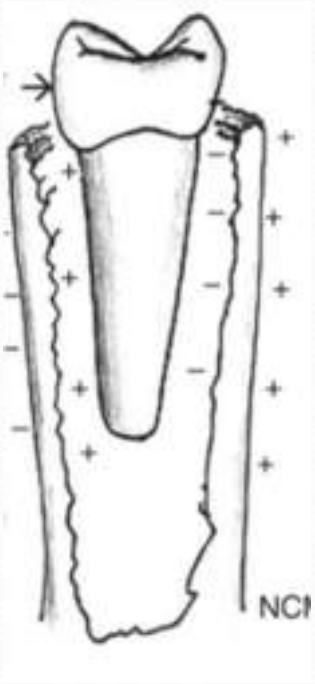
- According to this theory tooth movement occurs as a result of alternations in fluid.
- dynamics in PDL located in periodontal ligament space.



- PDL space contains a fluid system made up of interstitial fluid, cellular elements ,blood vessels and viscous ground substance in addition to PDL fibres.
- It is confined space & passage of fluid in & out of this space is limited.

Bone bending & piezoelectric theory

- suggest that bone bending may be a possible mechanism for bringing about tooth movement.
- Piezo-electricity is a phenomenon observed in many crystalline materials in which deformation of the crystal structure produces a flow of electric current as a result displacement of electrons from one part of the crystal lattice to the other. A small electric current is generated & bone is mechanically deformed.



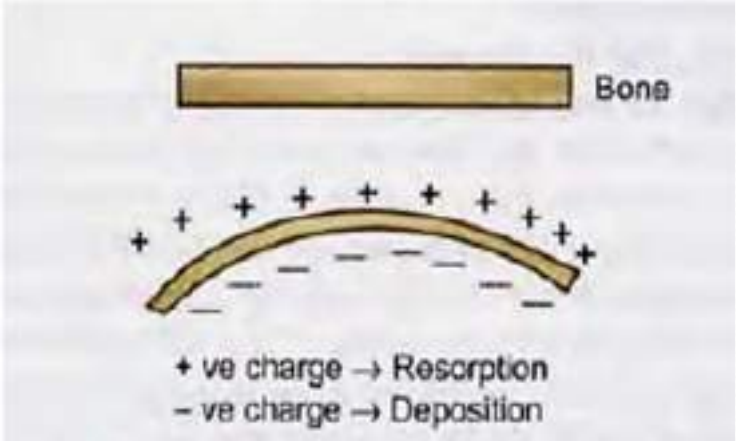
The possible source of electric current are :-

- Collagen
- Hydroxyapetite.
- Collagen hydroxyapetite interface
- Mucopolysaccharide.

- As long as the force is maintained ,The crystal structure is stable & no further electric effect is observed.
- When the force is released the crystals return to their original shape & reverse flow of electrons is observed.
- This rhythmic activity produces a constant interplay of electric signals .

Piezoelectric signals have two unusual characteristics.

- Quick decay rate:
- When the force is released electrons flow in the opposite direction.

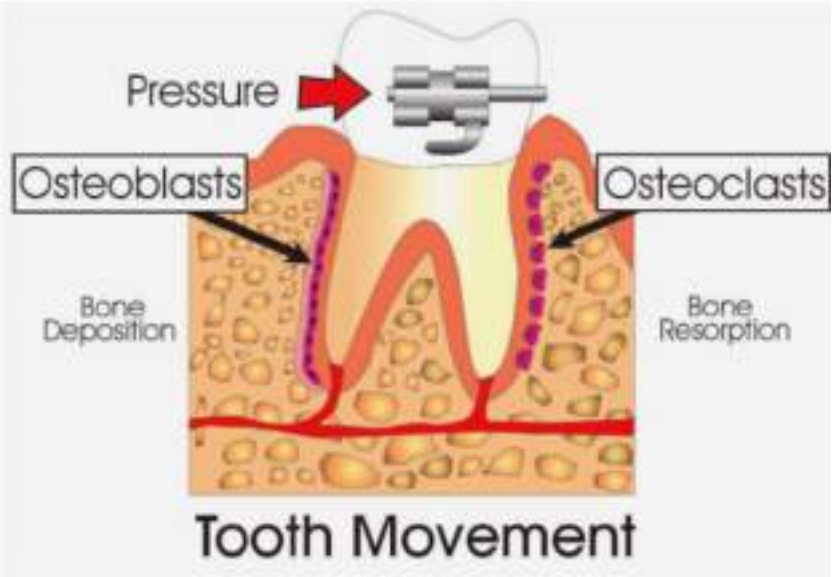


On application of a force on a tooth ,

- Areas of concavity → negative charges
  → bone deposition
- Areas of convexity → positive charges
  → bone resorption

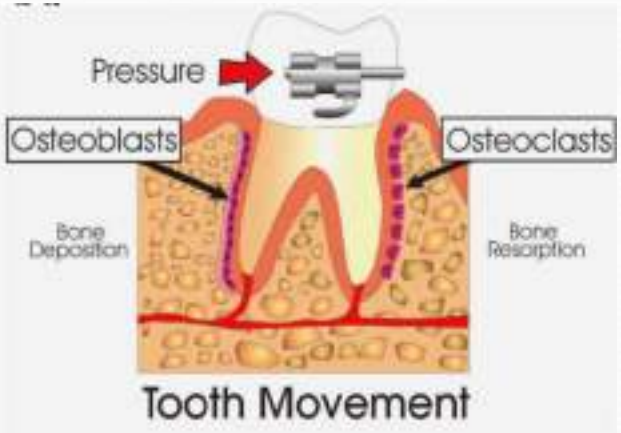
Bone Deposition

- On the tension side, osteoblast increase in number by proliferation of their precursor cells.
- The PDL fibers readapt to new position of the tooth by proliferation of intermediate zone.



Bone Resorption

- By OSTEOCLASTS
- Multi-nucleated giant cells and may have 12 more nuclei.
- They are irregularly and or club shaped with branching processes .
- They lie in bay like depressions called Howship's lacunae.
- The part of osteoclast in contact with resorbing bone has a ruffled border.

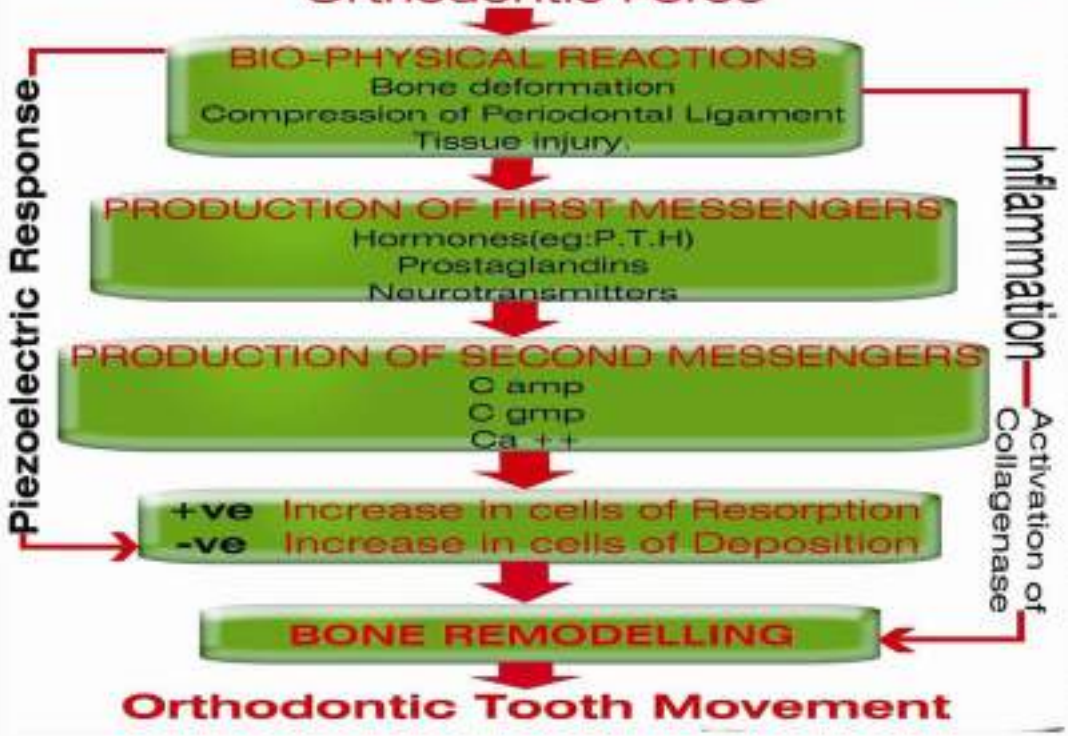


During bone resorption three processes occur:-

1. Decalcification.
2. Degradation of matrix.
3. Transport of soluble products to the extracellular fluid or blood vascular systems.

BIOLOGY OF TOOTH MOVEMENT

SUMMARY OF BIOCHEMICAL REACTIONS



TAKE HOME MESSAGE

Orthodontic tooth movement is made possible by the fact that teeth can be moved through the alveolar bone by applying appropriate forces.