BIOLOGY OF TOOTH MOVEMENT
Introduction

Orthodontic tooth movement is a unique process where a solid object (tooth) is made to move through a solid medium (bone).

Orthodontic treatment is possible due to the fact that whenever a prolonged force is applied on a tooth, bone remodelling occurs around the tooth resulting in its movement.
Bone subject to **pressure** as a result of **compression** of periodontal ligament **resorbs**. While, bone **forms** under **tensile** force, as a result of **stretching** of periodontal ligament.
I. Physiologic Tooth Movement

• Naturally occurring tooth movements that take place during and after tooth eruption.

This include:

• A) **Tooth Eruption**.

• B) **Migration** or drift of teeth.

• C) **Changes** in tooth position **during mastication**.
TOOTH ERUPTION:

- Tooth eruption is the *axial movement* of tooth from its development position in the jaw to its final position in the oral cavity.
- The following are some theories which explains the eruption process.
- a) **Blood pressure theory:**
  According to this theory, the tissue around the developing end of the root is highly vascular. This vascular pressure is believed to cause the axial movement of teeth.
b) **Root Growth:**

- According to this theory, the apical growth of roots result in an axially directed force that brings about the eruption of teeth.
- **This theory was rejected because:**
  - The tooth moves at a greater distance than the root length.
  - Onset of root growth and eruption do not coincide.
  - Teeth without roots also erupt.

c) **Hammock ligament theory:**

- According to Sicher, a band of fibrous tissue exists below the root apex spanning from one side of alveolar wall to other.
- This fibrous tissue appears to form a network below the developing root and is rich in fluid droplets.
- The developing root forces itself against this band of tissue, which in turn applies an occlusally directed force on tooth.
• **Periodontal traction theory:**

  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 of fibers) results in axial movement of the tooth.
B) **Migration or drift of teeth:**

- Refers to the minor changes in tooth position observed after eruption.
- Human dentition shows a natural tendency to move in a mesial & occlusal direction.
- Usually a result of proximal and occlusal wear of teeth,
- They move in a mesial and occlusal direction to maintain inter-proximal and occlusal contact.
C) Tooth movement during mastication:

- During mastication, the teeth and PDL structures are subjected to intermittent heavy forces which occur in cycles of one second or less and may range from 1-50 kg based on the type of food being masticated.
II. 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 and duration of force applied.
Orthodontic force

Tension Side
Pressure Side

Normal

Application of mild forces

Application of extreme forces

- Pulp
- Periodontal Ligament
- Dentin
- Cementum
- Bone resorption
- Bone deposition

Fig. 1: Histology of tooth movement
Changes following application of mild forces:

• 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.
- 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 reorption 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 remodelling changes:

- Bony changes also takes place elsewhere to maintain the width or thickness of alveolar bone. These changes are called secondary remodeling changes.
Change 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 the 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.

• Below the optimal level cause no reaction in PDL.

• Forces exceeding optimal level would lead to areas of tissue necrosis, preventing frontal bone resorption.
• Oppenheim and Schwarz following extensive studies state that the optimum force is equivalent to the capillary pulse pressure which is 20-26gm/sq.cm of root surface area.
Hyalinization:

• 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 20-30 hrs.
• The presence of hyalinised zone indicates that the ligament is non-functional and therefore bone resorption cannot occur. The tooth is hence not capable of further movement until the local damaged tissue has been removed and the adjacent alveolar bone resorbs.
Elimination of hyalinised tissue

- 2 mechanism:
  1. By osteoclasts differentiating in the peripheral intact PDL membrane and in the adjacent marrow spaces.
  2. Invasion of cells and blood vessels from the periphery of the compressed zone by which necrotic tissue is removed. The invading cells penetrate the hyalinized tissue and eliminate unwanted fibrous tissue by enzymatic action and phagocytosis.
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 upon 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 then stops.
• Represents displacement of tooth in PDL membrane space and probably bending of alveolar bone.
• Both light and heavy forces displace the tooth to the same extent.
• Between 0.4 to 0.9mm usually occurs in a weeks time.
• Both light & heavy forces displace the tooth to the same extent during this phase.
Lag phase:

- Little or no tooth movement occurs.
- Formation of hyalinized tissue.
- Extent up to 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 movement:

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 by Schwarz. (classic 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.
Fluid dynamic theory by Bien/ 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 substances in addition to PDL fibres.

• It is a confined space and passage of fluid in & out of this space is limited.
• The contents of PDL creates a unique hydrodynamic condition resembling a hydraulic mechanism & shock absorber.
• When force is removed, the fluid is replenished by diffusion from capillary walls & recirculation of interstitial fluids.
• Squeeze film effect by Bien.
• When orthodontic force applied, the compression of ligament results. Blood vessels of PDL gets trapped between the principle fibres & this results in stenosis.
• Vessels above the stenosis then balloons resulting in formation of an aneurysm
• Stenosis + Aneurysm $\rightarrow$ blood gases to escape into interstitial fluids, creating favourable local environment for resorption.
Bone bending & piezoelectric theory:

• Farrar in 1876, first noted deformation or bending of interseptal alveolar bones.
• 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:

1. Collagen.
2. Hydroxyapatite.
3. Collagen hydroxyapatite interface.
• 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 $\rightarrow$ negative charges $\rightarrow$ bone deposition.
- Areas of convexity $\rightarrow$ $^+\text{ve}$ charges and $\rightarrow$ bone resorption.
Bio - Physical Reactions
- Bone deformation
- Compression of periodontal ligament
- Tissue injury

Production of first messengers
- Hormones
- Prostaglandins
- Neurotransmitters

Production of second messengers
- CAMP
- CGMP
- Ca++

+VE increase in cells of resorption
-VE increase in cells of deposition

Bone Remodeling

ORTHODONTIC TOOTH MOVEMENT