Biology of Tooth Movement

Tooth movement can be induced orthodontically because of the gomphosis type of attachment of teeth where the teeth are suspended in their sockets by periodontal ligament rather than being ankylosed to the bone. By applying properly regulated forces, the teeth can be moved through the alveolar bone of jaws without causing permanent damage to either the teeth or their investing tissues. Despite a lot of research on the subject, the detailed biological mechanisms of orthodontic tooth movement are far from being completely understood.

While certain tooth movements occur naturally (physiologic tooth movement), teeth also exhibit movement in some pathologic conditions (pathologic tooth movement). In orthodontics, tooth movement is induced for therapeutic purposes. The tooth movement can be:

- Physiologic
- Pathologic
- Orthodontic.

PHYSIOLOGIC TOOTH MOVEMENT

Physiologic tooth movement can be described in three phases:

1. Pre-eruptive tooth movement
2. Eruptive tooth movement
3. Posteruptive tooth movement.

Pre-eruptive Tooth Movement

Both primary and permanent tooth germs move within the jaws after their differentiation and these movements are facilitated by the jaw growth. These movements help the teeth to occupy their preparatory positions within the jaws prior to their eruption.

Eruptive Tooth Movement

Eruption is the movement of the teeth from their developmental position within the jaws to their functional position in occlusion. Eruptive movement generally begins when about 2/3rd portion of the root is formed and is primarily brought about by the periodontal ligament traction.

Mechanisms of Tooth Eruption

Tooth eruption is the result of several factors, and many theories have been proposed to explain the mechanism of tooth eruption, including *bone remodeling*, *root formation*, *vascular pressure, and periodontal ligament traction theories*.

Periodontal ligament traction theory is the most accepted one and a lot of evidence suggest that the eruptive movement is brought about by the d*ental follicle—periodontal ligament complex*.

„ The contractile force exerted by the periodontal ligament fibroblasts is transmitted to the properly oriented collagen fiber bundles. Summation of these contractile forces causes tooth movement. Bone remodeling necessary for forming the eruptive pathway is facilitated by the cells of the dental follicle.

Posteruptive Tooth Movement

Even after the eruption is complete, the teeth move in order to maintain their position in occlusion until the jaw growth is completed. The teeth also exhibit movements in occlusal and mesial direction throughout a person's life to compensate for occlusal and proximal wear. Continuous deposition of cementum around the apices of the roots of teeth is believed to be sufficient to compensate for occlusal wear.

HISTOLOGICAL CHANGES OCCURRING DURING ORTHODONTIC TOOTH MOVEMENT

The histological changes occurring during tooth movement vary according to the magnitude and duration of the force applied **(Fig. 1)**. The histological changes occurring during tooth movement can be described under the following headings:

- „ Changes following application of mild orthodontic forces.
- „ Changes following application of excessive orthodontic forces.

Changes Following Application of Mild Orthodontic Forces

Whenever a force is applied to a tooth, areas of pressure and tension are created. The following changes occur on pressure and tension areas of the periodontal ligament

1. *Changes on the Pressure Side*

The periodontal ligament gets slightly compressed on the pressure side. As the mild forces are not sufficient to occlude the blood vessels of the periodontal ligament, vessels may dilate and there will be recruitment of osteoclasts to that area of periodontal ligament. The osteoclasts will cause resorption of the alveolar bone immediately adjacent to the periodontal ligament. This kind of resorption where the periosteal bone from the inner wall of the socket is resorbed is called as *frontal resorption* or *direct periosteal/ frontal resorption* **(Fig.1)**. There is no resorption of the tooth root.

2- *Changes on the Tension Side*

An area of tension is created in the supporting structure of the tooth, opposite to the direction of force. The periodontal ligament is stretched in this area and vascularity is increased. Increased vascularity leads to the

mobilization of osteoblasts and fibroblasts in those areas. The osteoblasts lay down a layer of osteoid bone immediately adjacent to the lamina dura, which matured over some time. In this way, the socket, as well as the tooth move due to osteoclastic and osteoblastic activity on the pressure and tension areas, respectively.

In summary, on the application of mild orthodontic forces:

- Hyperemia within the periodontal ligament, dilatation of the blood vessels.
- Increased number of osteoclasts and osteoblasts.
- Lamina dura resorbed from the area next to the periodontal ligament on the pressure side—frontal/ Direct resorption.
- Deposition of osteoid bone on the tension side, which calcifies subsequently.
- Tooth movement occurs due to bone resorption and deposition.
- No root resorption.

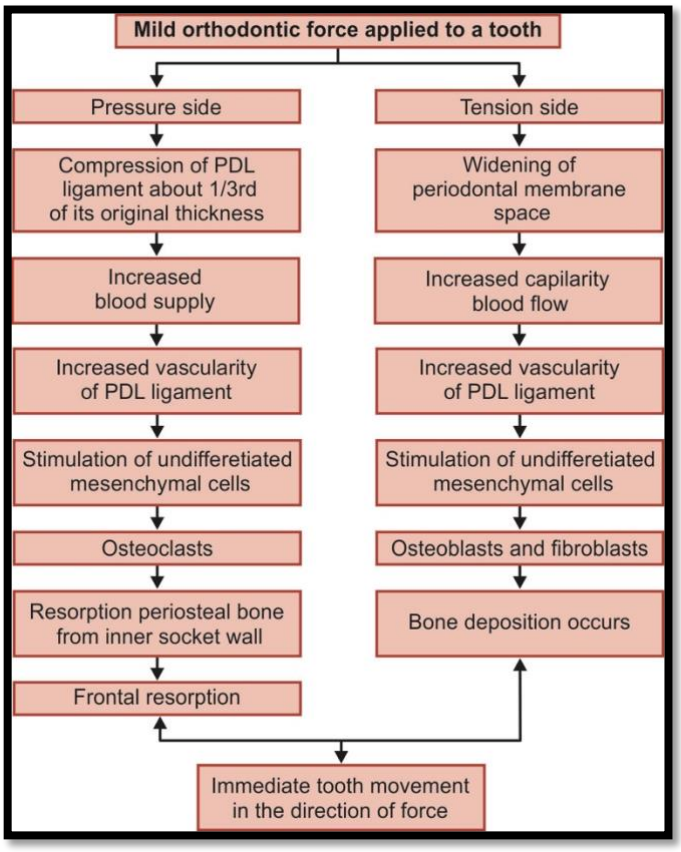


Figure 1: Changes Following Application of Mild Orthodontic Forces

Changes Following Application of Excessive Orthodontic Forces

Although it might appear logical to think that heavier forces can bring about faster tooth movement.

Changes on the Pressure Side

On applying excessive forces, the periodontal ligament on pressure side is extremely compressed/crushed, possibly causing contact between the tooth and the alveolar bone. as result, the periodontal ligament in these areas gets deprived of nutritional supply and begins to show regressive changes with cell free areas called *hyalinization*. Due to ischemia and hyalinization, there is no recruitment of osteoclasts in the pressure side. No resorption occurs on the periosteal surface of the socket, i.e., no frontal resorption and thus tooth does not move for a period of time.

After a lag period, bone resorption occurs in the adjacent marrow spaces under the hyalinized areas. Such endosteal resorption is termed as *undermining indirect* or *rearward resorption* **(Fig.2)**.

If the forces are grossly excessive, resorption of the root surfaces may also occur. Nonvitality and ankylosis of the tooth are other possible consequences of extreme orthodontic forces.

Changes on Tension Side

Periodontal ligament on the tension side gets over- stretched leading to tearing of blood vessels and ischemia. When excessive force is applied, there is an increased osteoclastic activity as compared to osteoblastic activity and thus the tooth may become loosened in its socket.

Thus, if the force applied is severely excessive and prolonged, the periodontal ligament in the area of pressure will be deprived of its blood supply and there may be necrosis of the ligament, with massive underlining resorption and possibly resorption of the root surface of the tooth. Application of very heavy orthodontic forces cause pain, loosening of the tooth in its socket and healing may occur by ankylosis of the tooth to the alveolar bone.

To summarize, on applying excessive orthodontic forces:

- Compression of periodontal ligament and occlusion of blood vessels in the areas of pressure and ischemia.
- Formation of wide zones of hyalinization and extended lag period.
- No frontal resorption and no immediate tooth movement.
- Increased endosteal vascularity and endosteal resorption of the socket wall under the hyalinized area—undermining/ rearward resorption.
- Eventually, the tooth moves as a result of this undermining resorption.
- Relatively rapid tooth movement with bone deposition in the areas of tension.

- Grossly excessive forces may cause root resorption, loosening, nonvitality, and ankylosis of the tooth.

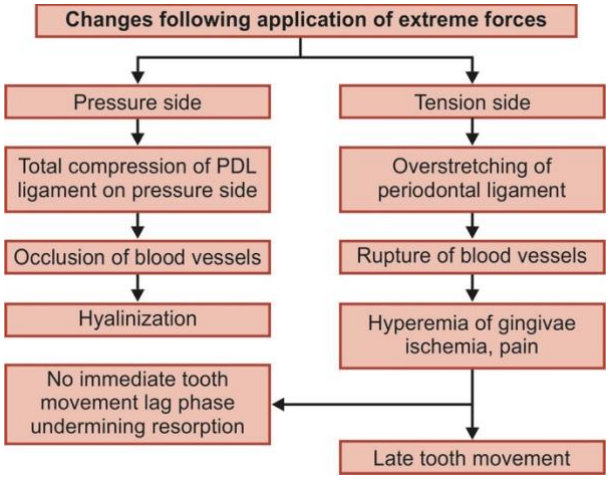


Figure 2 Changes Following Application of Excessive Orthodontic Forces

What is Optimum Orthodontic Force?

Having understood that heavy forces do not necessarily bring about faster tooth movement, it is important to know what is the optimum orthodontic force. The optimum orthodontic force is the one, which moves teeth most rapidly in the desired direction, with the least possible damage to tissues and with minimum patient discomfort. From a series of experiments, Oppenheinm and Schwarz concluded that the optimum force for tooth movement was one that induced a pressure of around 20–26 g/cm^2 of root surface, which is equivalent to the capillary pulse pressure.

The optimum orthodontic force has the following characteristics:

- **Clinically**

  - It produces rapid tooth movement.
  - Causes minimal patient discomfort.
  - Lag phase of tooth movement is shorter.
  - The tooth being moved does not become loosened in its socket.

- **Histologically**

  - The vitality of the tooth and periodontal ligament is maintained.
  - Initiates maximum cellular response.
  - Produces direct or frontal resorption.
  - The integrity of periodontal attachment is maintained by reorganization of the fibers.

Hyalinization

Hyalinization is a type of tissue degeneration characterized by the formation of a clear, eosinophilic homogeneous substance, which is free of cellular elements. The amount and site of hyalinized zones varies in different types of tooth movement and depends on the magnitude of force applied. **Figure 3 and 4**

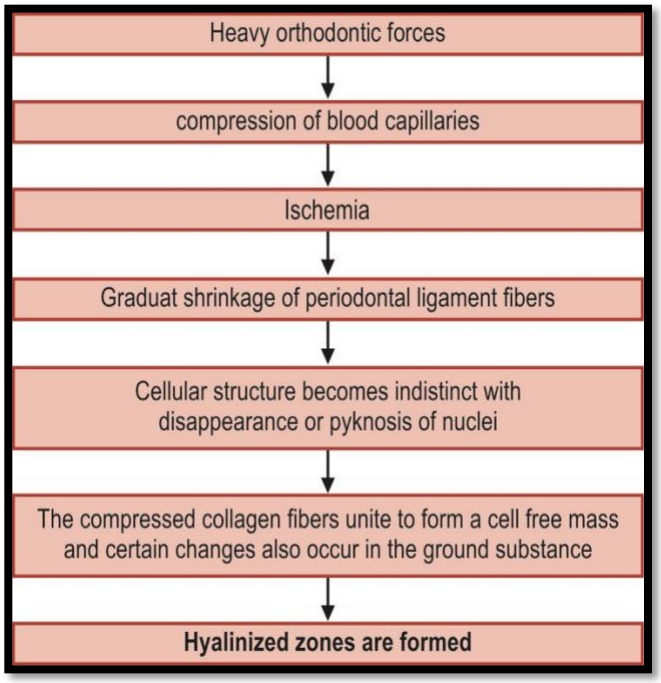
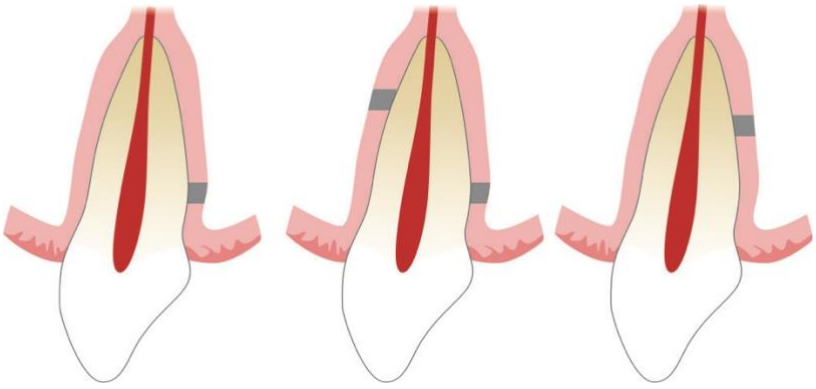


Figure 3 Formation of hyalinized areas



Figs 4 A to C: Areas of hyalinization during tooth movement. (A) During tipping movement, hyalinization zone is close to the alveolar crest; (B) Tipping with excessive force results in two areas of hyalinization, one near the alveolar crest and the other near apical region; (C) In bodily tooth movement, hyalinization zone is near the middle third of the root

PHASES OF TOOTH MOVEMENT

Investigations have shown that orthodontic tooth movement occurs in three stages **(Fig. 4)**:

1. Initial phase
2. Lag phase
3. Post lag phase.

initial Phase

When orthodontic therapy is begun, a rapid tooth movement occurs for a short distance, which then stops. It locks likes to be the same for both light and heavy forces. Usually, an initial tooth movement of 0.4–0.9 mm occurs
in a week.

Lag Phase

Following the initial phase, there is a lag period in which there is a little or no tooth movement. Lag phase occurs due to the formation of hyalinization tissue in the periodontal ligament, which has to be eliminated before tooth movement can progress further.

The duration of lag period varies in different types of tooth movement and depends on the amount of force applied. When light forces are applied, the area of hyalinization is small and frontal resorption occurs, whereas larger area of hyalinization occurs with heavy orthodontic forces. Generally, a lag period of 2–3 weeks is seen although it can extend for longer periods.

A number of factors determine the duration of lag phase including the following:

- Amount of force
- Duration of force
- Type of tooth movement and type of tooth
- Density of alveolar bone
- Age of the patient
- Extent of hyalinization.

Post Lag Phase

Since the hyalinized tissue is eliminated, tooth movement can now progress in a rapid rate. During the post lag phase, osteoclasts are formed over a large surface area, directly resorbing the bone surface facing the periodontal ligament.