Mechanics of Tooth Movement

Mechanics is the science that describes the effect of force on a body. In the context of orthodontics, tooth movement occurs as a response to application of a force. An understanding and proper application of the biomechanical principles enables efficient tooth movement in the shortest possible duration and with minimal tissue damage. The following terms are described for the ease of explanation of the subject:

- Force
- Moment
- Couple

FORCE

Force can be defined as load applied to an object that will tend to move it to a different position in the space. Although force is generally expressed in unit of Newtons (N), in orthodontics, forces have been commonly expressed in grams (g). Force is a vector having both direction and magnitude. In clinical terms**, the direction** may be: **Pull** (towards the source of force) or **Push** (away from the source of force). **The magnitude** may be: **Light or Heavy**. The point of application of force is also important for understanding tooth movements. Theoretically, point of application of force can be at: Center of mass, Center of gravity, Center of resistance.

Any force that is directed through this center of mass in any direction causes all points in the body to move to the same amount in the same direction as the line of force. When all points on a body (a tooth in the context of orthodontics) move the same amount in the same direction, such a movement is called as “translation or bodily movement.”

Center of Resistance

A tooth in the oral cavity, however, is not a free body because of its supporting tissues, which would restrain its movement. Hence, tooth in the oral cavity has a point analogous to the center of mass called as “center of resistance.”

Location of the center of resistance of a tooth depends upon several factors, such as the root length, morphology, number of roots and the level of alveolar bone support. The center of resistance of a single-rooted tooth with normal alveolar bone level is situated at about one-fourth to one-third the distance from the CEJ to the root

apex. The center of resistance shifts apically in case of alveolar bone loss), while it may shift coronally when the root is shortened due to its resorption. In case of multirooted teeth, the center of resistance is 1 to 2 mm apical to the furcation. Studies show that the center of resistance for maxilla is about 5-10 mm inferior to the orbitale.

Forces Acting at the Center of Resistance

Any force acting through the tooth's center of resistance would bring about translation of the tooth along the line of action of the force. Such a movement when all the parts of the tooth move the same amount in the same direction is called as bodily movement.

Forces not Acting at the Center of Resistance

If a force is applied to a body and the force does not act through the center of resistance, then the force tends to rotate the body rather than translating it. The tendency to rotate is called as "moment." Rotation can be defined as the movement of a body where no two points on the body move to the same amount in the same direction.

The total tooth movement, resulting from forces not acting through the center of resistance, is a combination of rotation and translation, occurring simultaneously. In other words, a single force applied not at the center of resistance causes the body to rotate around the center of resistance while the center of resistance simultaneously moves in the direction of the line of force.

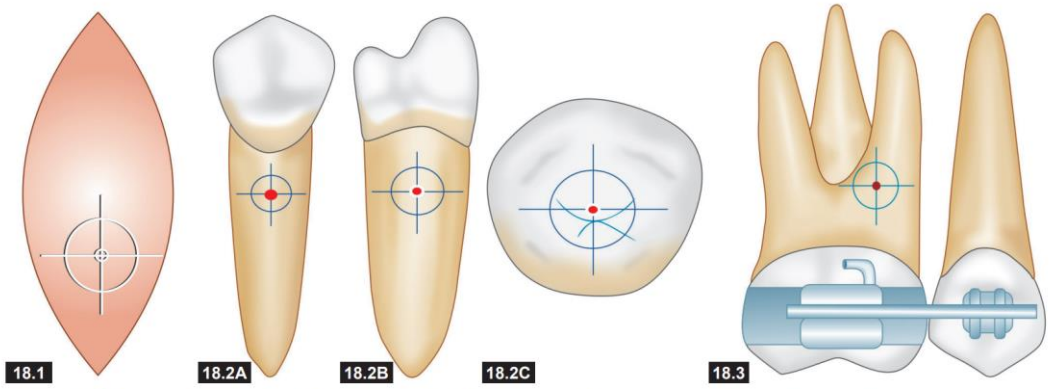


Fig. 18.1: Center of mass in a gravity-free body; **Figs 18.2A to C:** Center of resistance can be described in all three planes of space; **Fig. 18.3:** Center of resistance for a two cemento-enamel junction (CEJ) tooth segment

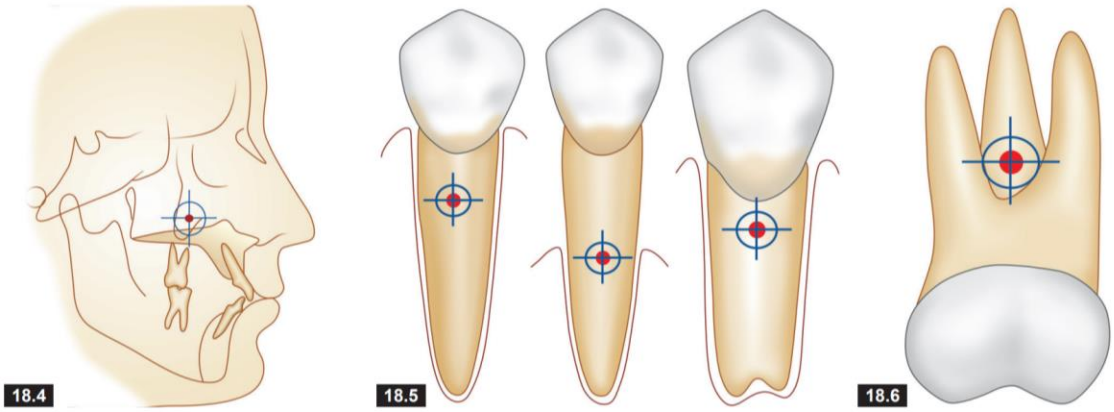


Fig. 18.4: Center of resistance for maxilla is about 5-10 mm inferior to the orbitale; **Figs 18.5A to C:** Location of center of resistance in a single rooted tooth, (A) with normal alveolar bone, (B) with alveolar bone loss, (C) with a shortened root; **Fig. 18.6:** Location of center of resistance in a multirooted tooth

Center of Rotation

Should it be in heading, of application of force as well? When a body rotates, there is another point located either internal or external to the body around which, the body turns and this point is called as center of rotation. Center of rotation can be defined as an arbitrary point about which a body appears to have rotated, as determined from its initial and final position. Location of the center of rotation varies and depends on how far the force is applied from the center of resistance. The center of rotation can approach but can never reach the center of resistance.

Center of Rotation in Bodily Movement

If the force is applied at the center of resistance, the body translates and the center of rotation is at infinity. Center of Rotation in Uncontrolled Tipping Here the center of rotation lies somewhere nears the center of resistance of the tooth.

Center of Rotation in Controlled Tipping

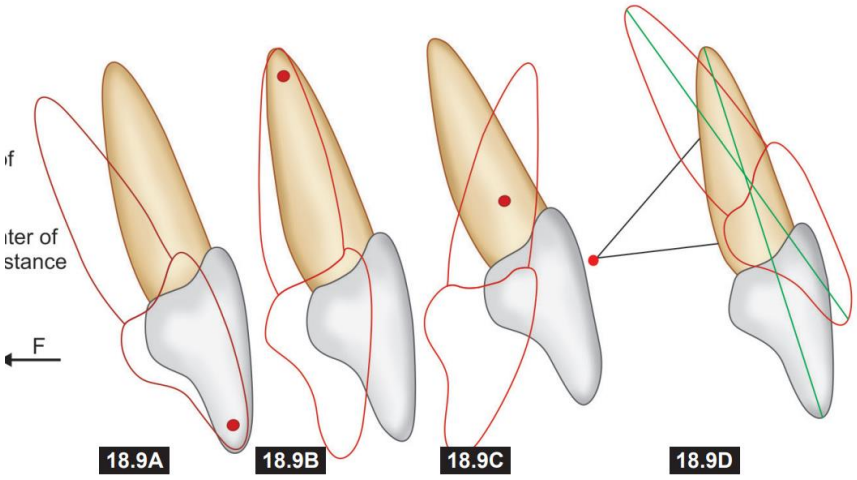
In controlled tipping, the center of rotation will be at the root apex.

Center of Rotation in Torquing Movement

It is at incisal edge during torquing.

Center of Rotation during Intrusion and Extrusion

It is outside the tooth during intrusion and extrusion.



MOMENT

A moment is a measure of the tendency to rotate. From the foregoing discussion, it is understood that if a force applied to a body is not acting through its center of resistance, the force causes a tendency for the body to rotate. This tendency of a force to produce a rotation is called as the moment of the force. The moment of the force is determined by multiplying the magnitude of the force with the perpendicular distance of the line of action of force with the center of resistance. The unit of measurement of moment is gram millimeters. Moment of force (Mf) = Magnitude of force (F) × distance (d) Thus, the clinician can achieve the desired force systems by altering these two variables, i.e. the magnitude of force and distance.

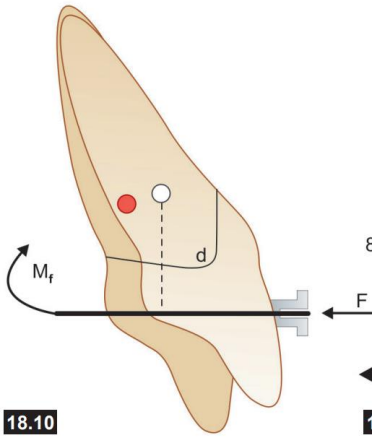
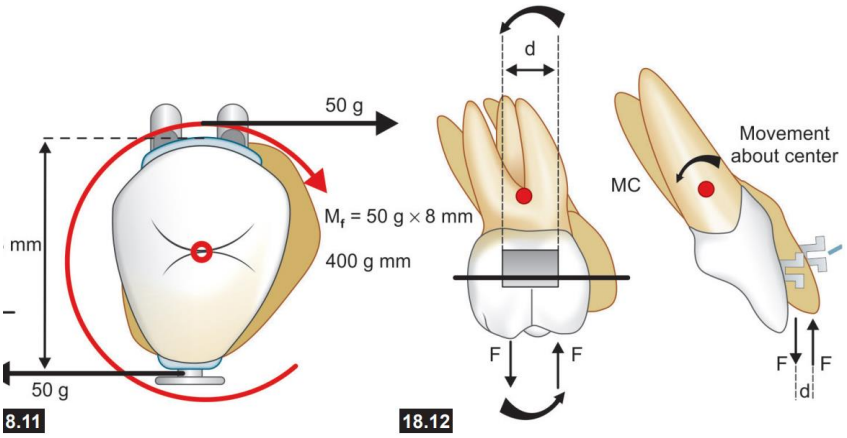


Fig. 18.10: Moment of force: **Fig. 18.11**

COUPLE

A couple is a pair of concentrated forces having equal magnitude and opposite direction with parallel but noncollinear line of action. In other words, a couple is a system of two parallel forces of equal magnitude, acting in opposite directions and separated by a distance. The action of a couple is the sum of the action of two equal and opposite single force systems. A couple brings about pure rotation of the body about the center of resistance. The control that couples provide in three planes of space is the unique feature of the original edgewise bracket and is the basic characteristic of most fixed appliances which are in use today.



TYPES OF TOOTH MOVEMENT

Basically there are two main types of tooth movement, which can occur—translation and rotation. However, because of the nature of the attachment of teeth to alveolar bone and placement of brackets only on the crowns, all the movements in orthodontic therapy are likely to be complex. Most of the tooth movements occurring in routine clinical practice, are the combination of both translation and rotation.

Pure Translation

A tooth is said to be translated when all points on a body move the same amount in the same direction. Such a movement can occur only when the force is acting through the center of resistance of the tooth. Clinically, pure translation can be seen in:

- Intrusion
- Extrusion
- Bodily movement of tooth in mesiodistal or labiolingual direction.

Pure Rotation

Forces applied at the bracket can almost never act through the center of resistance in all three planes of space. Rotation of a tooth occurs when the force is applied not through the center of resistance.

In orthodontics, the process of rotation:

- Around the long axis of the tooth is called rotation.
- Around a facio-lingual axis is called tipping.
- Around a mesiodistal axis is called torque.
- Combined Rotation and Translation

Most of the tooth movements, occurring during orthodontic treatment are neither pure rotation nor pure translation but a combination of both rotation and translation. Clinically, the following terms are used for various types of tooth movement:

- Tipping
- Bodily movement
- Torque
    - Vertical tooth movements (Intrusion and Extrusion).
    - Multiple tooth movements
- Rotation.

Tipping

Tipping is perhaps the simplest type of tooth movement and the one most readily carried out. A single force applied at one point of the crown of a tooth causes the crown to move in the direction of the force and the root in the opposite direction. Tipping tooth movement may be of two types; uncontrolled and controlled.

Uncontrolled Tipping

- Uncontrolled tipping occurs when a single force is applied to the crown of the tooth and it moves about a center of rotation, which is between the center of resistance and the root apex
- In uncontrolled tipping, the crown moves in one direction, while the root moves in the opposite direction
- This is the simplest type of tooth movement to produce but is often undesirable
- Stresses in the periodontal ligament are not uniform and are concentrated near the apex and cervical area.

Controlled Tipping

- Controlled tipping of a tooth occurs when the center of rotation is at the root apex
- Here, apart from applying force to move the crown, the movement of the root in the opposite direction of the force is controlled by application of couple at the bracket. The intention is to move the crown while maintaining the position of the root apex as it is
- Controlled tipping is a very desirable type of tooth movement
- Stress in the periodontal ligament is concentrated at the cervical area with minimal stress at the apex.

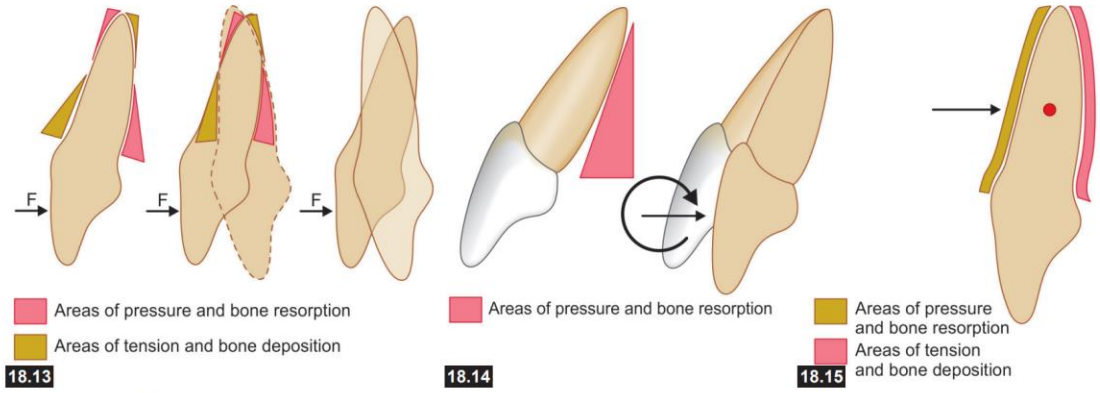
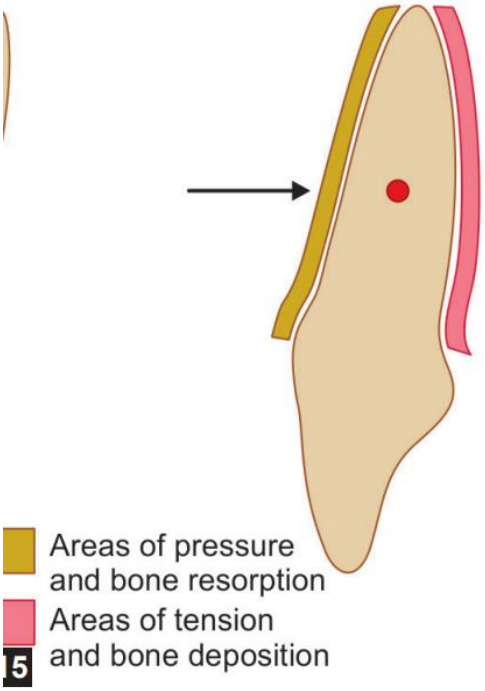


Fig. 18.13: Uncontrolled tipping. Stresses in the periodontal ligament are concentrated near the apex and cervical area; **Fig. 18.14:** Controlled tipping; **Fig. 18.15:** Bodily movement of the tooth

Bodily Movement

- When a force is applied through the center of resistance of the tooth, it causes all the points on the tooth to move the same amount in the same direction as the line of force. Such type of tooth movement is called bodily movement/translation.
- The term bodily movement is used to describe the complete translation of a tooth to a new position with all parts (crown and root) of the tooth moving an equal distance During bodily movement, the center of rotation is at infinity
- In clinical practice, it is difficult to carry out translation as a single movement, but something close to complete bodily movement can be achieved with appropriate appliances
- Like controlled tipping, bodily movement requires simultaneous application of a force and a couple at the bracket

- The magnitude of the force applied is usually greater than the force needed for tipping movement
- The pressure is more evenly distributed over the whole length of the periodontal ligament.



Torque

- The term 'torque' in orthodontics refers to the differential movement of one part of a tooth, while physically restraining any movement of the other parts.
- The term is often applied to movement of root without the movement of crown.
- Root torque is usually achieved by applying a force couple to the crown of the tooth, at the same time mechanically restricting crown movement in the opposite direction.
- The center of rotation of the tooth is at the incisal edge or bracket.
- Stresses in the periodontal ligament are more near the root apex.

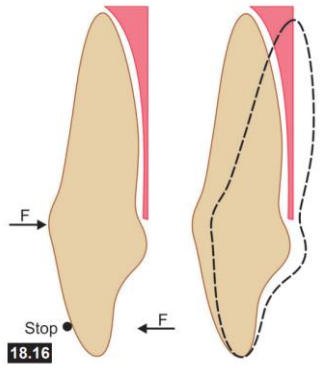


Fig. 18.16: Root torque;

Vertical Tooth Movement

Vertical tooth movement can be in the form of intrusion or extrusion.

Intrusion

Intrusion of the tooth involves resorption of bone, particularly around the apex of the tooth. In this movement, the whole of supporting structures are under pressure with virtually no areas of tension.

Extrusion

Extrusion of the teeth from its socket can be achieved without much resorption of bone, bone deposition being required to reform the supporting mechanism of the tooth. Generally speaking, tension is induced on the whole of the supporting structure rather than pressure.

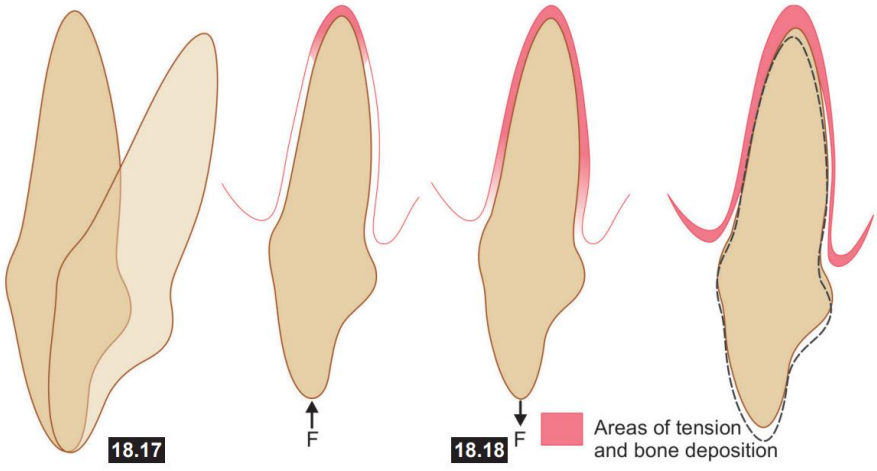


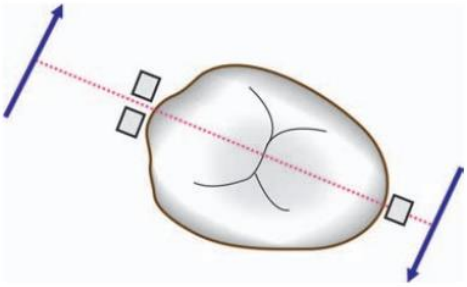
Fig. 18.17: Intrusive tooth movement; **Fig. 18.18:** Extrusive tooth movement

Rotation

The movement of the tooth around its long axis is termed as rotation in orthodontics

Pure rotation of a tooth in its socket requires the application of a force couple. A couple is created by applying equal and opposite forces to the different areas of the tooth

Rotational movement do not normally require any greater force than the tipping movement, but there is a much greater tendency for rotational movement to relapse.



TYPES OF ORTHODONTIC FORCES

Application of force is the basis of orthodontic therapy. Forces of different magnitude are applied in different directions for varying periods of time to treat different malocclusions. Based on the duration of application, force can be divided into the following three types:

1. Continuous force.
2. Intermittent force.
3. Interrupted force.

Continuous Force

- A continuous force is the one, whose magnitude does not decrease appreciably over time. The force decay is minimal between visits to the clinician
- Ideally, light and continuous forces are most efficient as they bring about tooth movement mainly by frontal resorption
- For example, flexible wires and light elastics used in light-wire differential force technique produce continuous forces.

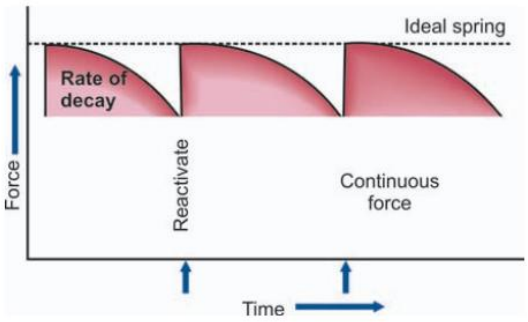


Fig. 20.13A: Continuous forces are maintained between activations

Intermittent Force

- The force is said to be intermittent when it decays to zero or nearly zero magnitude prior to the next appointment.
- For example, removable appliance with an expansion screw
- Usually, such intermittent forces are of high magnitude and cause undermining resorption while moving the tooth
- Force will decay to near zero magnitude once the tooth has moved and allows resumption of blood supply in the periodontal ligament tissue.

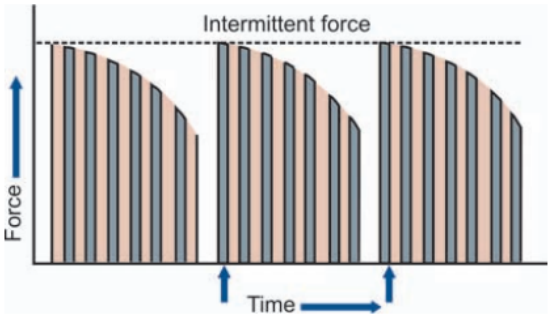


Fig. 20.13B: Intermittent forces fall to zero when the appliance is taken out and resume when the appliance is reinserted into the mouth

Interrupted Force

- Forces applied on the teeth get interrupted when the appliance is inactive (when removed from oral cavity) for an interval of time in a day by the patient For example, force exerted by headgears or facemask worn for a particular duration everyday
  - Appliances using interrupted forces use forces of heavy magnitude, which do not decrease. Usually such appliances exhibit, long-term specific magnitude-

time pattern, for example 200-300 gm of force 14 hours a day to bring about skeletal changes

- Although it appears logical to think that, continuous forces cause continuous tooth movement and an increased amount of tooth movement can be achieved by an increased amount of force, it is not true in reality
- This is because, tooth movement is the combined result of several complex biologic changes occurring in the periodontal tissues at cellular level; which are not completely understood yet

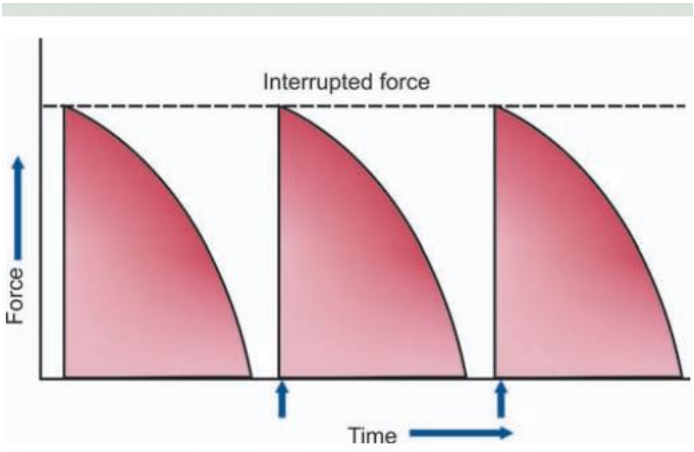


Fig. 20.13C: Interrupted forces drop to zero between activations