Biomechanical principles of orthodontics
The possibilities of tooth movement

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Effect of continuous optimal force

<1 second	PDL fluid incompressible, alveolar bone bends, piezoelectric signal generated
1-2 seconds	PDL fluid expressed, tooth moves within PDL space
3-5 seconds	Blood vessels within PDL partially compressed on pressure side, dilated on tension side; PDL fibers and cells mechanically distorted
Minutes	Blood flow altered, oxygen tension begins to change; prostaglandins and cytokines released
Hours	Metabolic changes occurring: chemical messengers affect cellular activity, enzyme levels change
~4 hours	Increased cAMP levels detectable, cellular differentiation begins within PDL
~2 days	Tooth movement beginning as osteoclasts and osteoblasts remodel bony socket

W.R. Proffit, H.W. Fields, and D.M. Sarver. :Contemporary Orthodontics, 2012, Elsevier: St. Louis, United States.

Effect of heavy force

W.R. Proffit, H.W. Fields, and D.M. Sarver. :Contemporary Orthodontics, 2012, Elsevier: St. Louis, United States.

<1 second	PDL fluid incompressible, alveolar bone bends, piezoelectric signal generated
1-2 seconds	PDL fluid expressed, tooth moves within PDL space
3-5 seconds	Blood vessels within PDL occluded on pressure side
Minutes	Blood flow cut off to compressed PDL area
Hours	Cell death in compressed area
3-5 days	Cell differentiation in adjacent narrow spaces, undermining resorption begins
7-14 days	Undermining resorption removes lamina dura adjacent to compressed PDL, tooth movement occurs

Force

- Can be described mathematically as a vector
  - Magnitude
  - Point of application
  - Line of action
  - Sense
- Measurement unit is N (cN), or in orthodontics usually gramms

Principle of **transmissibility**

The principle of transmissibility states that the point of application of a force can be moved anywhere along its line of action without changing the external reaction forces on a rigid body

Center of resistance – CR

- The movement of a rigid body through a force can be described by the body's center of resistance
- Should be distinguished from the center of mass, the 2 points are only equal to free bodies
- Clinical definition: When the line of action of force runs through the center of resistance, we get physical movement (Burstone and Choy 2015)

Center of resistance

- The center of resistance depends more on the environment in which the body is fixed than on the shape of the body itself
- In the case of an upper incisor, the CR is approximately 1 / 3-2 / 3 the length of the root in the alveolus

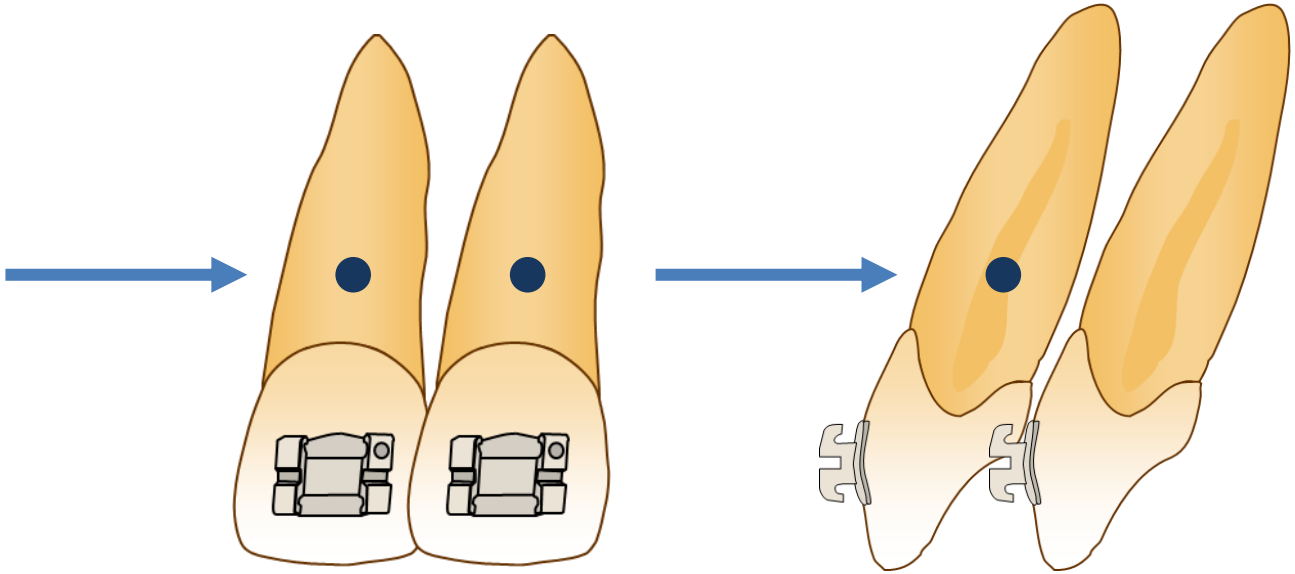
Moment

- When the line of action of the force does not pass through the CR, a Moment is generated
- The moment is a mathematical description of the body's tendency to rotate around its CR under the influence of force.
- it is represented by a curved arrow, with the arrow indicating the direction of rotation (CW, CCW).
- Its unit of measurement in orthodontics is typically gmm (SI: Nm)
- When a force couple acts on the tooth, pure rotation can occur in which all points of the tooth rotate around the CR

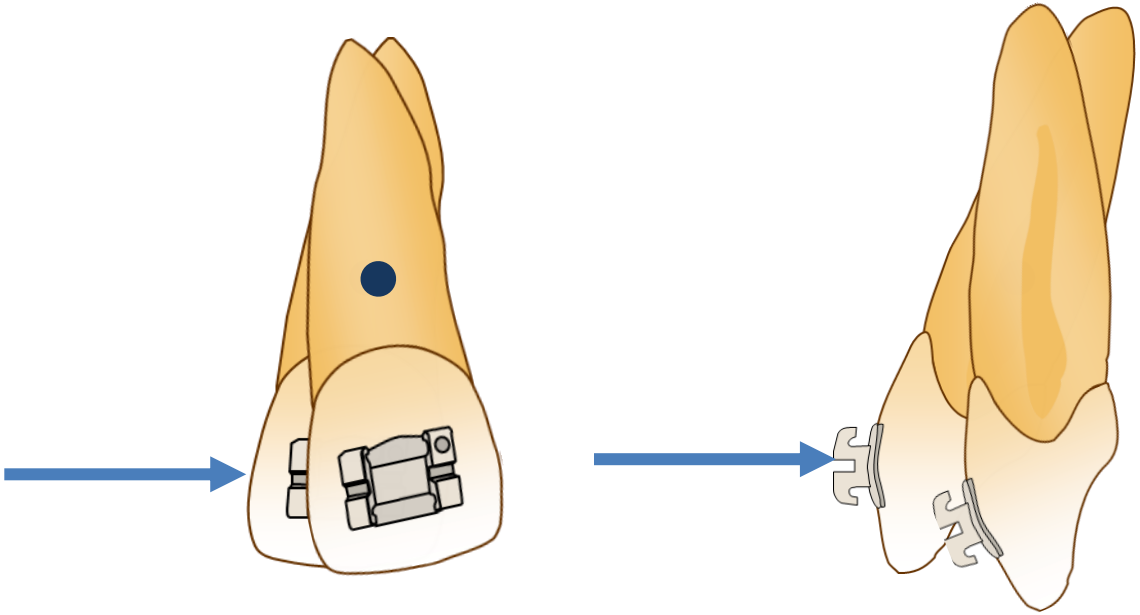
Forces and moments needed for tooth movement

- Type of movement (intrusion / extrusion, body movement)
- Loaded area of PDL
- Biology of the PDL and the alveolus
  - Age
  - Underlying diseases
  - Hormonal Effects (Pregnancy)

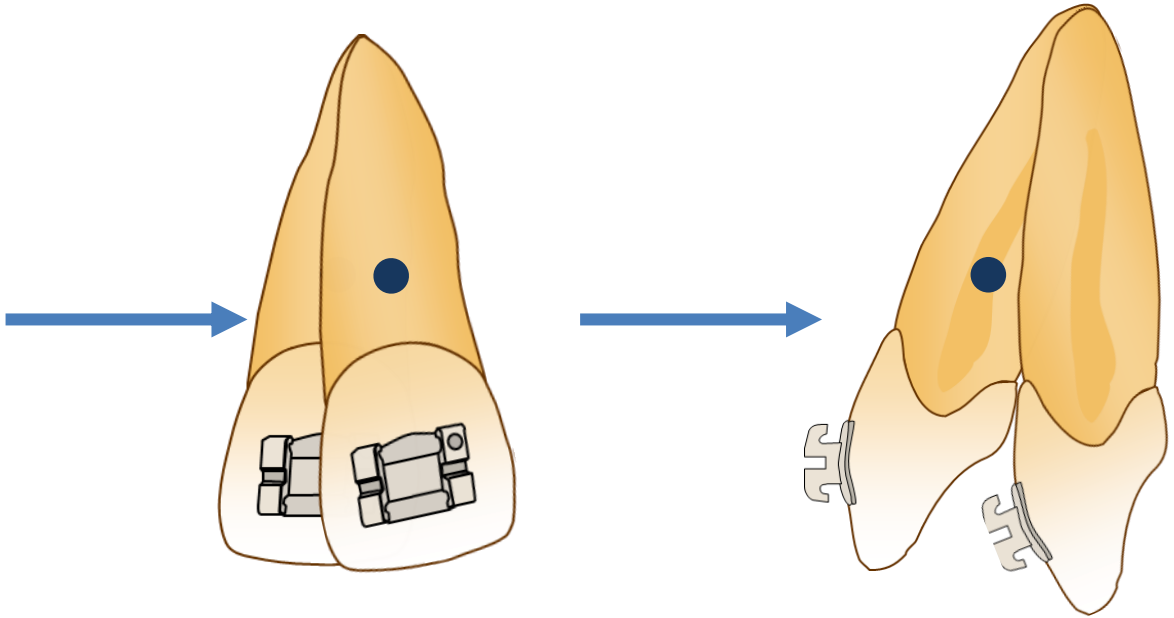
Translation



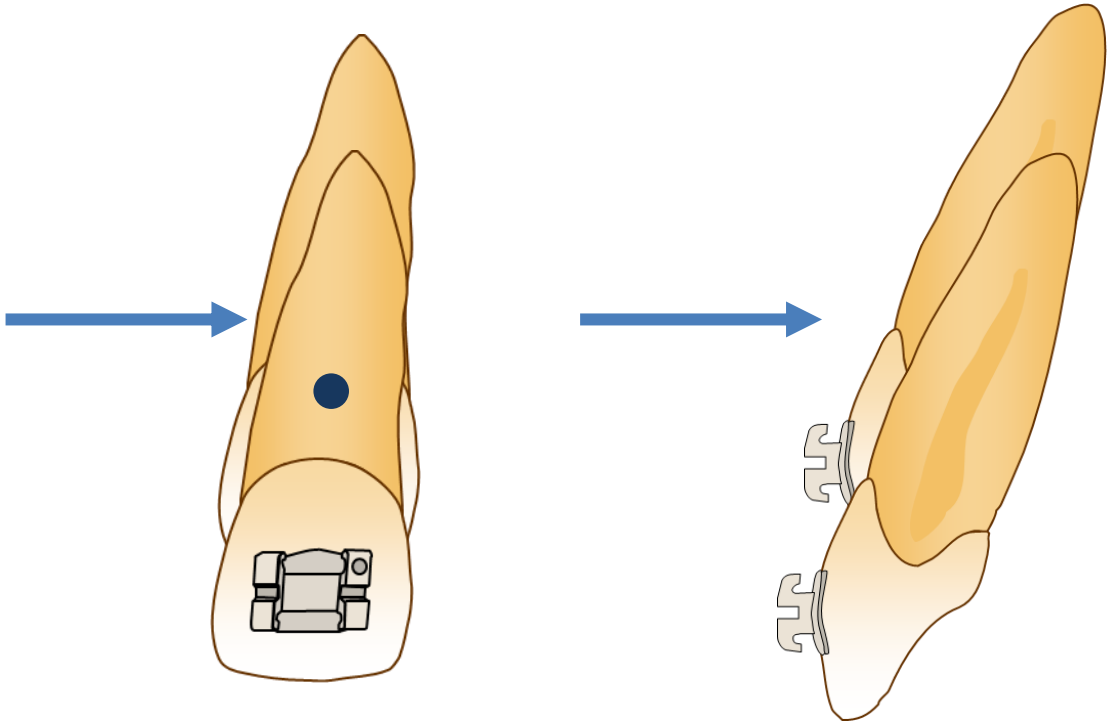
Uncontrolled tipping



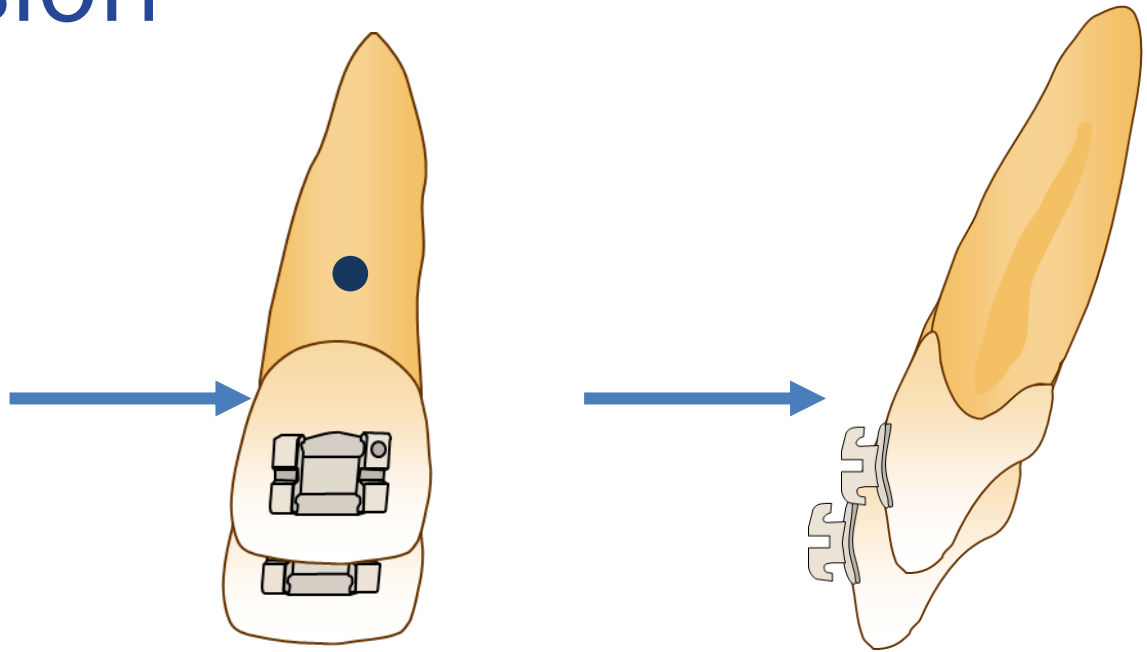
Controlled tipping



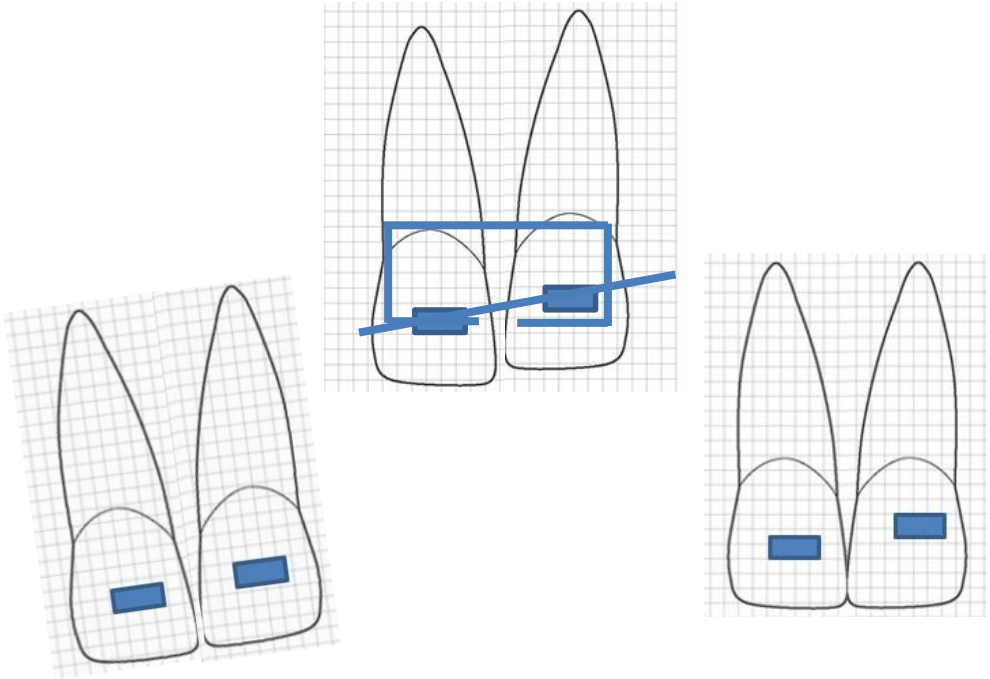
Extrusion



Intrusion



Shapedriven vs forcedriven



Equilibrium (Newton lex tertia)

- Within the orthodontic system there is an opposing force to any force, the two cancel each other out so that the system remains in equilibrium
- Because of this, we cannot move all teeth in one direction without the use of an external anchor
- We must always carefully consider the opponents of our exerted forces and the desired / potentially undesirable tooth movements that they create

Anchorage

- Anchorage: Resistance to unwanted tooth movement (Proffit, 2018)
- For most orthodontic treatments that fail, the cause of failure is loss of anchorage; → undesirable displacement of the passive unit
- What is to be considered?
  - What kind of tooth movement our forces and opposing forces will cause
  - How much resistance can the units of this movement offer?
    - → occlusion
    - → Anatomy of the PDL (intrusion / extrusion, inclination / body displacement)

Friction

- Resistance to sliding (clearance)
- Binding (interference)
- Notching (obstruction)

Statically determined systems

- A biomechanical system is considered statically determinable if its mechanical effect can be determined clinically by simple measurements.
- Dynamometers and callipers are used for the measurement
- The moment can be easily and precisely determined from the force and distance measured (M = F.d)
- Moment cannot be measured clinically

Statically determined systems

- In orthodontics, only the system can be biomechanically determined in which the arch is integrated in a maximum of one unit in the slot or in the tube and the connection at the other unit is point-like
- Such a system could be, for example, a rubber chain between two extension arms (if the units are not also connected with an arch)
- The most typical representatives of this system are the cantilevers
- These systems are characterized by their high quality constancy

Statically undetermined systems

- The arch is ligated into two or more slots
- The resulting forces and torques cannot be determined under clinical conditions
- A typical example is the straight wire technique, in which the tooth movement forces between the brackets are generated due to the elastic deformation of the superelastic arch.
- A NiTi arch that has been tied into all brackets and slots is in fact a series of statically indeterminate systems in which the resulting tooth movement forces cannot be estimated.
- It is not characterized by qualitative inconsistency

General considerations when designing appliances

- Bracket width
  - friction
  - Interbracket distance
- Active elements
  - Uniform force delivery over a long period below the iatrogenic range
  - Good flexibility (formability)
- Passive elements
  - The goal is to form rigid, stable units
  - It should be rigid and malleable
- Cross section of the arch
  - Control of movement
  - flexibility
  - Movement along the arch

Archwire materials

- Stainless Steel - SS
- NiTi
- Titanium Molibdenium Alloy – TMA or ß-Titan

Thank you for your kind attention!