Biomechanical principles of orthodontics
The possibilities of tooth movement

Dr. Radó Zsuzsanna

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250 years in medical education, research & innovation and healthcare

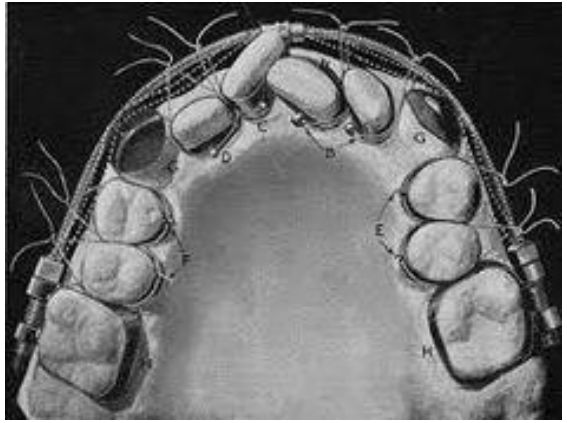
Semmelweis University
http://semmelweis.hu/
Department of Pediatric Dentistry and Orthodontics

Introduction

„Historically, the mainstay of orthodontic treatment has been the appliance. Orthodontists have been trained to fabricate and use appliances and sequences of appliance shapes called techniques. However, appliances are only the instrument to produce force systems, which are the basis of tooth position and bone modification…

…Dentofacial changes are primarily achieved by the orthodontist applying forces to teeth, the periodontium, and bone. Hence, the scientific basis of orthodontics is physics and Newtonian mechanics applied to a biologic system. The modern clinician can no longer practice or learn orthodontics as a trade or a technique. He or she must understand forces and how to manipulate them to optimize active tooth movement and anchorage.”

Burstone, C. J. and K. Choy, Eds. (2015). The biomechanical foundation of clinical orthodontics.



Forceapplication

↓

lagtime

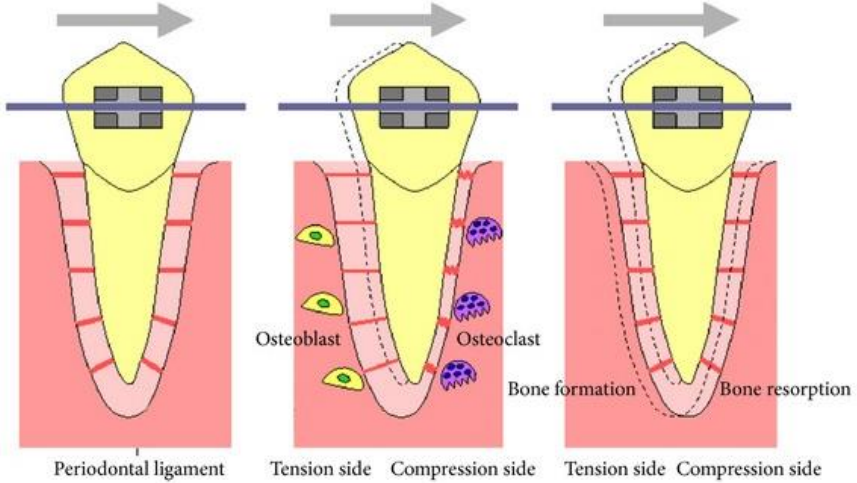
↓

Change in position

Broadening of PDL

(temporary)
mobility

Remodelling of alveolar bone-
Compression site - Resortpion
Tension site - Apposition



Phases of tooth movement

Initialisation phase (1-2 Days)

- Force → minimal change in position → stationary stage with changed tension pattern in the PDL
- 1-2 hours → changed oxygenization
- 4 hours → cell differentiation cAMP increases
- On about the 2nd day, the tooth movement begins to be clinically visible as a consequence of the remodeling

Hyalinisation phase (2-4 Weeks)

- Nectrotization, signs of absorption on the root surface
- PDL broadening (radiological finding)
- Osteoid appears on the tension side, mineralization begins

Types of forces that can be appiead

- Orthopedic - orthodontic
- intermittent – continous
- magnitude
  - Value below the stimulus threshold for tooth movements
  - Capillary pressure range
  - Iatrogenic area, excessive forces, undermining absorption

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

- Burstone, C. J. and K. Choy, Eds. (2015). The biomechanical foundation of clinical orthodontics.

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

- Burstone, C. J. and K. Choy, Eds. (2015). The biomechanical foundation of clinical orthodontics.

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)

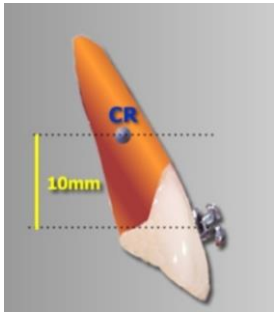
- Burstone, C. J. and K. Choy, Eds. (2015). The biomechanical foundation of clinical orthodontics.

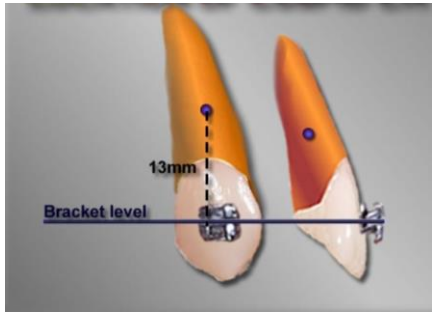
Center of resistance

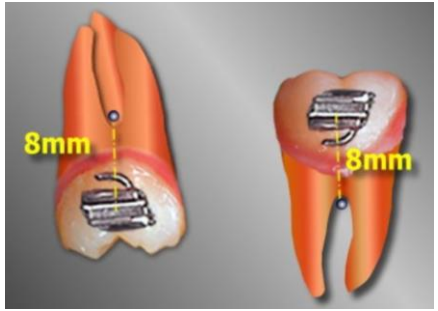
- The center of resistance depends more on the environment in which the body is fixed than on the shape of the body itself
- In the case of an upper incisor, the CR is approximately 1 / 3-2 / 3 the length of the root in the alveolus

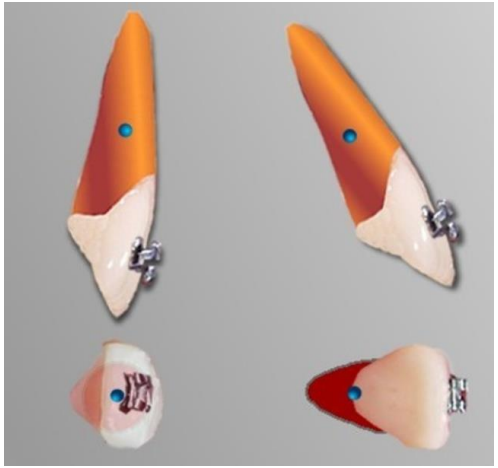
- Burstone, C. J. and K. Choy, Eds. (2015). The biomechanical foundation of clinical orthodontics.

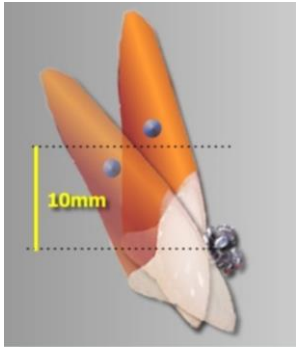
CR of single teeth and units

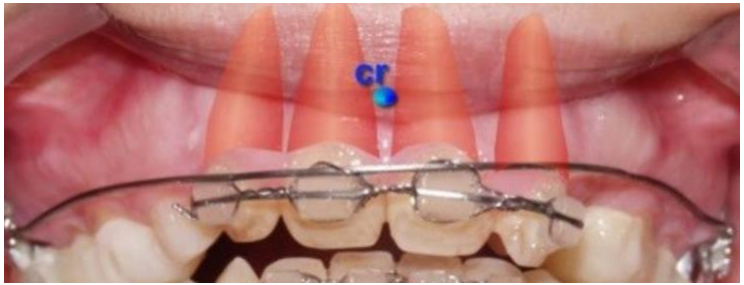








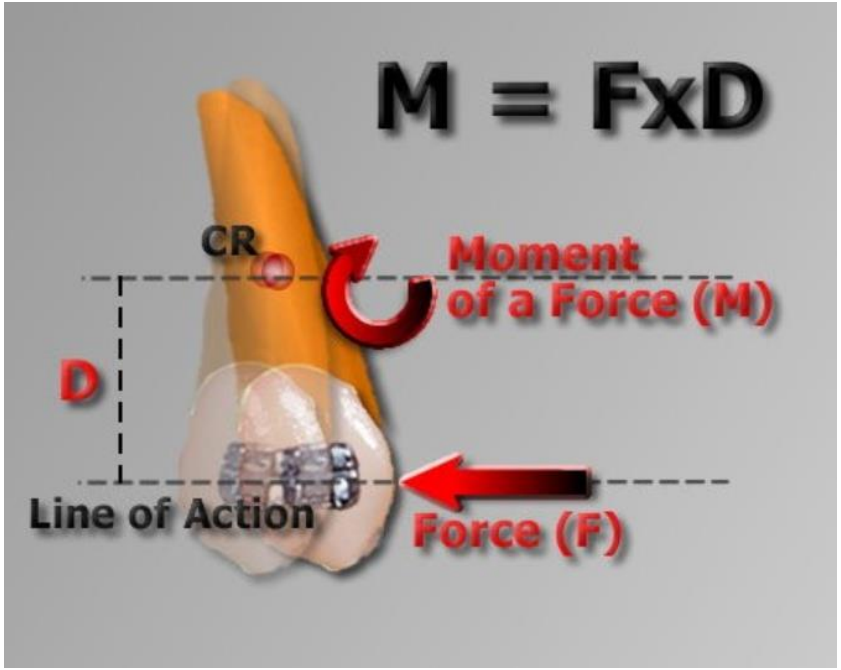




- Fiorelli, G. and B. Melsen (2013). "Biomechanics in orthodontics 4."

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



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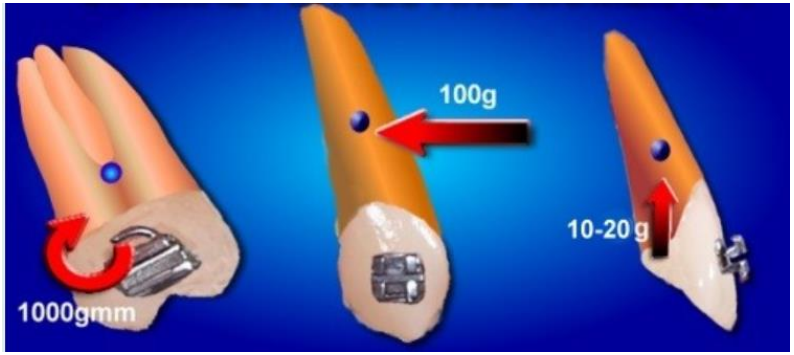
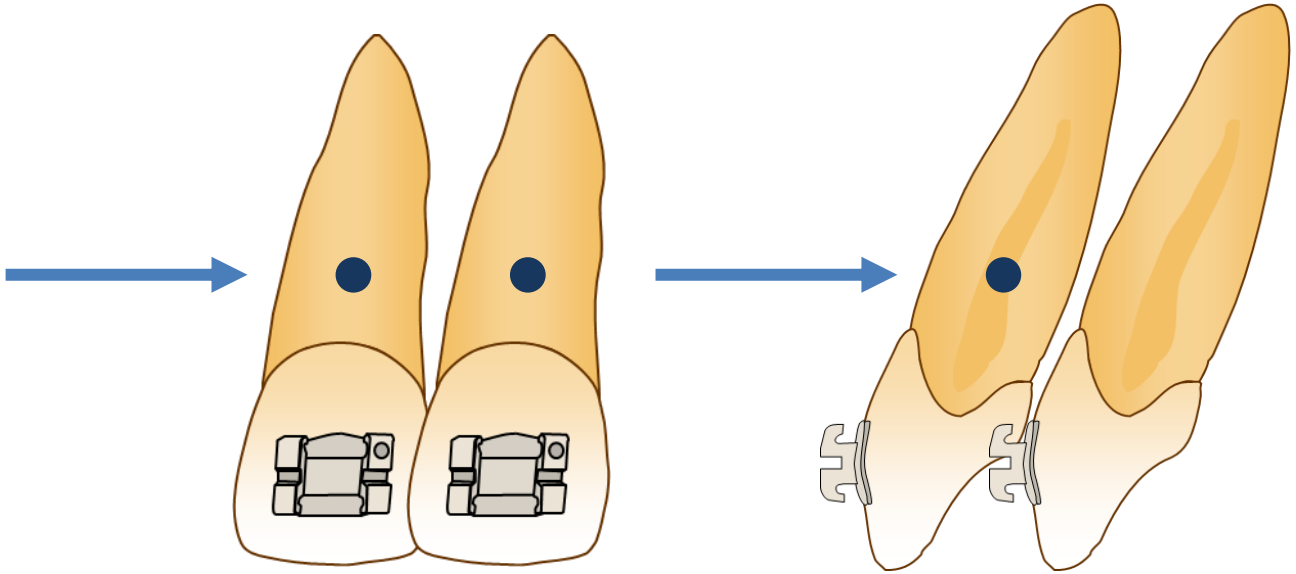
Forces and moments needed for tooth movement

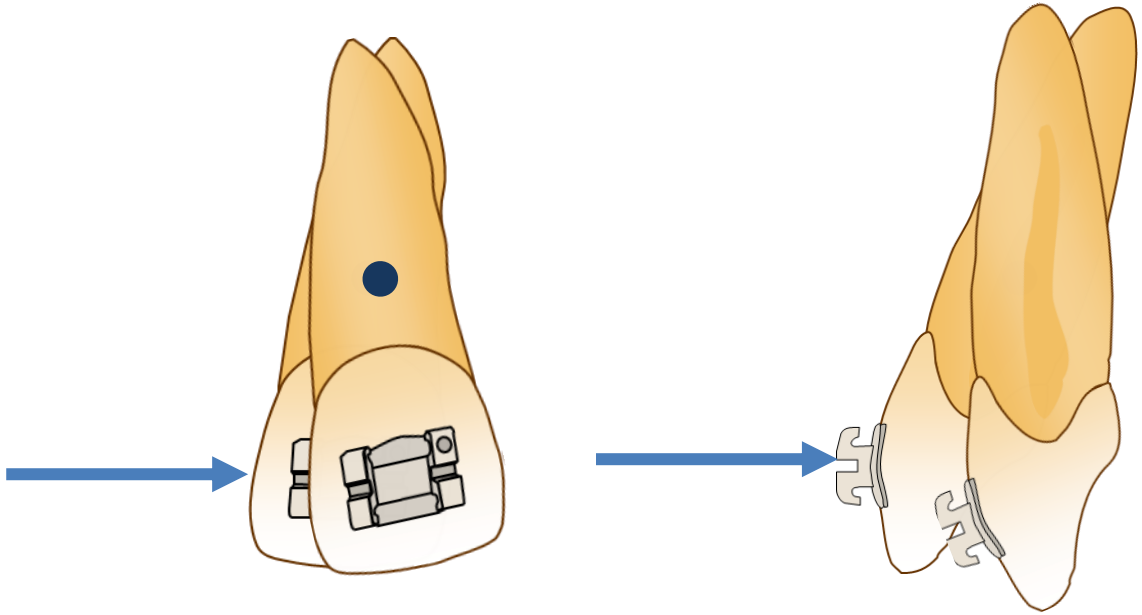
- Type of movement (intrusion / extrusion, body movement)
- Loaded area of PDL
- Biology of the PDL and the alveolus
  - Age
  - Underlying diseases
  - Hormonal Effects (Pregnancy)



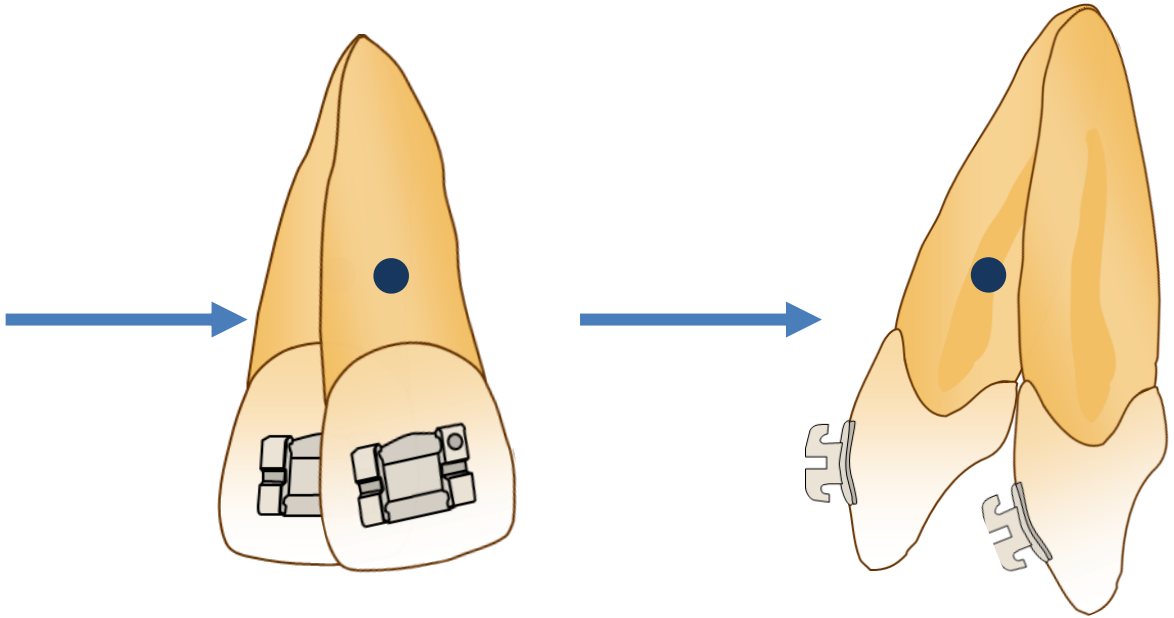
Translation



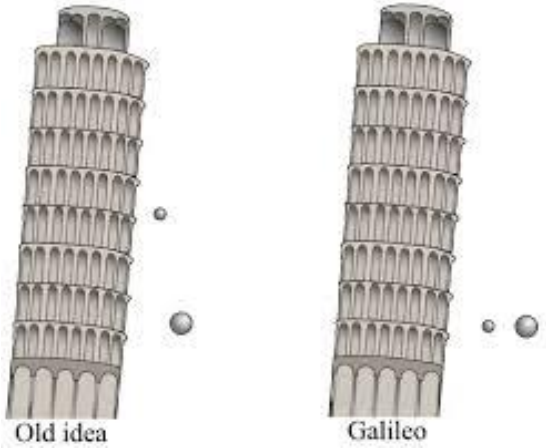
Uncontrolled tipping

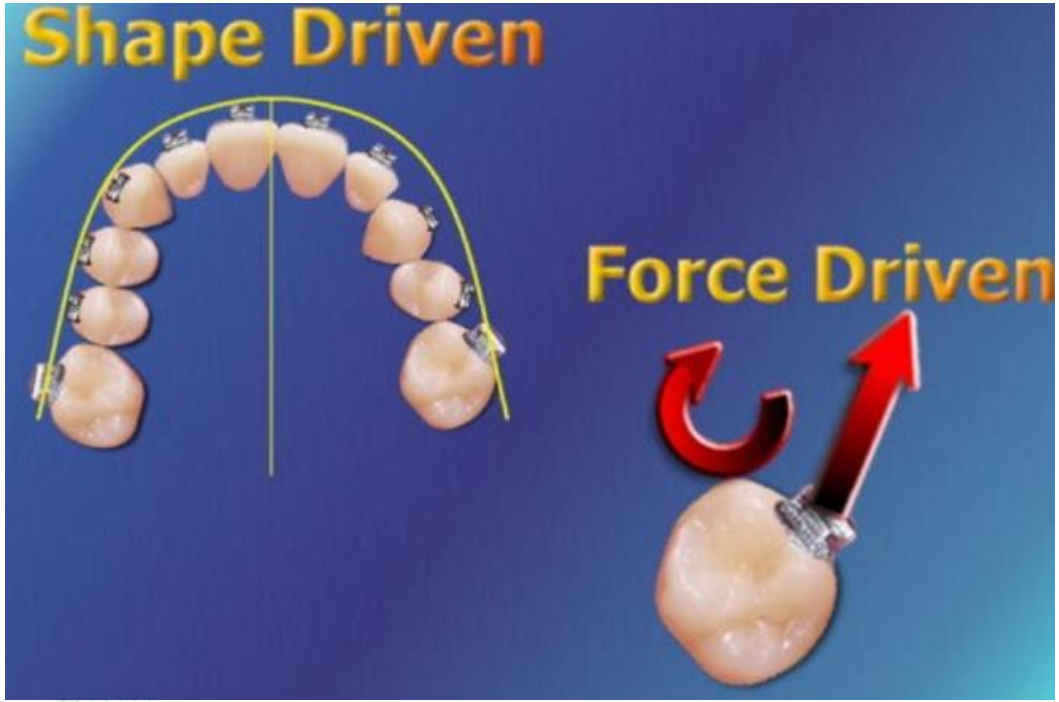


Controlled tipping



Shapedriven vs forcedriven





Equilibrium (Newton lex tertia)

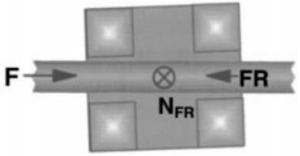
- Within the orthodontic system there is an opposing force to any force, the two cancel each other out so that the system remains in equilibrium
- Because of this, we cannot move all teeth in one direction without the use of an external anchor
- We must always carefully consider the opponents of our 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)

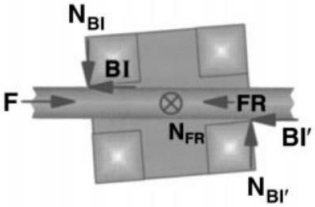
Friction

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



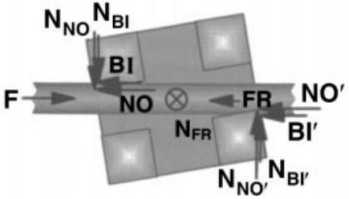
Clearance:
Only classical friction (FR) is causing resistance to sliding (RS).

RS = FR



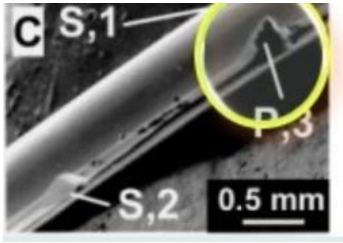
Interference:
Binding (BI), as well as FR, is contributing to RS.

RS = FR + BI



Obstruction:
Notching (NO) is ceasing bracket movement altogether.

RS + FR + BI + NO



Articolo, L. C., Kusy, K., Saunders, C. R., & Kusy, R. P. (2000). Influence of ceramic and stainless steel brackets on the notching of archwires during clinical treatment. *Eur J Orthod, 22*(4), 409-425. doi:10.1093/ejo/22.4.409

Kusy, R. P., & Whitley, J. Q. (1997). Friction between different wire-bracket configurations and materials. *Semin Orthod, 3*(3), 166-177.

Proffit, W. R., Fields, H. W., Larson, B. E., & Sarver, D. M. (2019). *Contemporary orthodontics*.

Fiorelli, G., & Melsen, B. (2013). Biomechanics in orthodontics 4. Retrieved from http://www.ortho-biomechanics

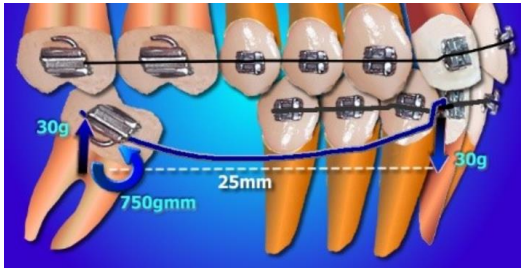
Statically determined systems

- 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

- Fiorelli, G. and B. Melsen (2013). "Biomechanics in orthodontics 4."

Statically determined systems

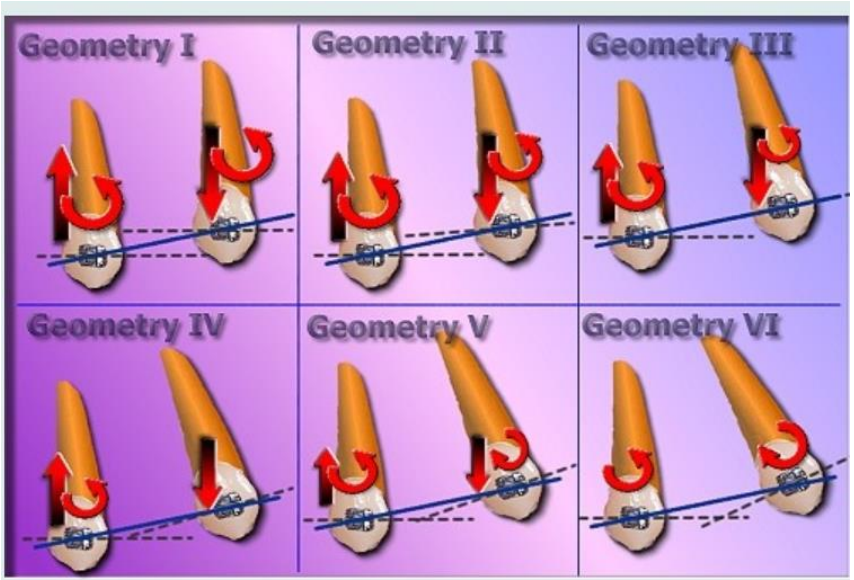
- In orthodontics, only the system can be biomechanically determined in which the arch is integrated in a maximum of one unit in the slot or in the tube and the connection at the other unit is point-like
- Such a system could be, for example, a rubber chain between two extension arms (if the units are 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



➢ Fiorelli, G. and B. Melsen (2013). "Biomechanics in orthodontics 4."

Statically undetermined systems

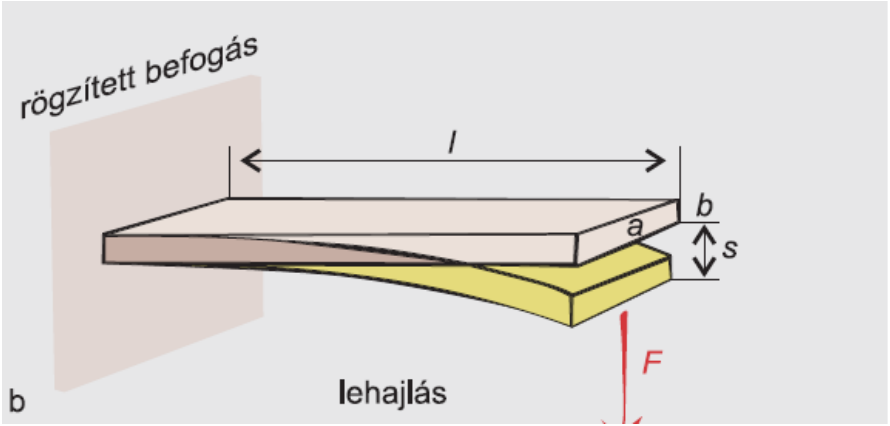
- The arch is ligated into two or more slots
- The resulting forces and torques cannot be determined under clinical conditions
- A typical example is the straight wire technique, in which the tooth movement forces between the brackets are generated due to the elastic deformation of the superelastic arch.
- 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

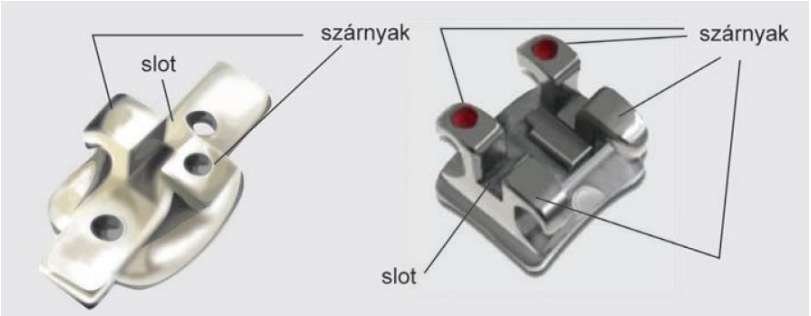


- Fiorelli, G. and B. Melsen (2013). "Biomechanics in orthodontics 4."
- Koenig, H. A. and C. J. Burstone (1989). "Force systems from an ideal arch--large deflection considerations." Angle Orthod **59**(1): 11-16.

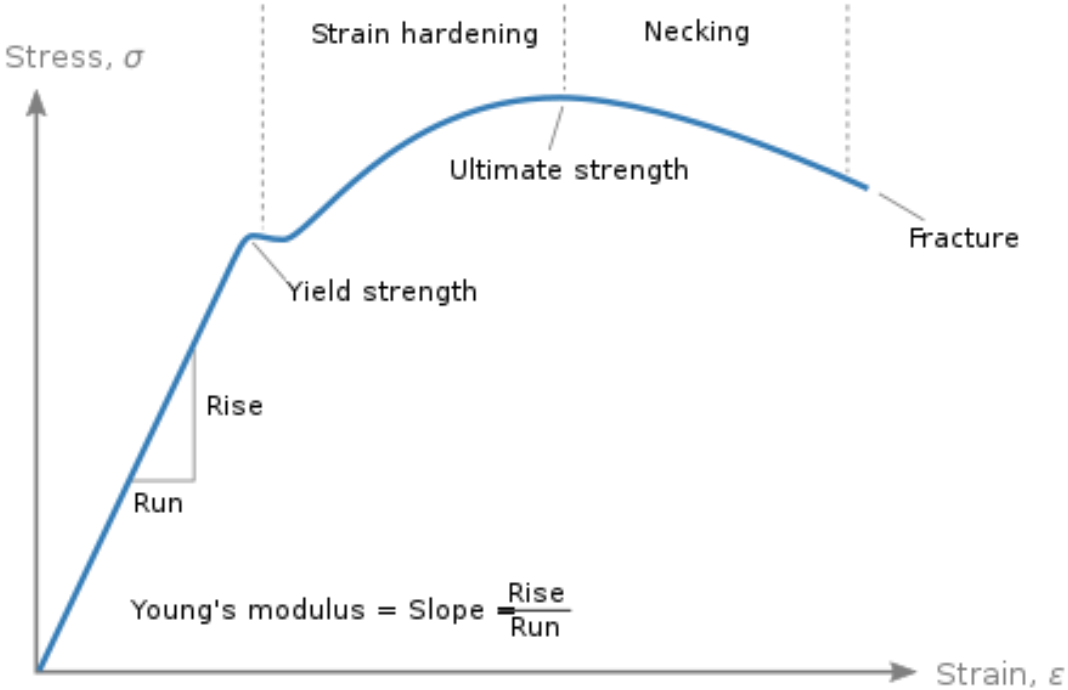
General considerations when designing appliances

- 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



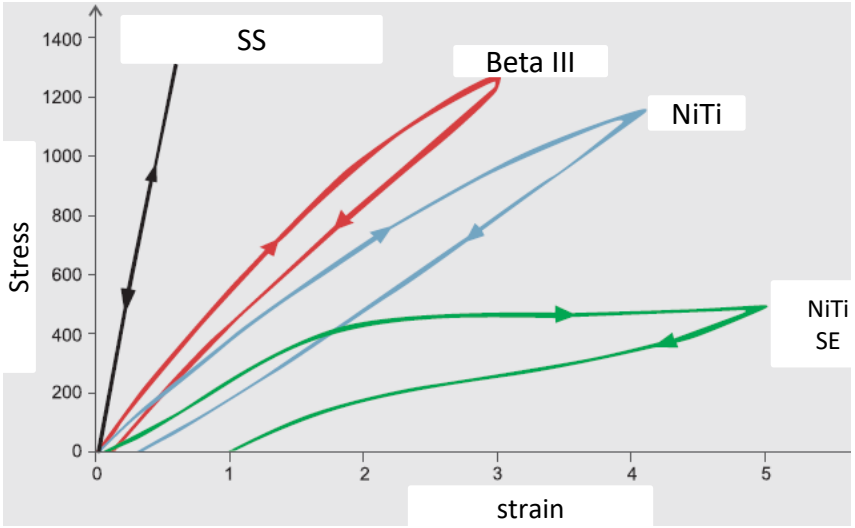


Stress–strain curve



Archwire materials

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



Thank you for your kind attention!