

Physical base of Orthodontics



Physical basis of dental material science
14.

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Orthodontics

before



after



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Physiological forces in the mouth

Mastication:

Large, and short:

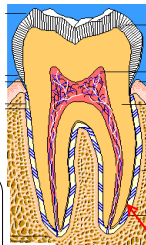
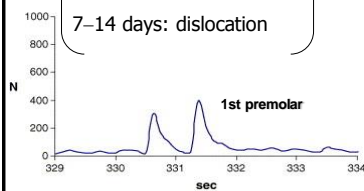
$$F = 100-800 \text{ N}$$

$$t \leq 1 \text{ s}$$

3-5 s: pain

≈ hour: lesion

7-14 days: dislocation



forces „in rest“:

small, „constant“:

$$F = 1-10 \text{ cN}$$



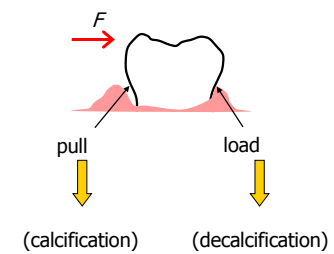
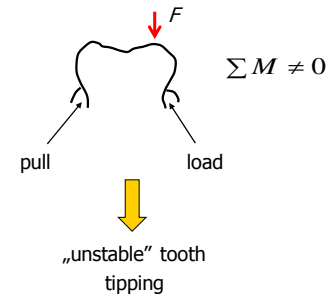
„active“
stabilization
(PDL)

periodontal ligament

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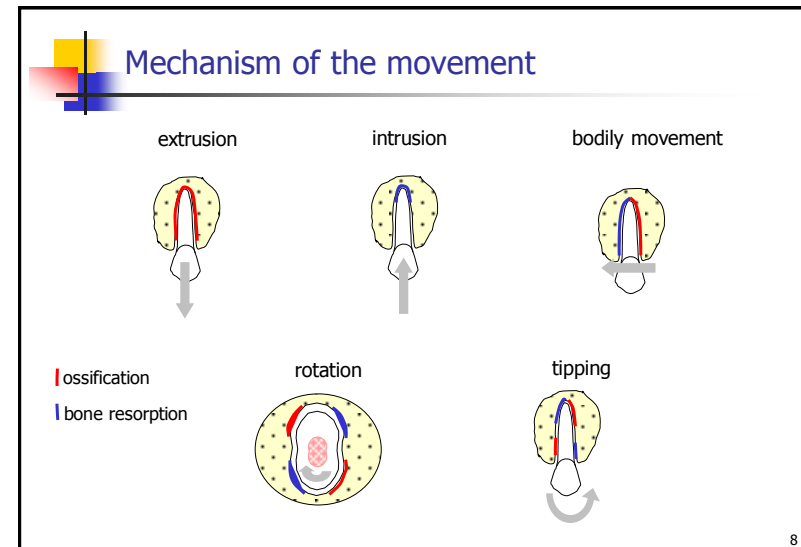
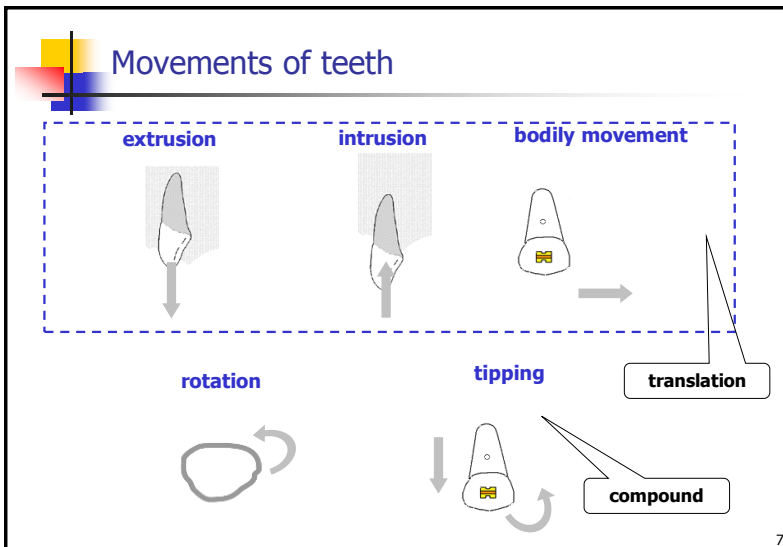
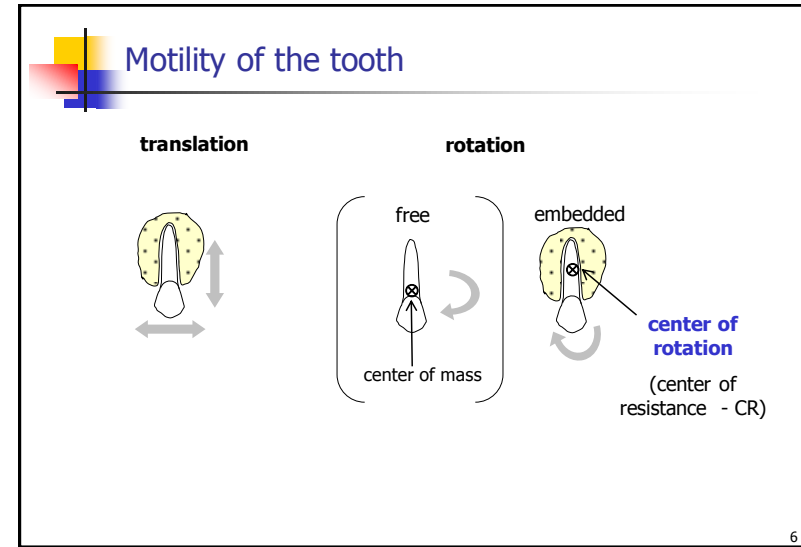
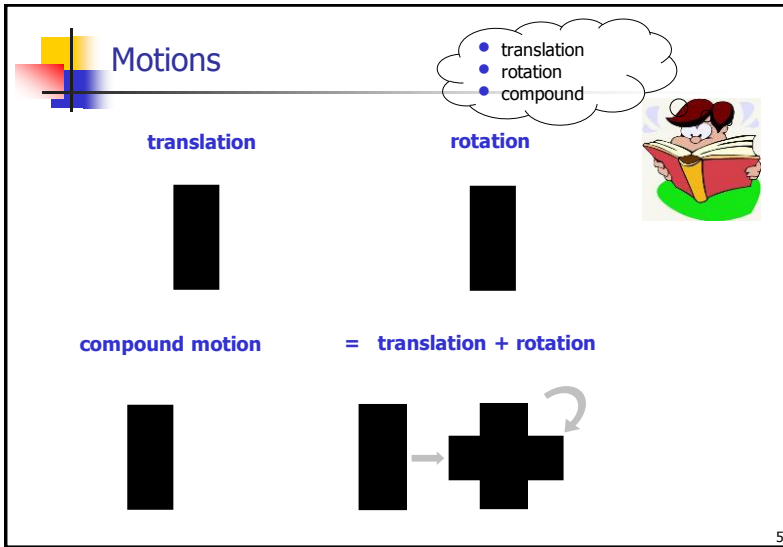
Instability and motion

„permanent“ force ($> 10 \text{ cN}$):

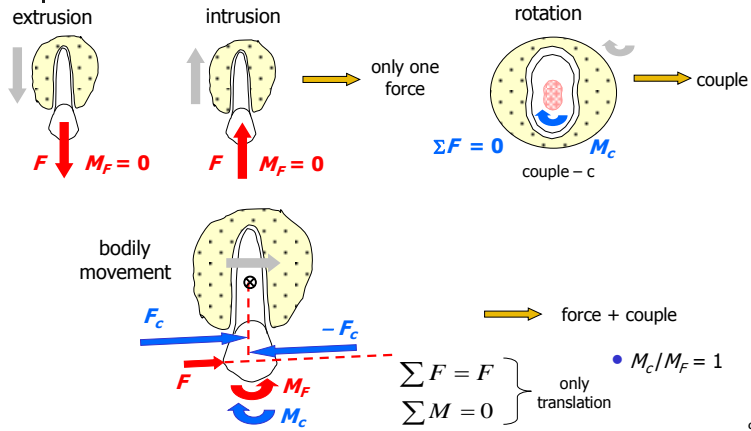


dislocation (= remodeling)

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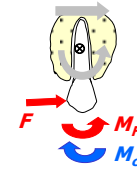


Forces and torques



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tipping



force	couple	ΣF	ΣM	
-	✓	0	M_c	rotation
✓	-	F	M_F	tipping
✓	✓	F	$M_F - M_c$	controlled tipping

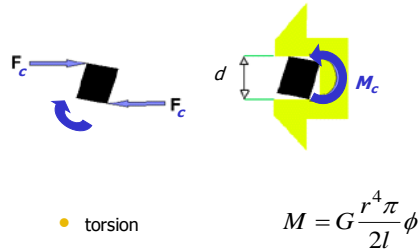
translation + rotation ($M_c = 0$)

translation + rotation

- $0 < M_F - M_c$ ($M_c/M_F < 1$)
- $M_F - M_c < 0$ ($1 < M_c/M_F$)

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Realization of a couple

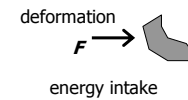


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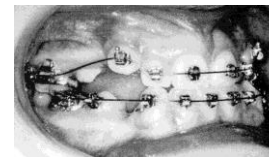
Orthodontic brace

An elastic object, that stores the mechanical energy and exerts a force on teeth, („**mechanical accumulator**”).

before application:



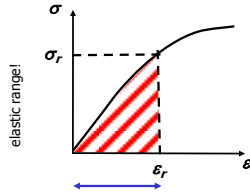
under application:



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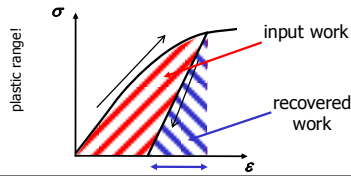
Mechanical properties of the brace

- material properties: stiffness, elastic strain recovery, resilience



$$\text{resilience} = \frac{1}{2} \sigma_r \cdot \varepsilon_r = \frac{1}{2} E \varepsilon_r^2$$

input work = recovered work,
if there is no friction!!!



examples:

- plastics
- steel
- cobalt-chrome alloys
- titanium alloys

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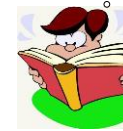
- geometrics: shape, size (e.g. thickness, length, ...)

- stretching/compression $F = E \frac{A}{l} \Delta l$ $W = \frac{1}{2} E \cdot \frac{A}{l} \Delta l^2$
- bending $F = 3E \cdot \frac{\Theta}{l^3} \cdot s$ $W = \frac{1}{2} 3E \cdot \frac{\Theta}{l^3} \cdot s^2$
- torsion $M = G \frac{r^4 \pi}{2l} \phi$

Stiffness of the body
spring stiffness

Problems:

- friction



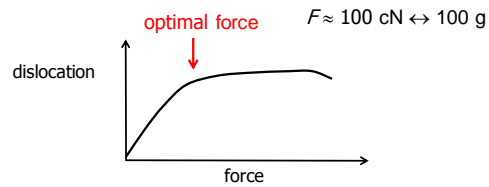
Friction force (F_f):

$$F_f = \mu \cdot F_p$$

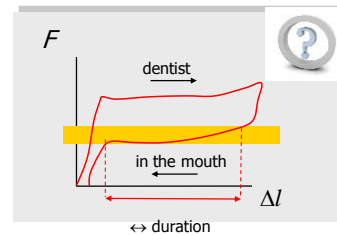
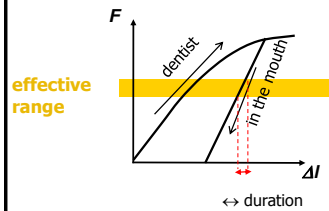
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Restoring force

- amplitude?



- stability?



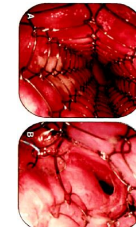
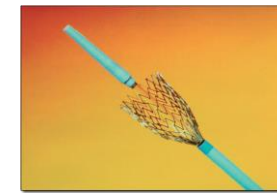
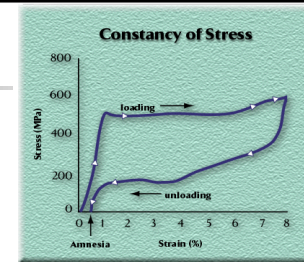
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Superelasticity

Ni+Ti Cu+Al+Zn Cu+Al+Ni

Nitinol (Nickel-Titanium Naval Ordnance Laboratory)

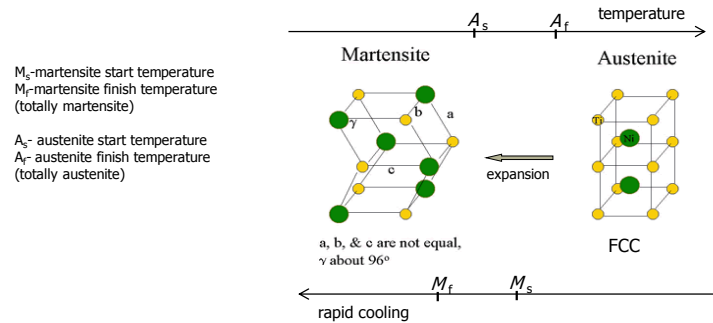
- superelastic (pseudoelastic)
- It has shape memory
- biomechanical compatibility
- biocompatible



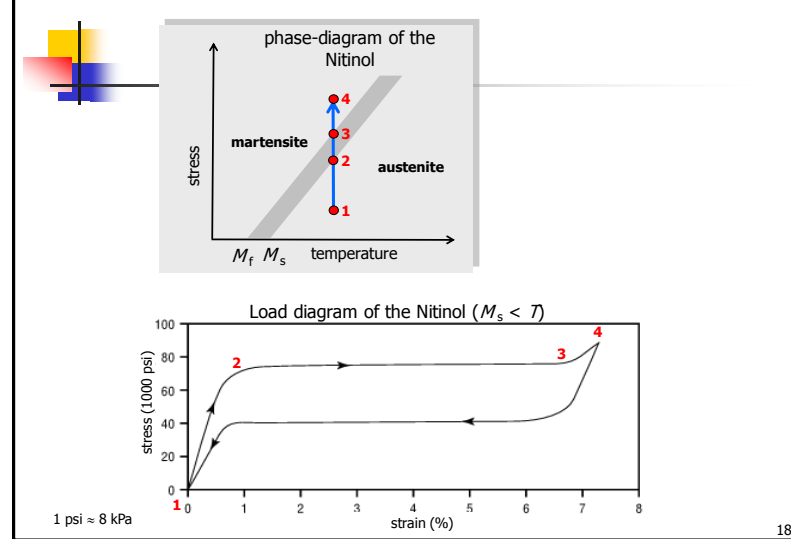
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Superelasticity

elastic (reversible) response to an applied stress, caused by a phase transformation between the austenitic and martensitic phases of a crystal.

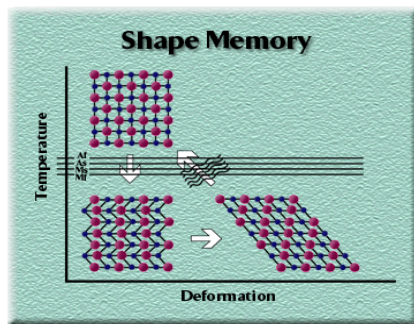


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Shape memory



- one-way**
 below A_s : change the shape after heating shape changes to its original.
- two-way**
 the material remembers two different shape: at low and at high temperature.

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Artificial „muscle“



FLEXINOL®
 Actuator Wire



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Selection

Aspects of selection:

- good mechanical properties
- tissue compatible
- acid-proof
- non allergic
- cheap