Physical base of Orthodontics

Physical basis of dental material science
14.

Orthodontics

before

after

Physiological forces in the mouth

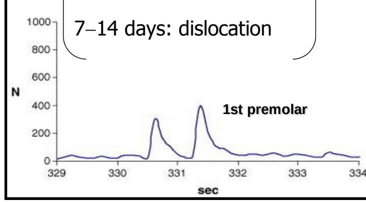
Mastication:

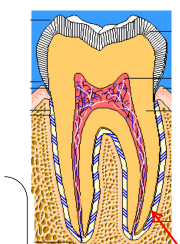
Large, and short:

***F* = 100–800 N**

***t* ≤ 1 s**

- 3–5 s: pain
- ≈ hour: lesion
- 7–14 days: dislocation





forces „in rest”:

small, „constant”:

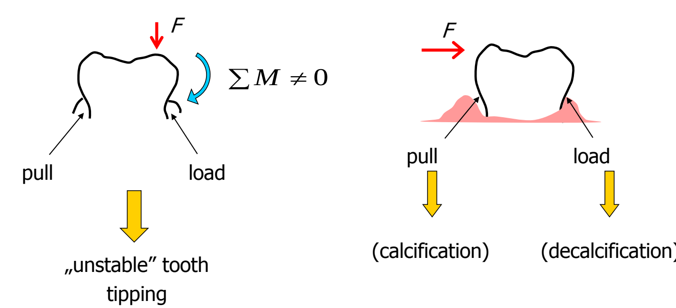
***F* = 1–10 cN**

„active” stabilization (PDL)

periodontal ligament

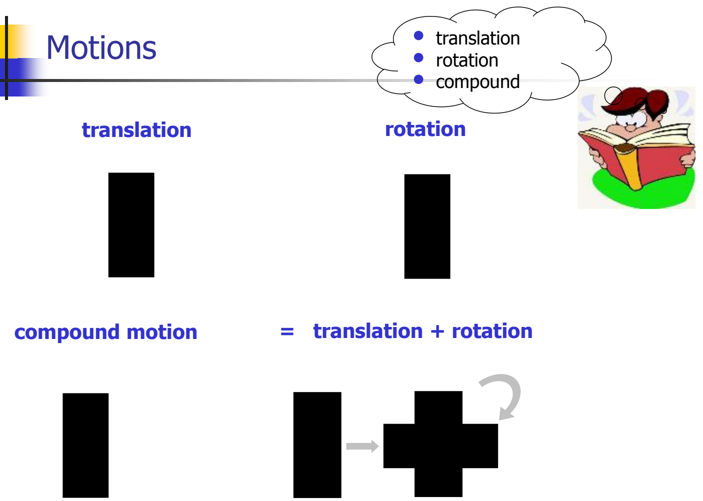
Instability and motion

„permanent” force (> 10 cN):



dislocation (≡ remodeling)

Motions



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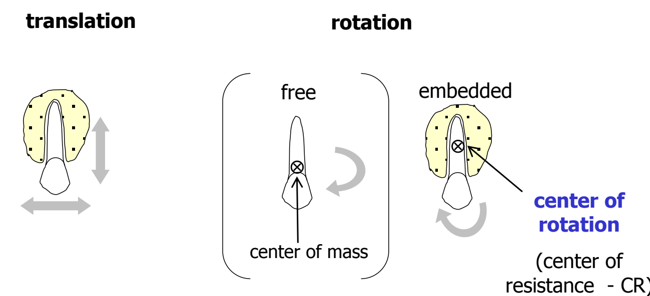
Motility of the tooth



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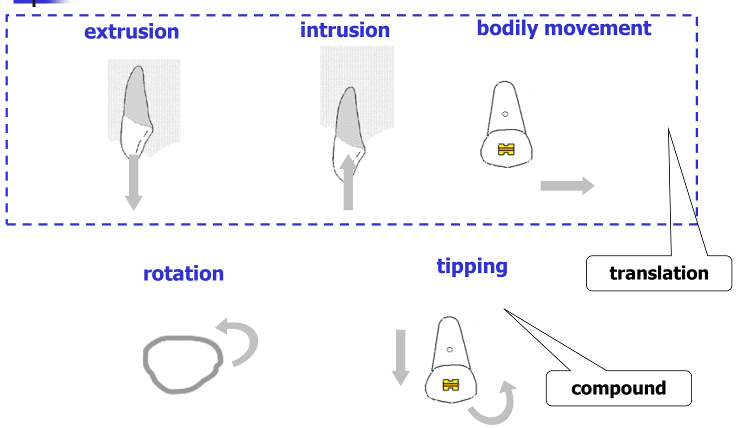
Movements of teeth



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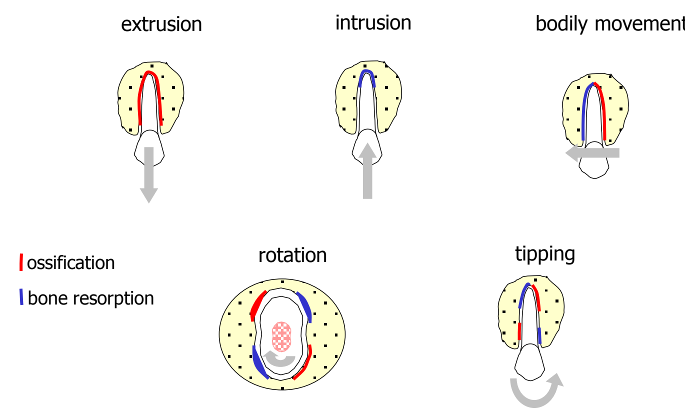
Mechanism of the movement



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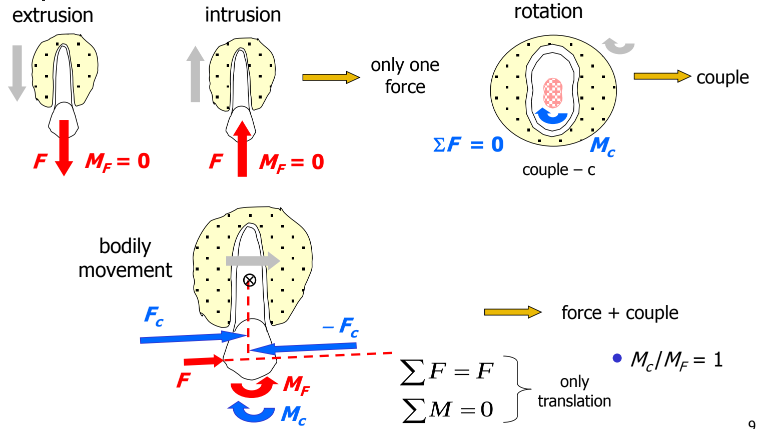
Forces and torques



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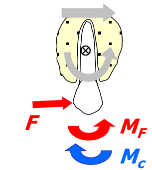

force	couple	$\sum F$	$\sum M$	
–	✓	0	M_c	→ rotation
✓	–	F	M_F	→ **tipping** translation + rotation ($M_c = 0$)
✓	✓	F	$M_F - M_c$	→ **controlled tipping** translation + rotation

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

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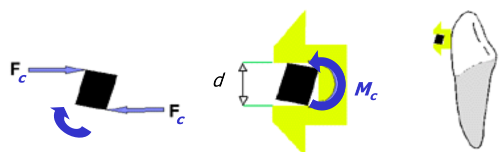
Realization of a couple



- torsion

$$M = G \frac{r^4 \pi}{2l} \phi$$

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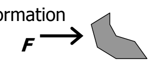
Orthodontic brace

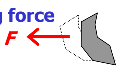
An elastic object, that stores the mechanical energy and exerts a force on teeth, („**mechanical accumulator**”).

before application:

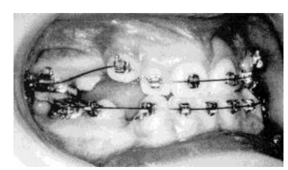


energy intake

under application:



utilization of the stored energy



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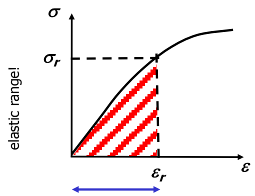
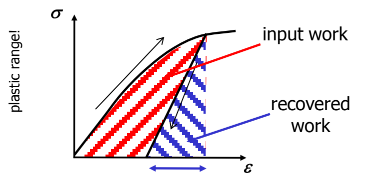
Mechanical properties of the brace

- material properties: stiffness, elastic strain recovery, resilience



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!!!



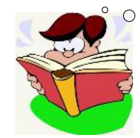
examples:
- plastics
- steel
- cobalt-chrome alloys
- titanium alloys

- geometrics: shape, size (e.g. thickness, length, ...)
  - stretching/compression $F = E\frac{A}{l}\Delta l$ $\quad W = \frac{1}{2}E\cdot\frac{A}{l}\Delta l^2$
  - bending $F = 3E\cdot\frac{\Theta}{l^3}\cdot s$ $\quad W = \frac{1}{2}3E\cdot\frac{\Theta}{l^3}\cdot s^2$
  - torsion $M = G\frac{r^4\pi}{2l}\phi$

Stiffness of the body
spring stiffness

Problems:

- friction

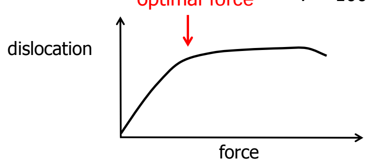


Friction force (F_f):
$F_f = \mu \cdot F_p$

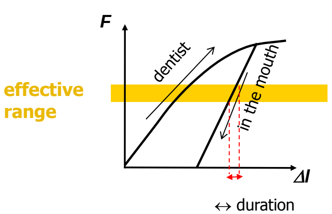
Restoring force

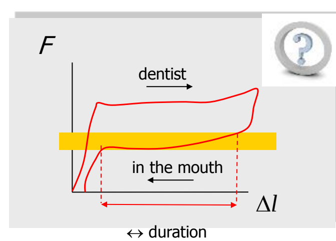
- amplitude?

optimal force $\quad F \approx 100$ cN ↔ 100 g



- stability?



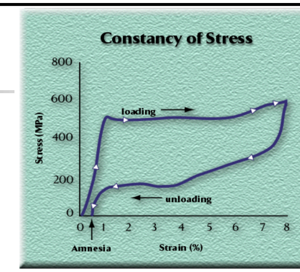


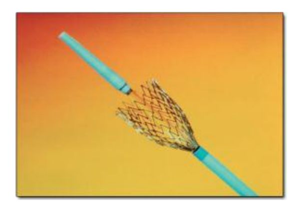
Superelasticity

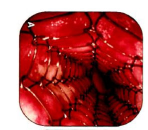
Ni+Ti Cu+Al+Zn Cu+Al+Ni

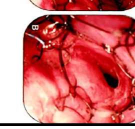
Nitinol (**Ni**ckel-**Ti**tanium **N**aval **O**rdnance **L**aboratory)

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







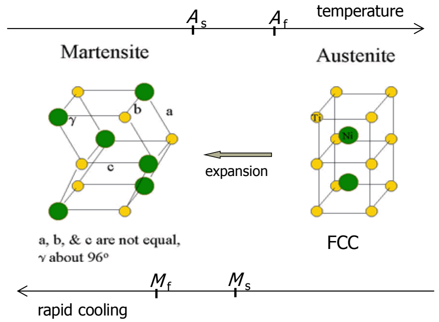


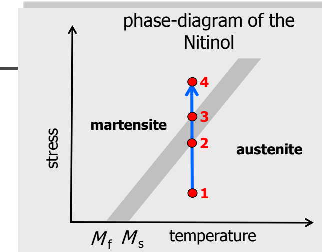
Superelasticity

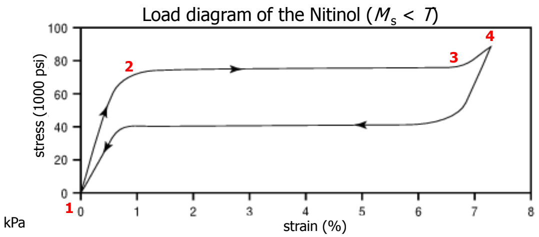
elastic (reversible) response to an applied stress, caused by a phase transformation between the austenitic and martensitic phases of a crystal.

M_s-martensite start temperature
M_f-martensite finish temperature
(totally martensite)

A_s- austenite start temperature
A_f- austenite finish temperature
(totally austenite)

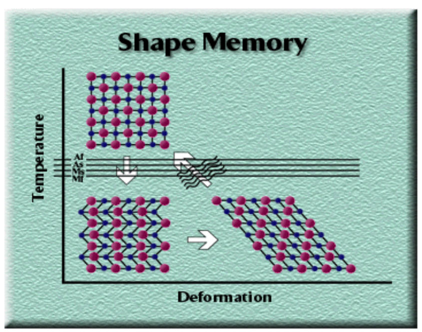






1 psi ≈ 8 kPa

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.

Artificial „muscle”

FLEXINOL®
Actuator Wire

Selection

Aspects of selection:

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

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