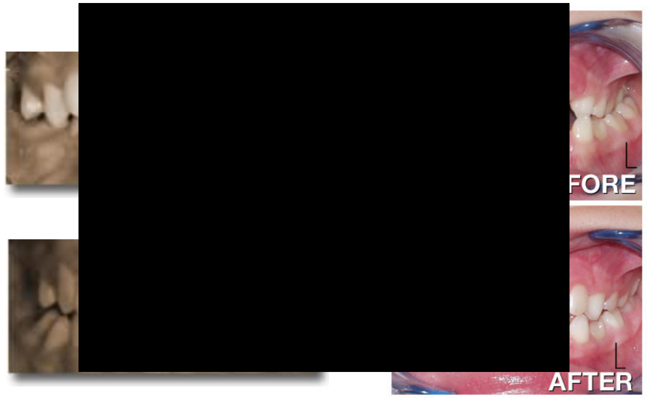
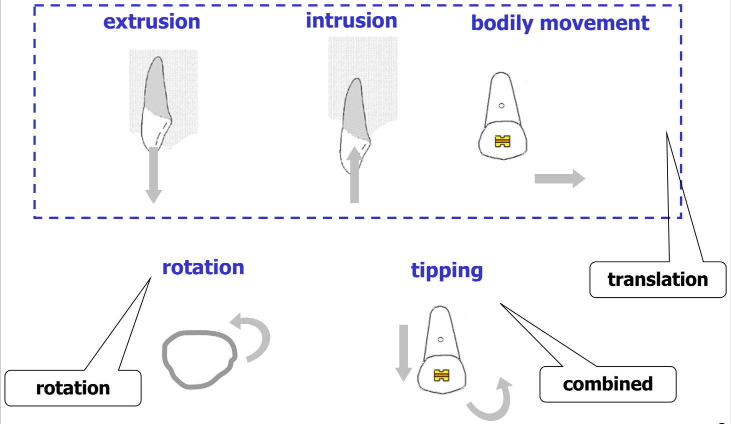
Physical bases of orthodontics



Tooth movement in orthodontics

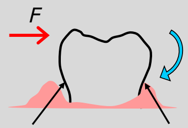


Moving tooth by forces

Resting forces:
F = 1–10 cN
„constant"

no consequence

Forces used in orthodontics:
F = 50 cN — 400 cN
„constant"



compressive stress → bone growth (calcification)

tensile stress → bone decay (decalcifitation)

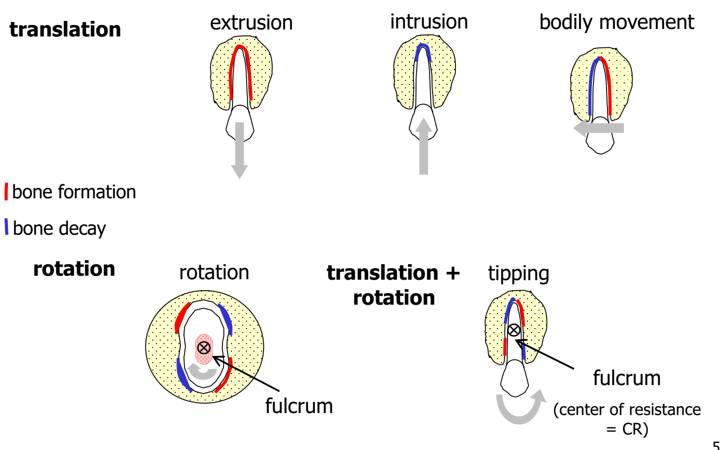
bone remodelling ⇒ tooth movement

Mastication:
F = 100–800 N
$t \leq 1$ s

If it would be constant,

t = 3–5 s: pain
≈ hours: damage
7–14 days: loosening

Mechanisms of tooth movements



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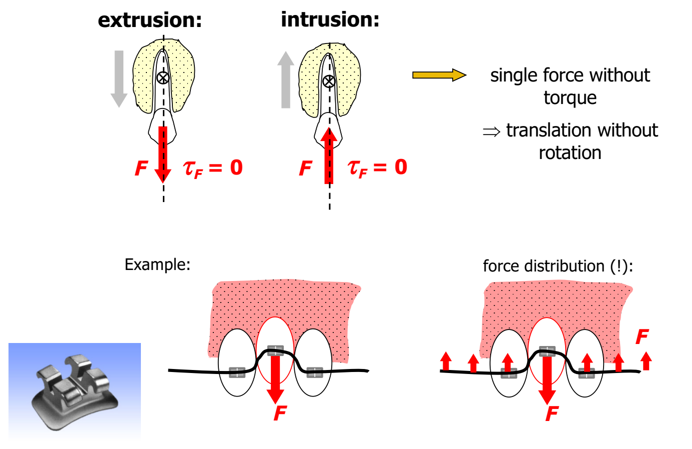
Forces required for tooth movements



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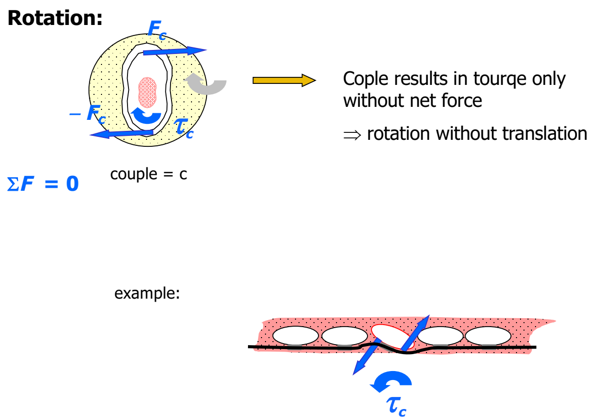

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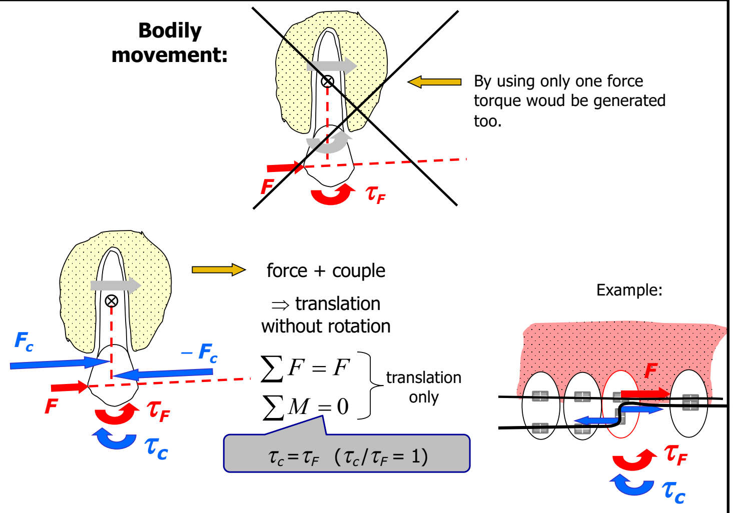

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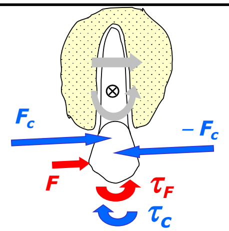
Tipping:



force	couple	$\sum F$	$\sum \tau$	
–	✓	**0**	τ_c	⇒ rotation
✓	–	***F***	τ_F	⇒ **tipping: :** translation + rotation
✓	✓	***F***	$\tau_F - \tau_c$	⇒ **controlled tipping:** translation + rotation

$0 < \tau_F - \tau_c$ $\quad (\tau_F - \tau_c < 1)$

$\tau_F - \tau_c < 0$ $\quad (1 < \tau_F - \tau_c)$

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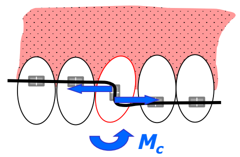
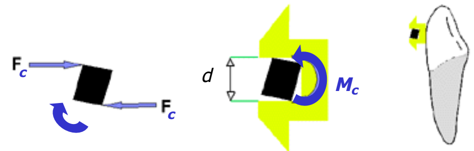
Example:





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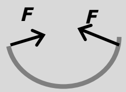
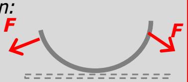
Dental brace

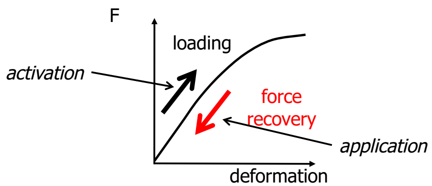
Dental braces are elastic bodies, that will recover the elastic energy after deformation by exerting forces on the teeth (**„mechanical battery”**).

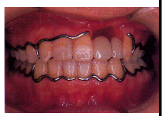
activation:
deformation
(energy input)



dental application:
recovery
(stored energy
utilizued)







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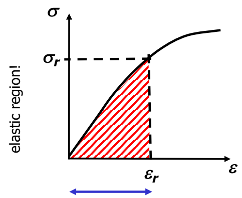
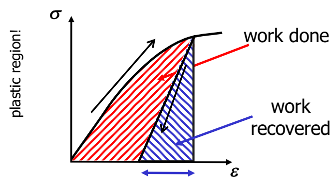
Mechanical properties of braclets

- properties: stiffness, elastic strain recovery, resilience



work done = work recovered,
assuming no friction!!



Example:
- polymers
- steel
- Co-Cr alloys
- Ti alloys

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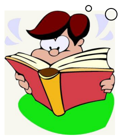
- geometry: shape, dimensions (i.e. thickness, length, ...)

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

body stiffness

Problems:

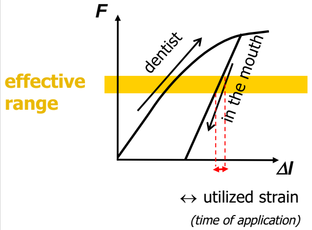
- friction

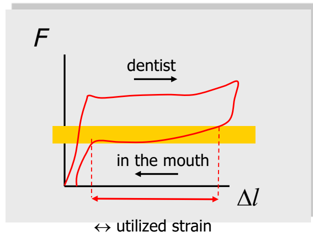


Frictional force (F_f): $F_f = \mu \cdot F$

Restoring force

- magnitude?
- time course?



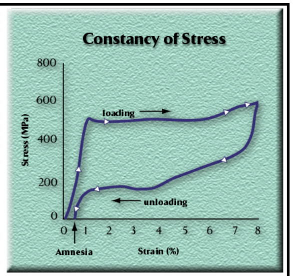


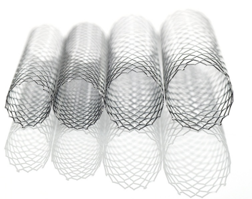
Superelastic materilas

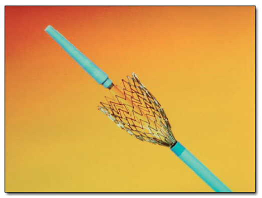
Ni+Ti Cu+Al+Zn Cu+Al+Ni

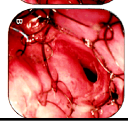
Nitinol (**Ni**ckel-**Ti**tanium **N**aval **O**rdnance **L**aboratory)

- Superelastic (pseudoplastic)
- shape memory
- biomechanical compatibility
- biocompatible





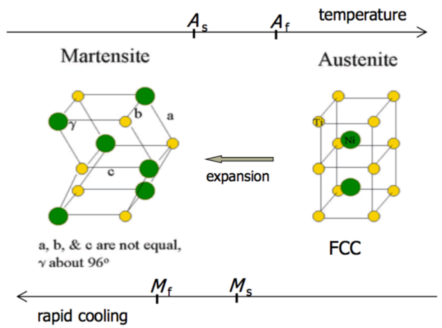


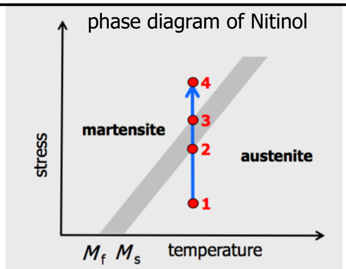


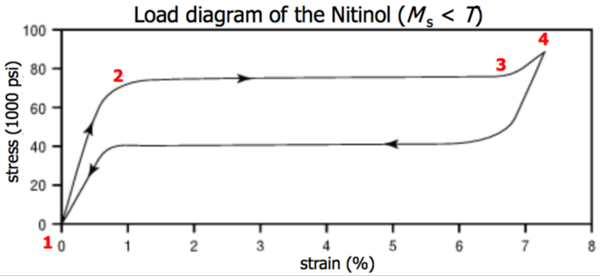
elastic (reversible) response to an applied stress, caused by a phase transformation between the austenitic and martensitic phases of a crystal.

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

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




phase diagram of Nitinol
stress
martensite
austenite
4
3
2
1
M_f M_s
temperature


Load diagram of the Nitinol ($M_s < T$)
stress (1000 psi)
100
80
60
40
20
0
1
2
3
4
0
1
2
3
4
5
6
7
8
strain (%)

1 psi ≈ 8 kPa