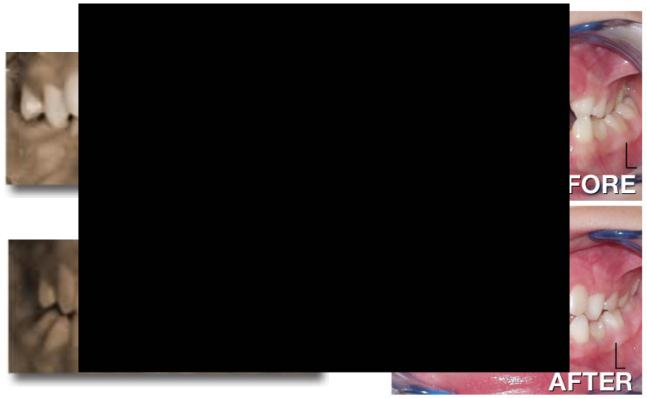
Physical bases of orthodontics

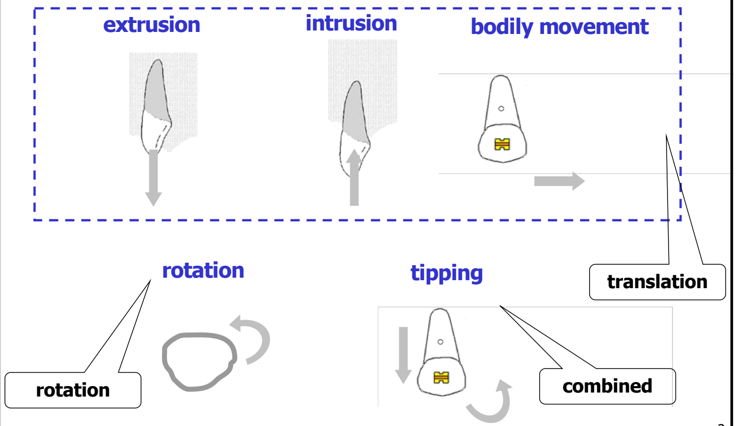
1



[redacted]

2

Tooth movement in orthodontics

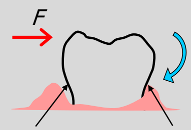


3

Moving tooth by forces

Resting forces:
F = 1–10 cN
„constant"
↓
no consequence

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



tensile stress → bone growth (calcification)

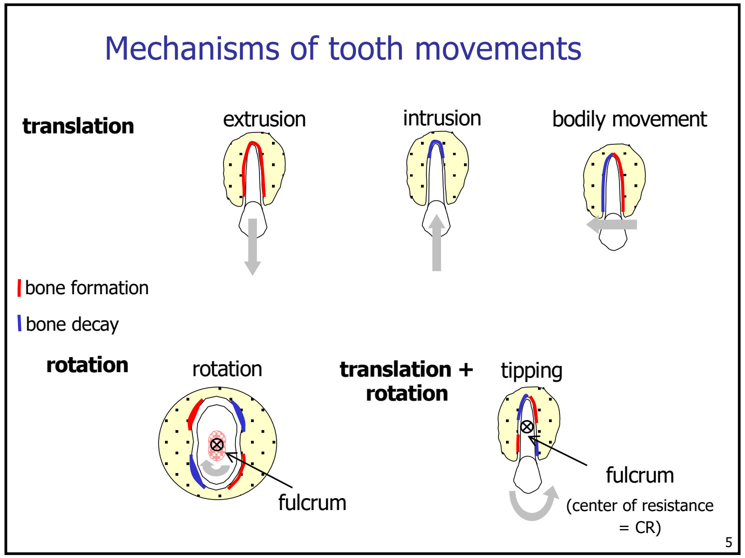
compressive stress → bone decay (decalcifitation)

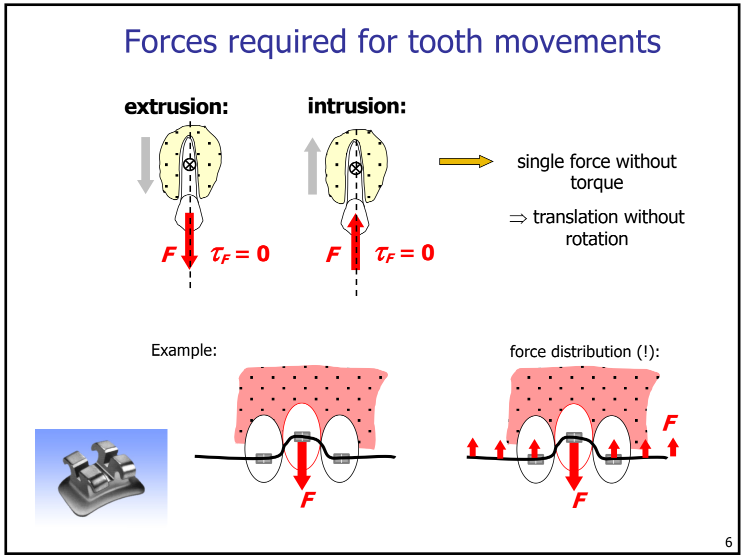
↓

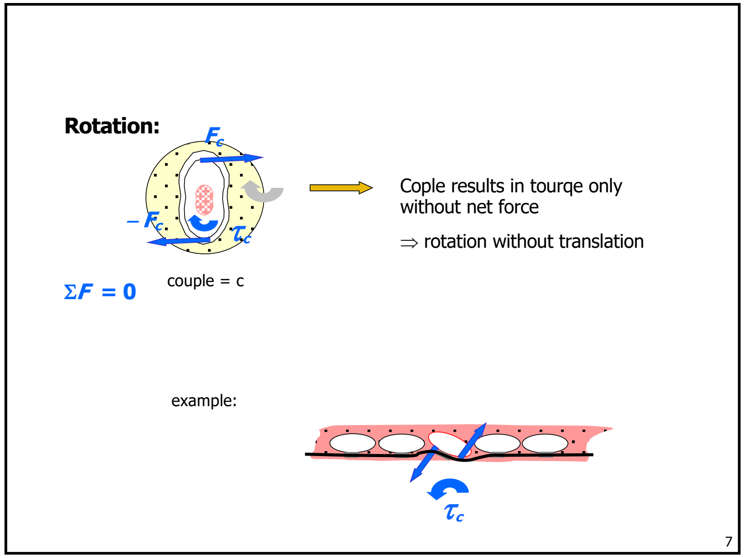
bone remodelling ⇒ tooth movement

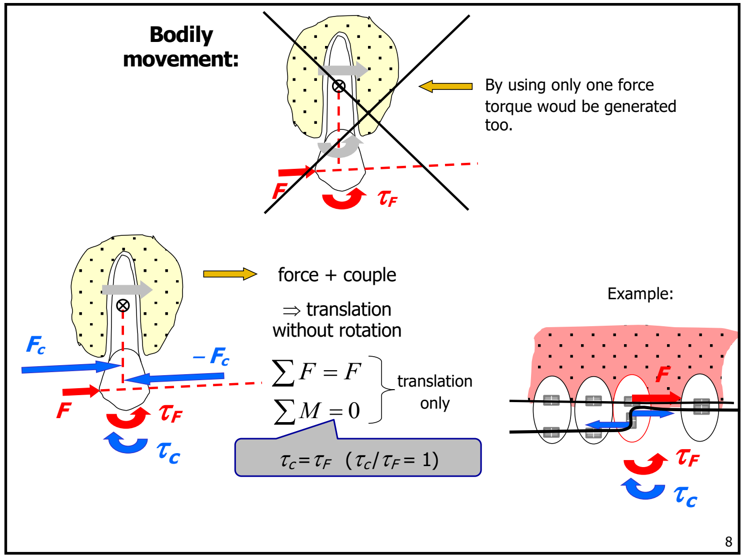
Mastication:
F = 100–800 N
$t \leq$ 1 s
If it would be constant,
↓
t = 3–5 s: pain
≈ hours: damage
7–14 days: loosening

4

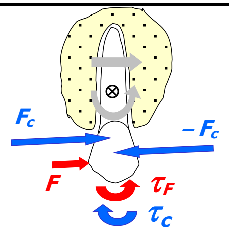

Mechanisms of tooth movements
translation
extrusion
intrusion
bodily movement
bone formation
bone decay
rotation
rotation
fulcrum
translation + rotation
tipping
fulcrum
(center of resistance = CR)
5


Forces required for tooth movements
extrusion:
intrusion:
F
$\tau_F = 0$
F
$\tau_F = 0$
single force without torque
⇒ translation without rotation
Example:
F
force distribution (!):
F
F
6


Rotation:
F_c
$-F_c$
τ_c
couple = c
$\Sigma F = 0$
Cople results in tourqe only without net force
⇒ rotation without translation
example:
τ_c
7


Bodily movement:
F
τ_F
By using only one force torque woud be generated too.
F_c
$-F_c$
F
τ_F
τ_c
force + couple
⇒ translation without rotation
$\sum F = F$
$\sum M = 0$
translation only
$\tau_c = \tau_F \quad (\tau_c / \tau_F = 1)$
Example:
F
τ_F
τ_c
8

Tipping:

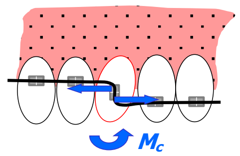


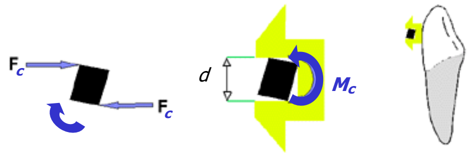
force	couple	$\sum F$	$\sum \tau$	
–	✓	**0**	τ_c	→ rotation
✓	–	F	τ_F	→ **tipping: :** translation + rotation
✓	✓	F	$\tau_F - \tau_c$	→ **controlled tipping:** translation + rotation

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

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

Example:

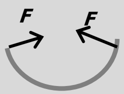




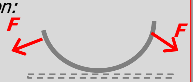
Dental brace

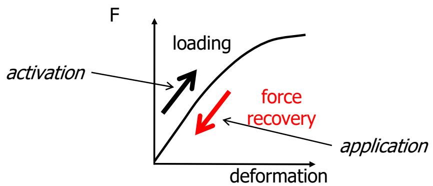
Dental braces are elastic bodies, that will recover the elastic energy after deformation by exerting forces on the teeth (**„mechanical battery"**).

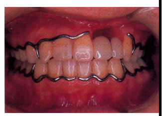
activation:
deformation
(energy input)



dental application:
recovery
(stored energy utilizued)

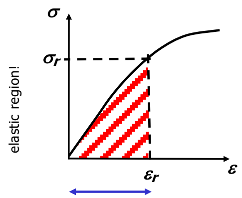




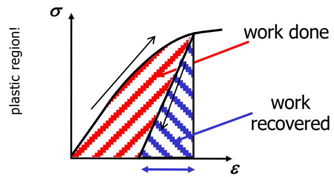


Mechanical properties of braclets

- properties: stiffness, elastic strain recovery, resilience



(work done = work recovered, assuming no friction!!)



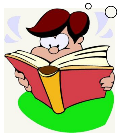
Example:
- polymers
- steel
- Co-Cr alloys
- Ti alloys

- 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

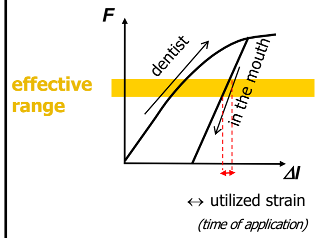


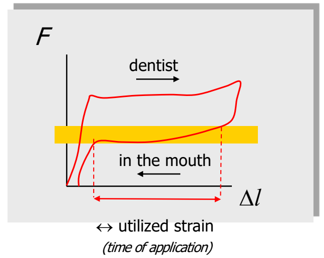
Frictional force (F_f):

$$F_f = \mu \cdot F$$

Restoring force

- magnitude?
- time course?



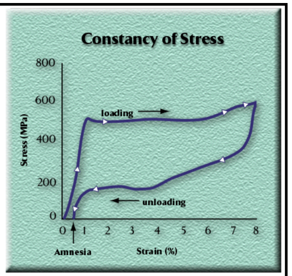


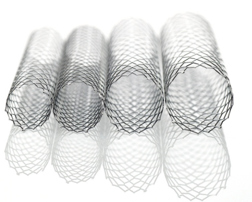
Superelastic materilas

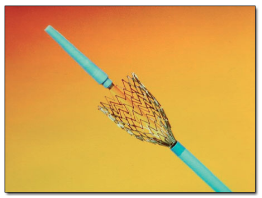
Ni+Ti Cu+Al+Zn Cu+Al+Ni

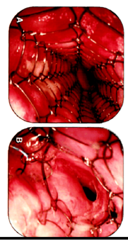
Nitinol (**Ni**ckel-**Ti**tanium **N**aval **O**rdnance **L**aboratory)

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





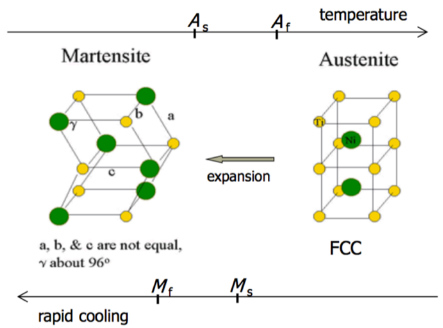


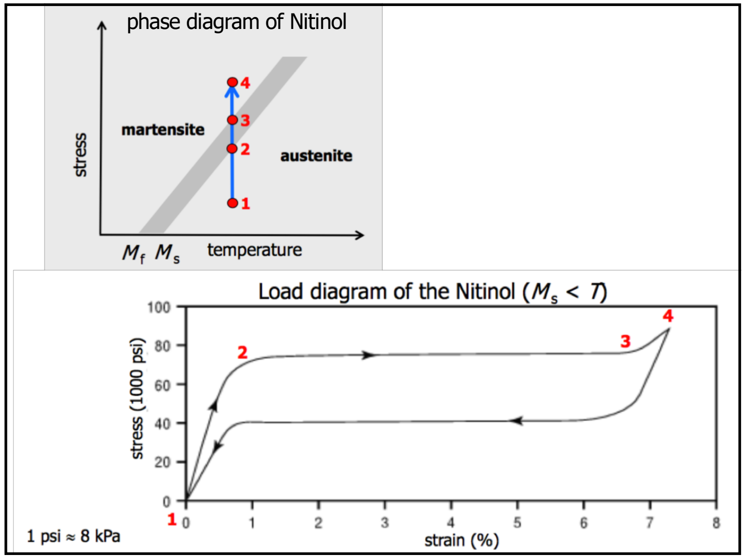


elastic (reversible) response to an applied stress, caused by a phase transformation between the austenitic and martensitic phases of a crystal.

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)
strain (%)
1 psi ≈ 8 kPa