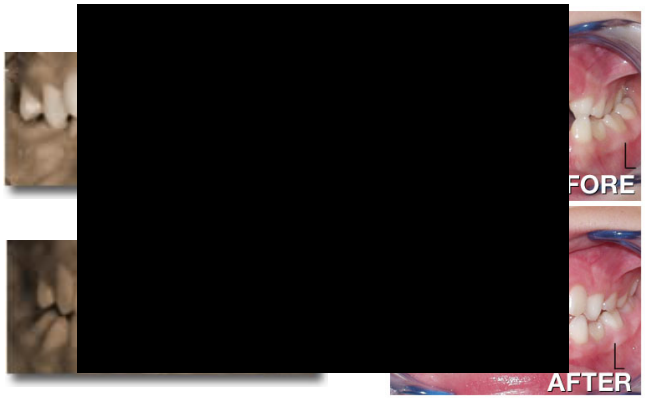
Physical bases of orthodontics

1

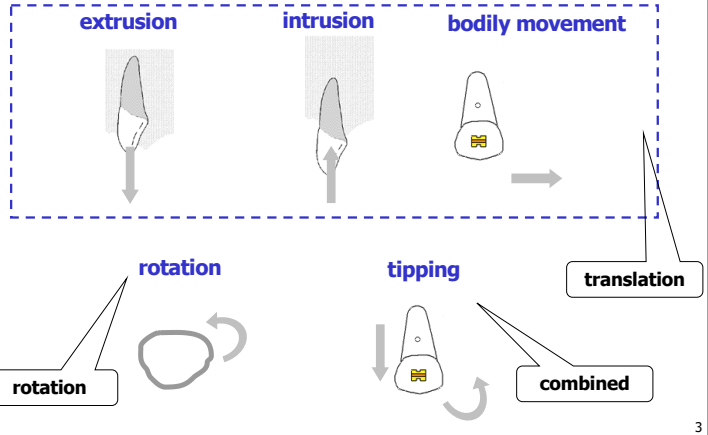
1



2

2

Tooth movement in orthodontics



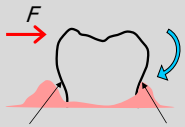
3

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

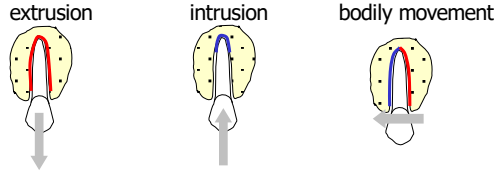
Mastication:
F = 100–800 N
$t \leq 1$ s
If it would be constant,
⇓
t = 3–5 s: pain
≈ hours: damage
7–14 days: loosening

4

4

Mechanisms of tooth movements

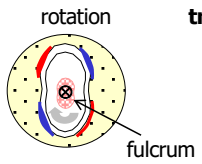
translation



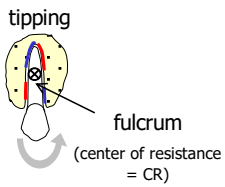
bone formation

bone decay

rotation



translation + rotation

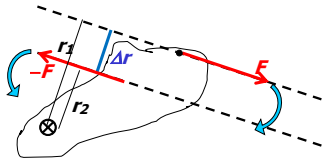


5

5

Force couple

Couple: a pair of forces, equal in magnitude, oppositely directed, and displaced by perpendicular distance.



Resultant force:

$$F_r = F + (-F) = 0$$

Resultant torque:

$$\tau_r = \tau_1 + \tau_2$$
$$\tau_r = (F \cdot r_1) + (-F \cdot r_2)$$
$$\tau_r = F \cdot (r_1 - r_2) = F \cdot \Delta r$$

„couple = torque"

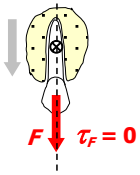
Any set of forces on a body can be replaced by a single force and a single couple.

6

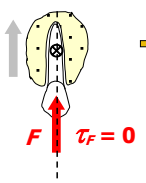
6

Forces required for tooth movements

extrusion:



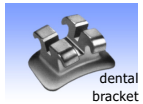
intrusion:

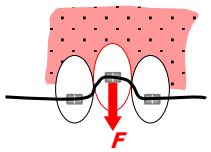


single force without torque

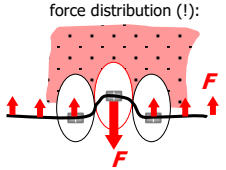
⇒ translation without rotation

Example:





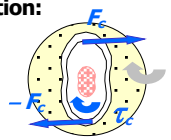
force distribution (!):



7

7

Rotation:



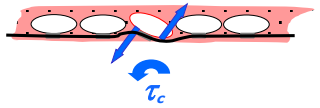
Couple results in tourqe only without net force

⇒ rotation without translation

$\Sigma F = 0$

couple = c

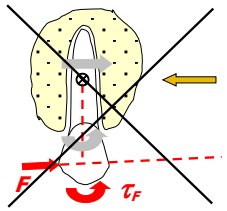
example:



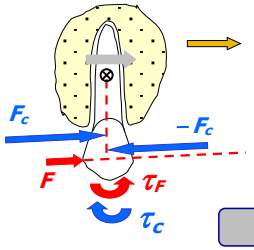
8

8

Bodily movement:



By using only one force torque woud be generated too.



force + couple

$\Rightarrow$ translation without rotation

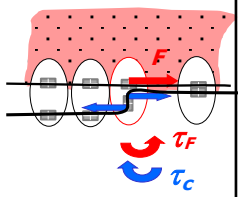
$\sum F = F$

$\sum M = 0$

translation only

$\tau_c = \tau_F$ $(\tau_c / \tau_F = 1)$

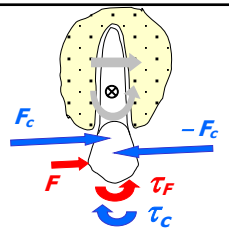
Example:



9

9

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

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

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

10

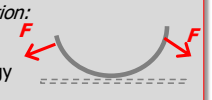
10

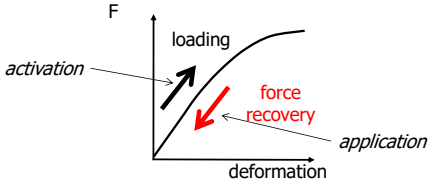
Dental brace

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)



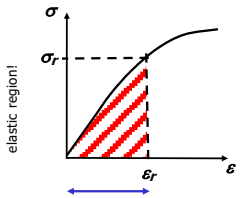


11

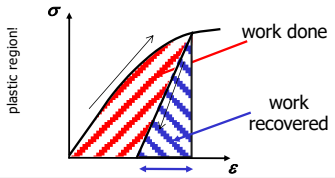
11

Mechanical properties of braclets

- properties: stiffness, elastic strain recovery, resilience



work done = work recovered, assuming no friction!!



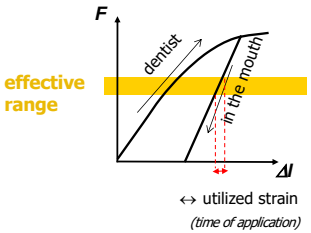
Example:
- polymers
- steel
- Co-Cr alloys
- Ti alloys

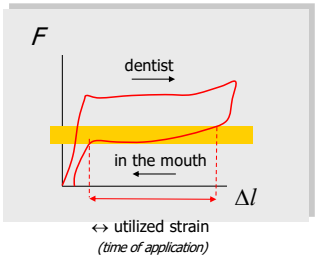
12

12

Restoring force

- magnitude?
- time course?





13

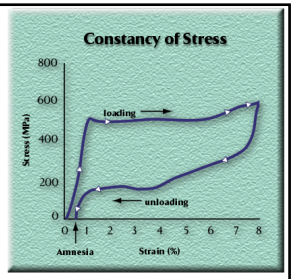
13

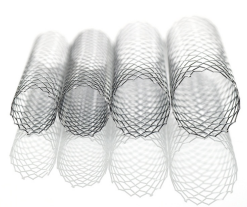
Superelastic materilas

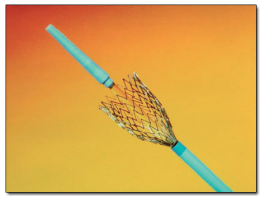
Ni+Ti Cu+Al+Zn Cu+Al+Ni

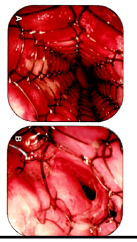
Nitinol (**Ni**ckel-**Ti**tanium **N**aval **O**rdnance **L**aboratory)

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









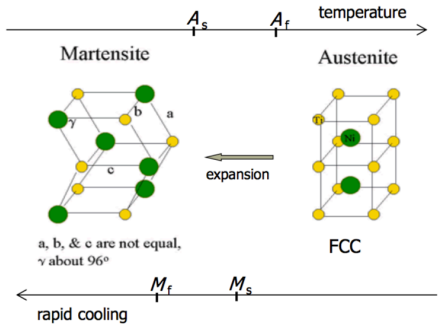
14

14

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

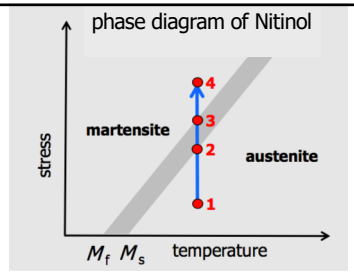
M_s-martensite start temperature
M_f-martensite finish temperature
(totally martensite)

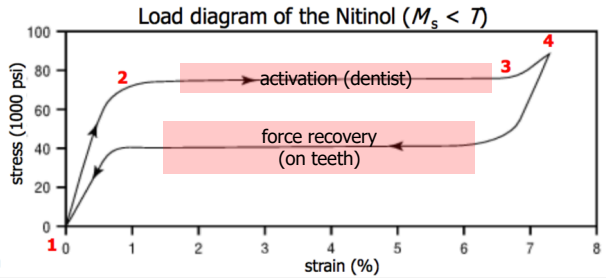
A_s- austenite start temperature
A_f- austenite finish temperature
(totally austenite)



15

15





1 psi ≈ 8 kPa

16