The fundamental biomechanics of oral implants

Dr. Szűcs Attila

Physical elements I.

- **Mechanics**

  solving of technical problems by physical laws

  »» investigation of prosthesis and the connection to abutments

- ***Biomechanics***

  In vivo investigation of mechanical processes according to biological reactions

  »» Dynamic examination of the bone-implant connection

Physical elements II.

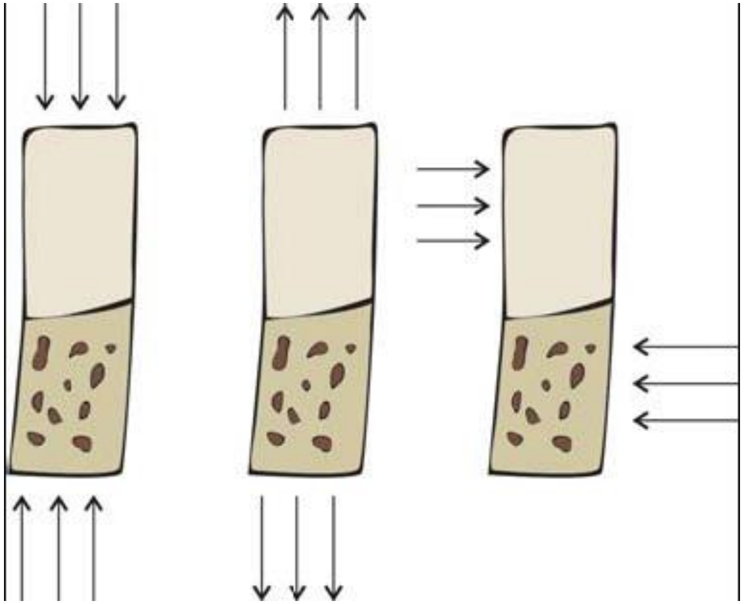
- **Force**

  -The physical strength of mechanical interactions of objects

  -vector (scale, direction, fulcrum)

  [Newton (N) ≈ 0,1 kilopond (kp)]

  - **Compressive force**
  - **Tensile force**
  - **Shearing force**



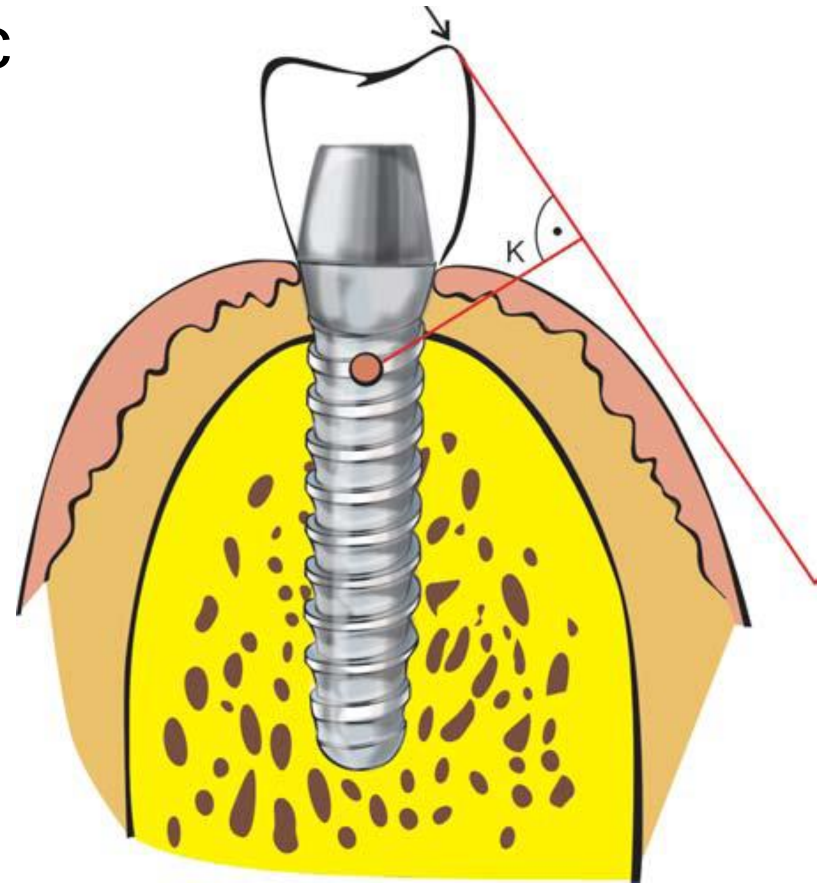
Physical elements III.

- **Bending moment**

-the scale of bending capac
of forces (M=F·k)

-direction ↶ ↷

[Nm; 1 Nm = 100 Ncm]



Physical elements IV.

- **Mechanical stress** $$P = \frac{F}{A}$$

  [Pascal,1Pa=1N/m^2**=**10^{-6}N/mm^2**;** 1N/mm^2=10^6 N/m^2=1MPa]

- **Deformation**

  -depends on the mechanical properties of the substance

  -**elastic modulus** (e.g.. tensile, shearing)

  -Young-modulus

  tensile elastic modulus – the required stress for relative unit stretching [Pa]

- **Strength**

  -the maximal stress-wear of the object without destroying it

Physical elements V.

- **Isotropic substances –** the physical properties of a substance (e.g. elastic modulus, refraction of light) are equal with the different directions
- **Anisotropic substances**

Biomechanical investigative methods in clinical practice I.

- **Measuring of biting forces**

  -dynamometer between occlusal units

  -scale +, direction ?, division of force ? dynamic measurments ?,

  -standardisation, reproducibility ?

- **Measurment of bending moment**

  -insertion torque of implants +;

  by torque wrench >> primary stability

  -prostheses, implants ?

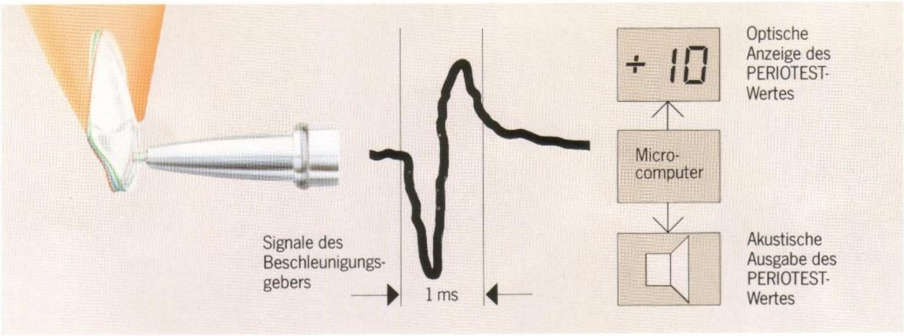
  conjectural calculations only

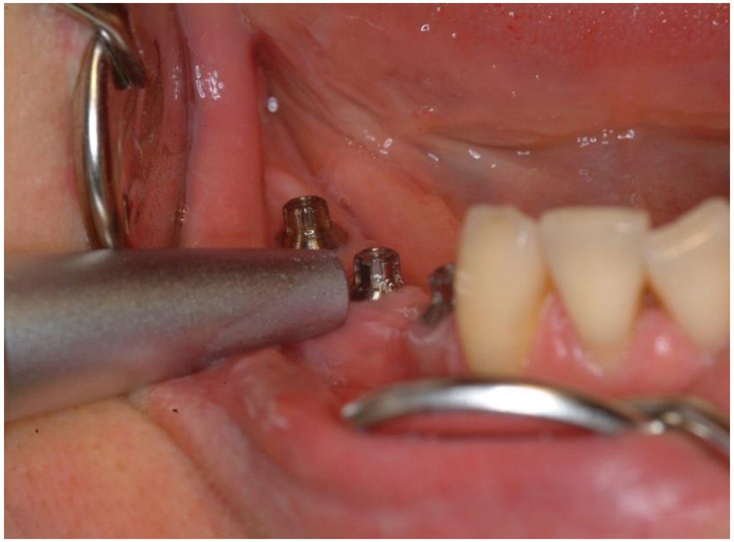
Biomechanical investigative methods in clinical practice II.

- **Periotest®** method

  - **stability test** for teeth and implants

  - a small metal rod knocks against the implant, a **value** is calculated based on the reflection



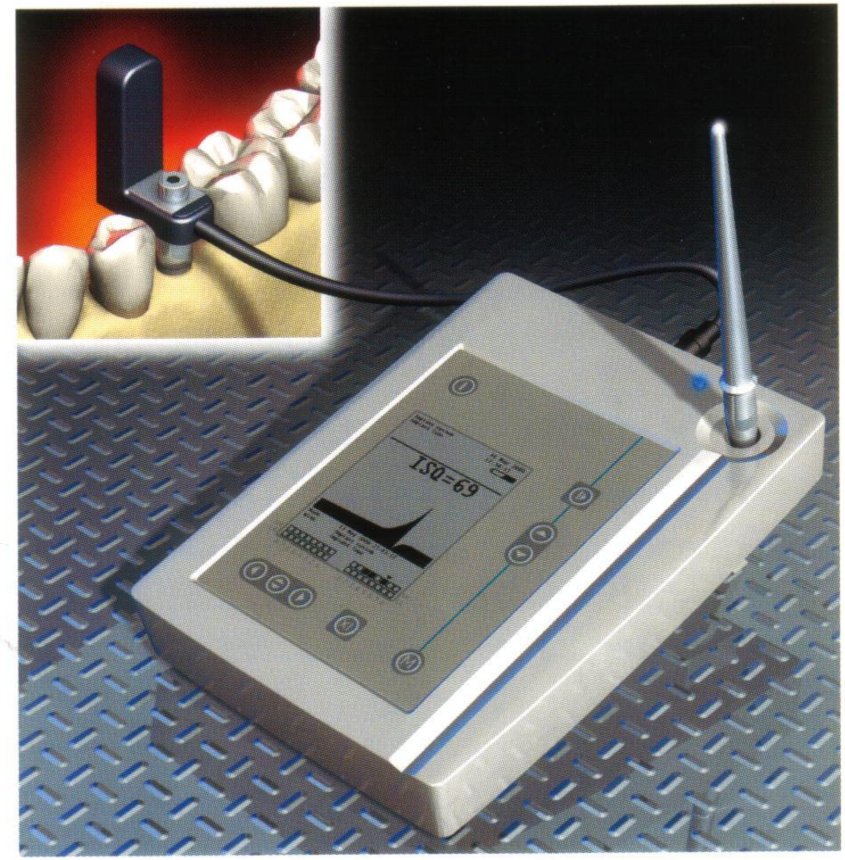


Biomechanical investigative methods in clinical practice III.

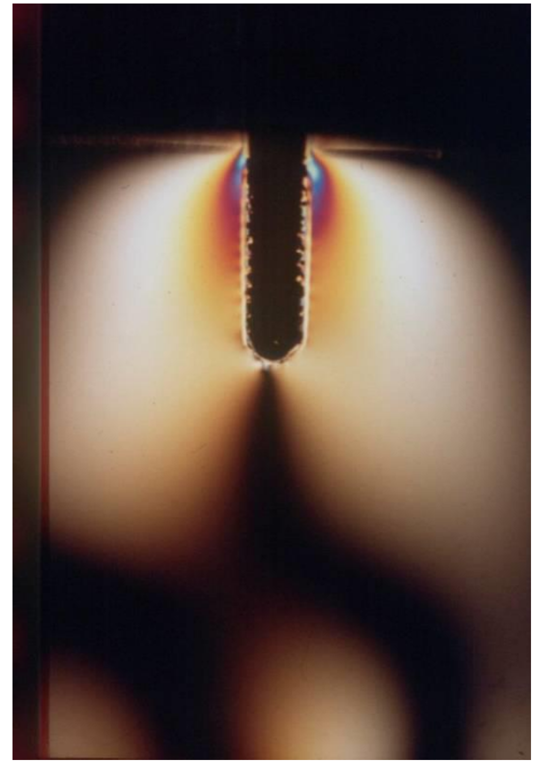
Resonance Frequency Analysis

(RFA - **Osstell®** instrument)

-vibration is transmitted to the implant by a special transducer, the stability is computed based on the interference analysis



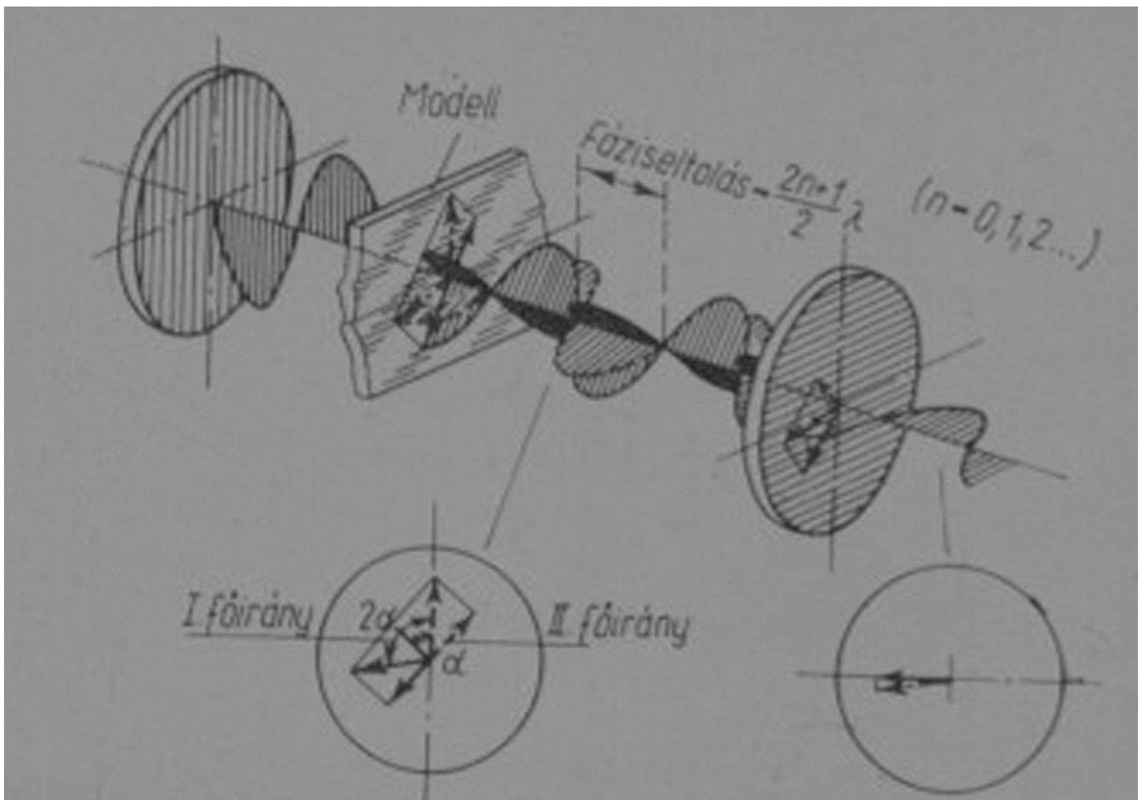
Biomechanical investigative methods, model simulations I.



Photoelastic stress analysis

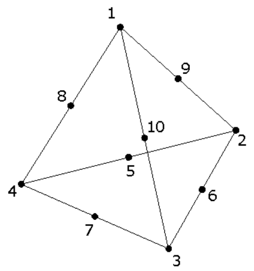
-Direct modelling necessary

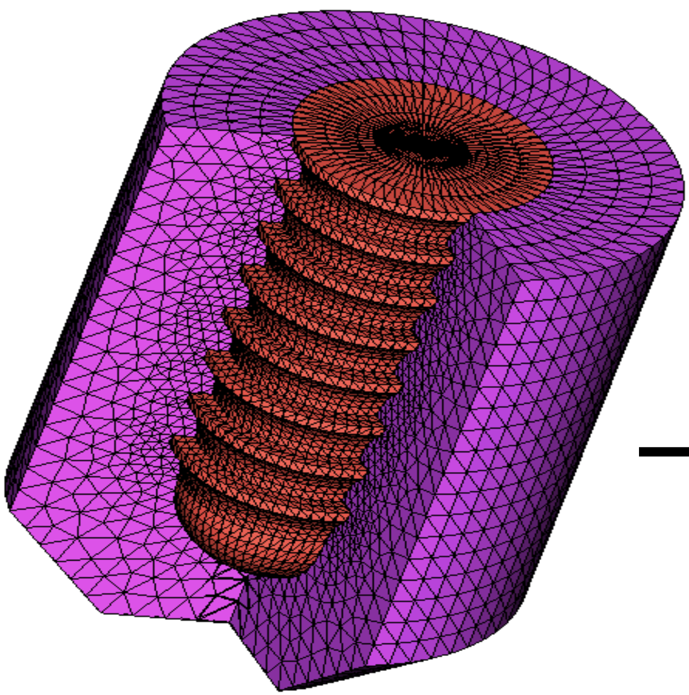
-results in relative units

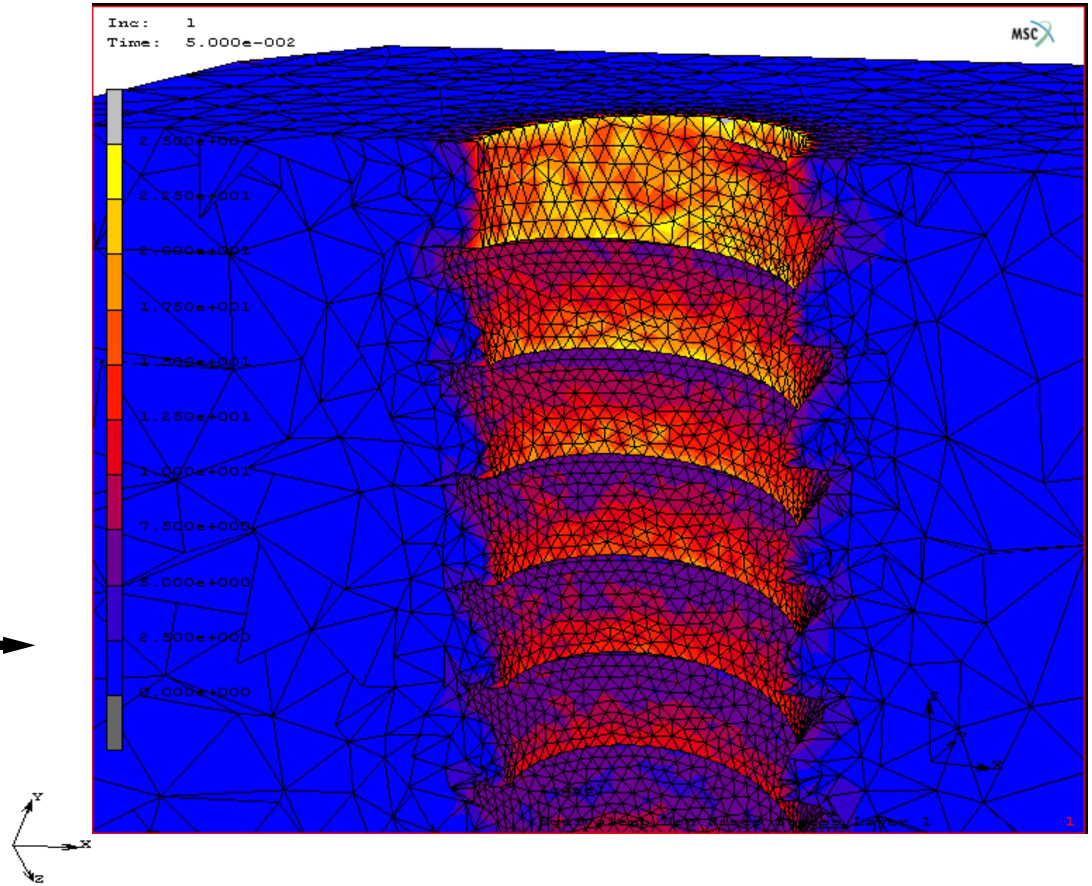


Biomechanical investigative methods, model simulations II.

Finite element analysis – a computer method – high accuracy – is dependant on input data (uncertainty is possible)







The biomechanical role of the implant: ***TRANSMISSION*** of ***FORCES*** *between the restoration and the jaw*

- Mechanical solidity
- Forces transmitted to bone within physiological range
  - Prevention of inactivity and bone atrophy
  - Prevention of arising peak mechanical stresses, overloading or microdamaging of bone
  - Importance of compressive and tensile stresses
  - Minimized shearing stresses

Transmission of forces I.

Natural teeth

periodontal tissues-viscoelastic biomechanical behaviour

(Sharpey fibres + fluids in periodontal space)

-Physiological mobility of teeth (axially ≈10-50 μm, laterally ≈500 μm)

- forces are prolonged in time

Enosseal implants

- **Fibroosseointegration** –fibrous capsule, transmission the compressive forces, - **undesirable**
- **Osseointegration –** bone-healing, direct bone-implant connection – simpler than periodontium

  - compressive, tensile and shearing stressed are directly transmitted

Transmission of forces II.

- **Optimal case:**

  implants – neighbouring tissues have an equal elastic modulus

- **Reality:**

  Bone and implant – different elastic modulus, forces >> **stresses**

Transmission of forces III.

Stresses correlate with forces and the inequality of different elastic modules

Important Young-modules in implantology:

Cortical bone	~ 15-30 GPa	(~ 15-30 $\cdot 10^3$ N/mm^2)
Titanium (Ti-6Al-4V)	~ 120 GPa	(~ 120 $\cdot$ 10^3 N/mm^2)
Co-Cr alloy	~ 222 GPa	(~ 225 $\cdot 10^3$ N/mm^2)
Aluminium-oxide	~ 400 GPa	(~ 350 $\cdot 10^3$ N/mm^2)
Polyethylene	~0.6-1.8 GPa	(~ 0.6-1.8$\cdot 10^3$ N/mm^2)

Measurements of masticatory forces

Molars-premolars (axial comp.)	200-880 N
Full dentures	77-196 N
Max. value on implants	412 N
Horizontal component	20 N
Frequency of chewing	60-80/perc
Duration of antagonist occl.	0,23-0,3 s

The shape of implants

Blade, cylindrical, conical, tapered, or screw type implants?

- Maximal utilisation of available bone
- Primary stability
- Maximal bone-implant contact surface (surgical technique)
- Optimal load distribution according to implant shape

Extended (blade) implants

- Effective bone utilisation
- Doubtful direct bone-implant contact surface
- Peak stresses in the neck portion of the implant

Axisymmetric implants

Cylindrical implants

Shear stresses

Screw type implants

Compressive and tensile stresses

Cylindrical implants

- Straight-cylindrical shape –

  neck region- higher stresses

  other parts of surface – equal stresses

- Stepped shape –

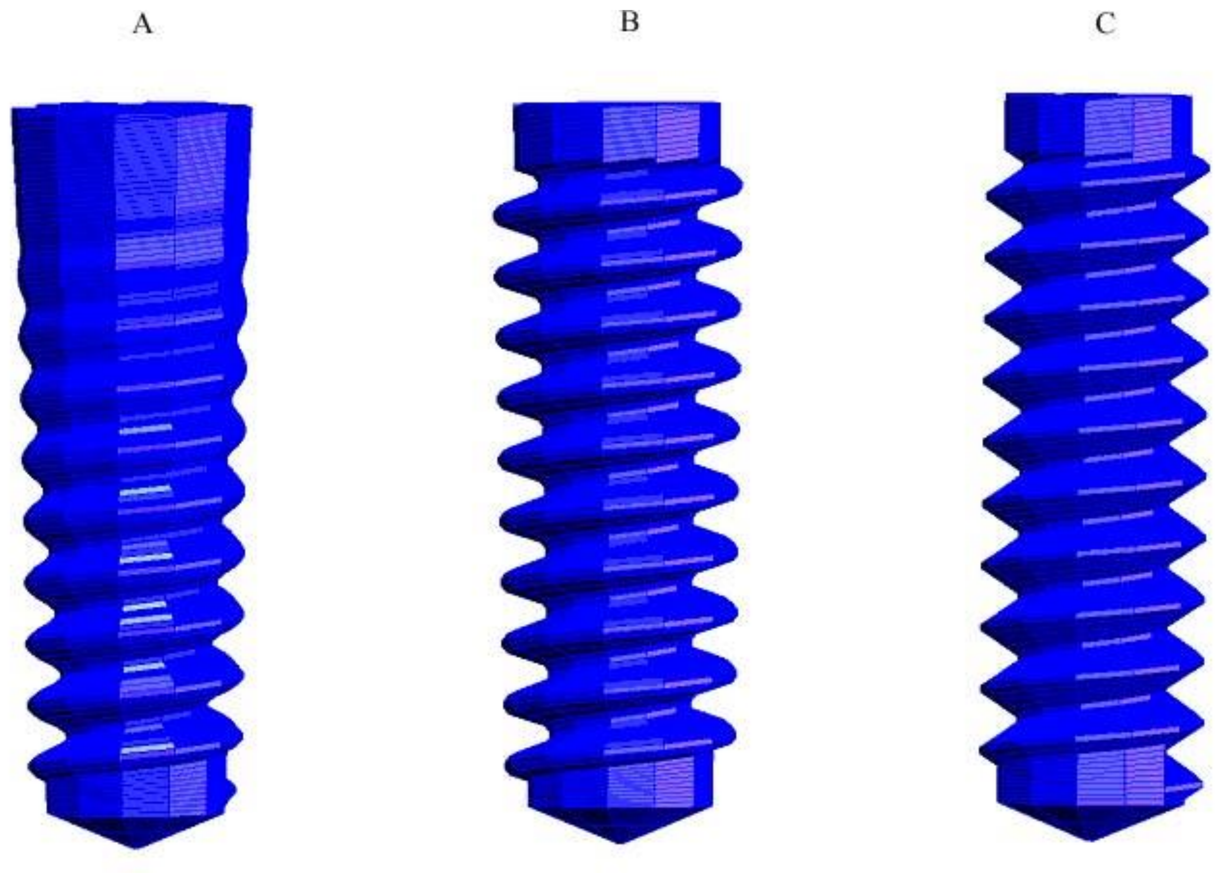
  neck region - moderate stresses ,

  other part of surface -steps – peak stresses

  Lateral loading – elevated crestal stresses

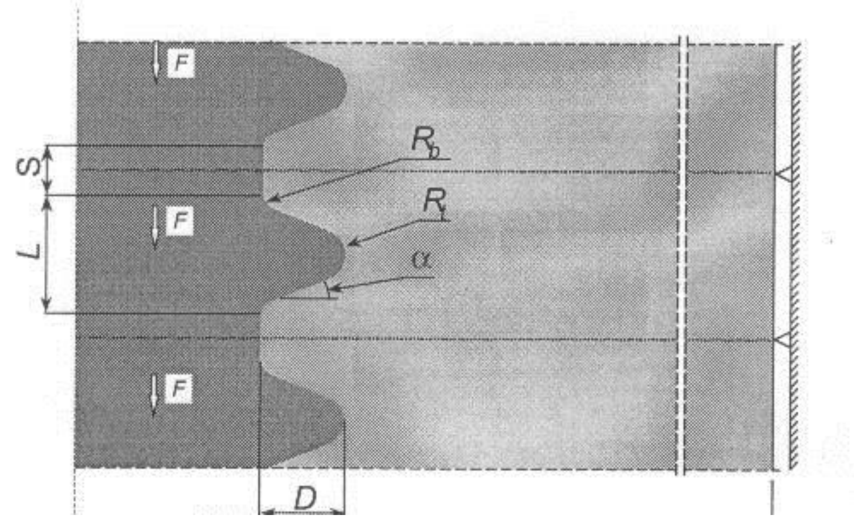
Screw type implants

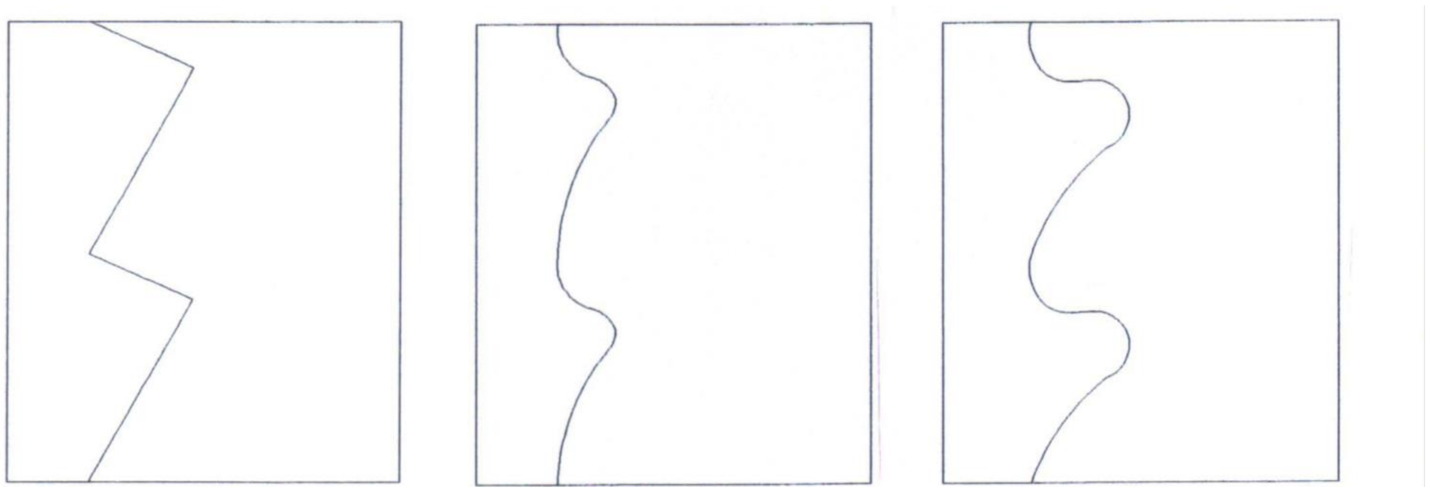
- The shape of screw body



Screw type implants

- Geometry of thread profile





Load distribution of screw type implants *(FEA*)

- Stresses are more equal compared to cylindrical implants
- High stresses in the neck region
- ***Direction of loading*** is determined
- Low ***rising of threads*** is favourable, especially in compact bone
- High ***profile depth*** in trabecular bone
- ***Rounded quadrangular thread profile*** is favourable, sharp profiles are unfavourable
- Studies have no final results

Loading capacity of periimplant bone

- ***function – mechanical stresses >> remodelling***

- ***Physiological range ?* –** bone quality, density, individual differences, anisotropy …

  compact bone ≈100-150 MPa (100-150 N/mm^2), trabecular bone ≈25-35 MPa (25-35 N/mm^2)

  mean stresses around implants ≈ 2-3 N/mm^2 (≈400 N/200 mm^2)

  peak stresses – microdamages, resorption

  too low stresses- atrophy - involution

BIOMECHANICAL PRINCIPLES OF IMPLANT SUPPORTED RESTORATIONS

- **optimal distribution of load**
- **tensionless (passive) fit**
- **decrease of horizontal forces**
- **decrease of moment of rotation**
- **stress breaking, if possible**

Optimal load distribution I.

To reach the maximal implant surface

-Placing more implants with larger surface

- Equal number of implants as teeth to be replaced (in molar region 2 implants/tooth)

The extension of implant surface I.

Axisymmetric implants: A~r^2,l; $P = \frac{\mathrm{F}}{\mathrm{A}}$

- **Increasing the radius of the implant (r)**

  -stresses are decreased effectivly

  -optimal implant diameter depending the bone dimension

- **Increasing the length of the implant (l)**

  -decreasing of stress is limited (the highest stresses are located in the neck region of implants)

The extension of implant surface II.

Axisymmetric implants : A~r², l; $P = \frac{F}{A}$

- **macromorphology:**

  -threads, holes, hollows (>100-200 μm –

  in growing the bone)

  -hollow cylinder implants, the inner superficies
- **micromorphology:**

  surface roughness, surface coating

Optimal load distribution II.

- splinting of implants
- balanced articulation
- avoiding the rigid connection of implants and remaining teeth

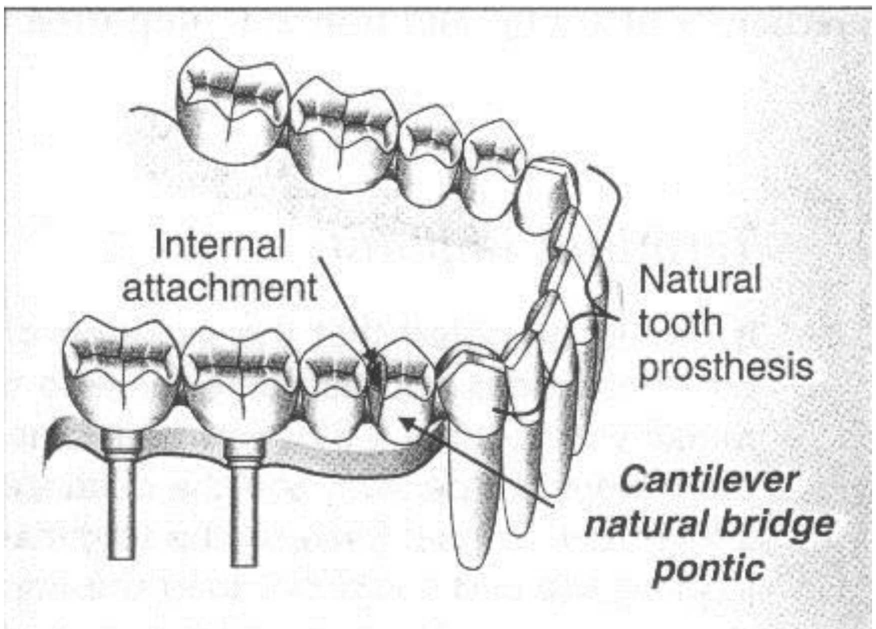
Optimal load distribution III.

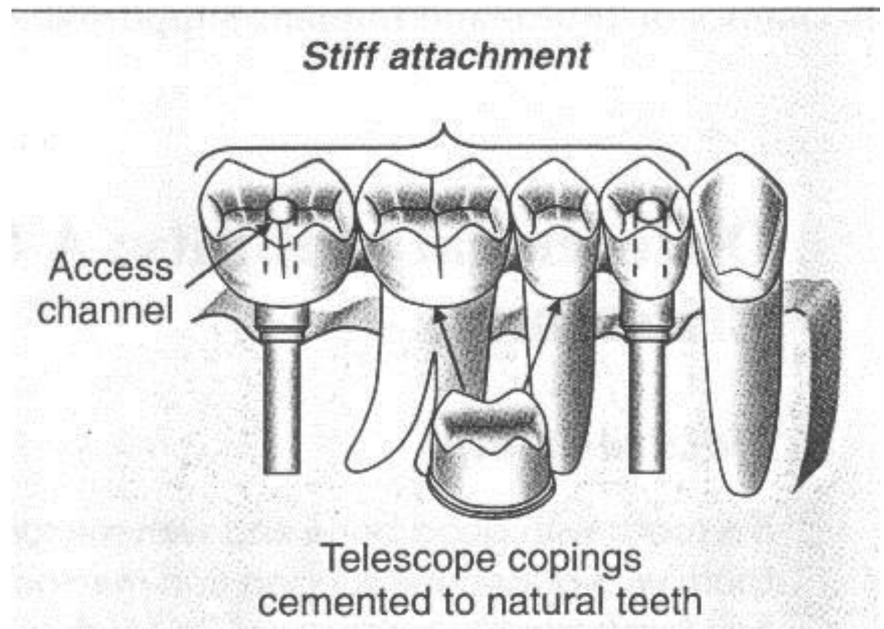
Required from a biomechanical point of view,

- Prostheses supported on implants only, if connecting implants and natural teeth using attachment elements providing the possibility of micromovements between the abutments is necessary

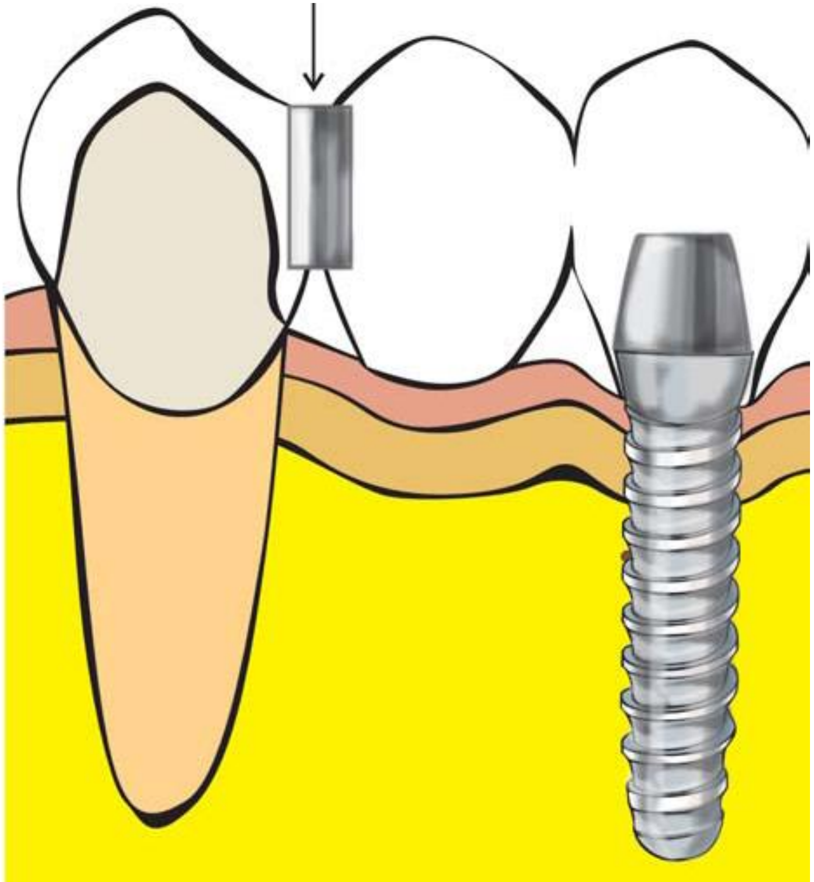
  (e.g. screw joint retention on implants, telescope copings cemented to natural teeth, or internal pin attachment in the prostheses with possibility of axial movements)

Optimal load distribution IV.

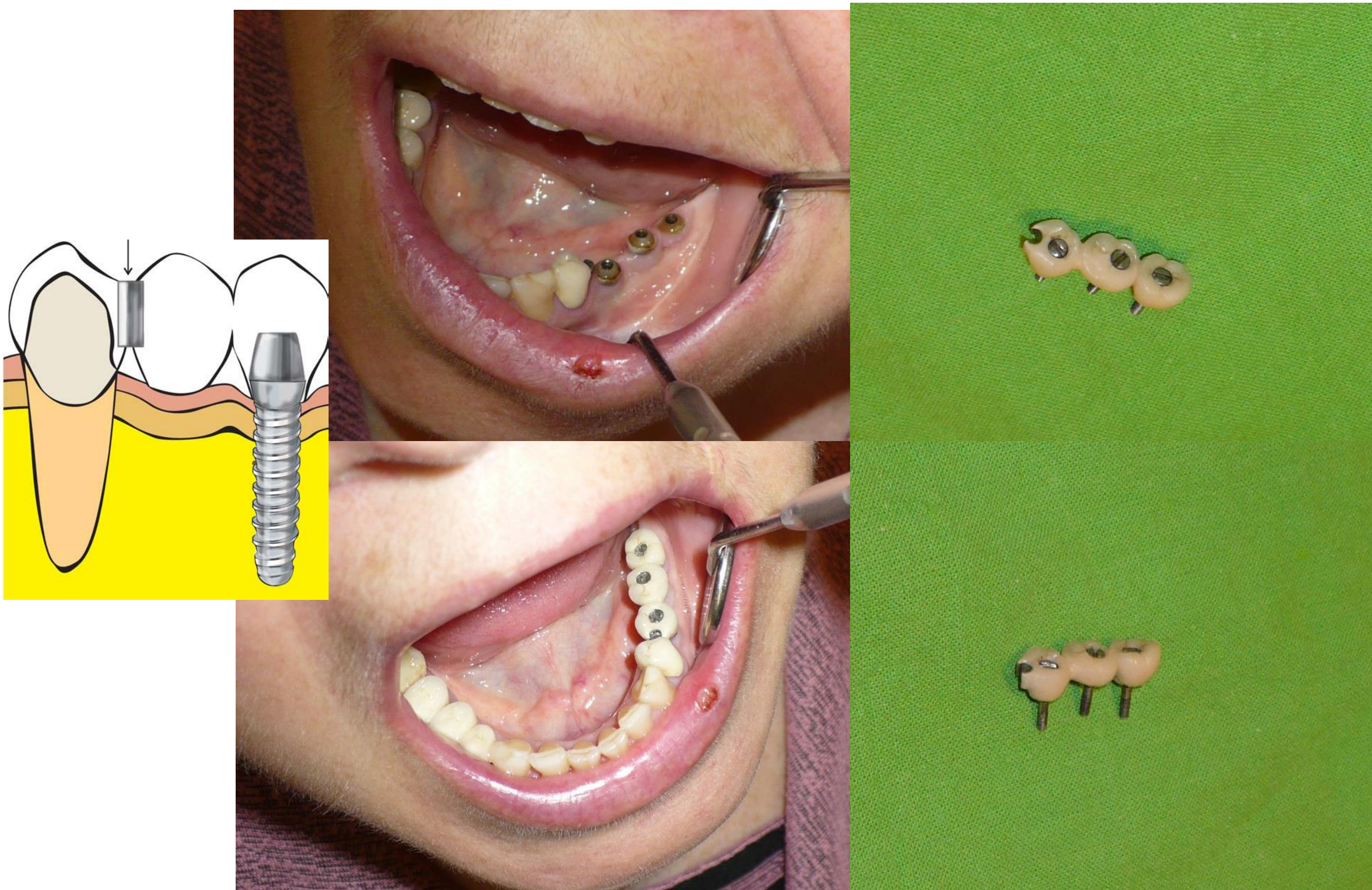




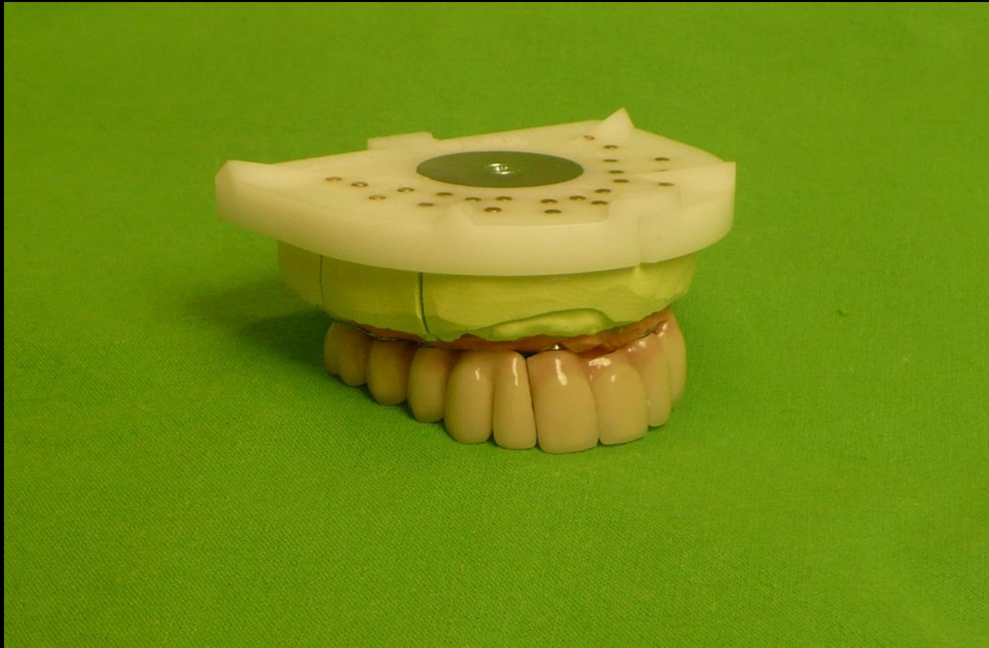
Optimal load distribution V.



Optimal load distribution V.





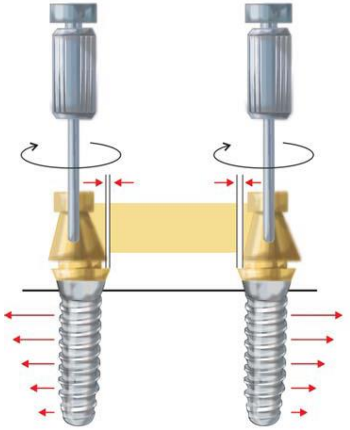



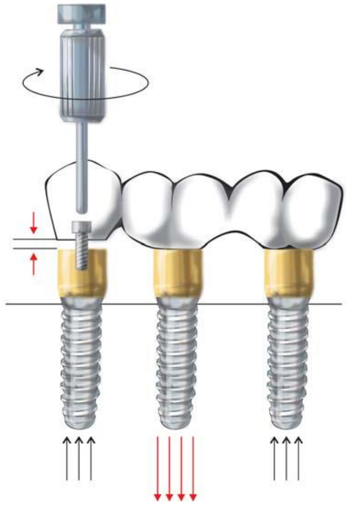

Tensionless fit

Imprecise fit – permanent stresses after insertion of fixed prostheses („preload”)

Danger: dislocation of abutments, unfavourable bone remodelling, injury of prostheses

- Cemented prostheses- strongly divergent prosthetic heads + technological mistakes
- Screw joint – technological mistakes, misfit, space at abutments, tilting of prostheses, - stress arising at screw driving





Decreasing bending moment I.

Bending moment >> elevated stresses around the implant
-(Would be) necessary to know **forces** + **center of rotation for** calculation

Center of rotation (?)
- Close to the border of the neck and middle third of the implant, or
- Other part of the implant or
- Out of the implant, somewhere in the bone…

The site of the center of rotation is determined by
- Jaw bone anatomy, quality, the ratio of compact and trabecular bone &
- type of prosteses

Forces
- Scale is measurable, the division on and abutment and directions are presumable only

>> Doubtfulness

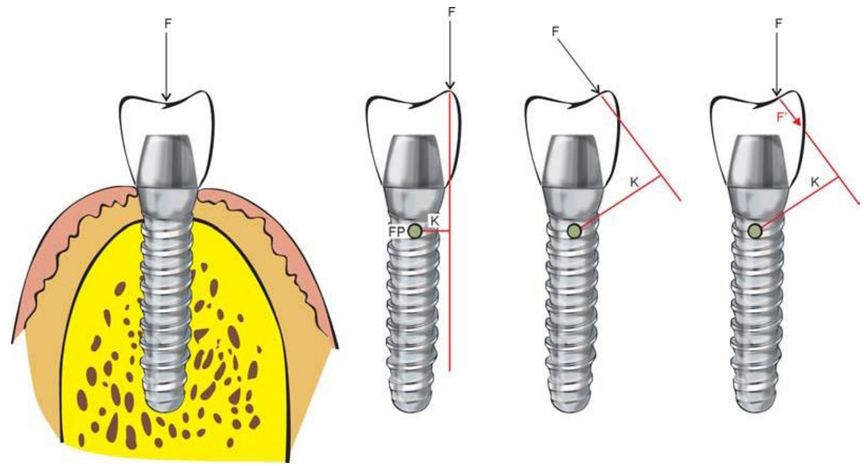
Decreasing bending moment II.

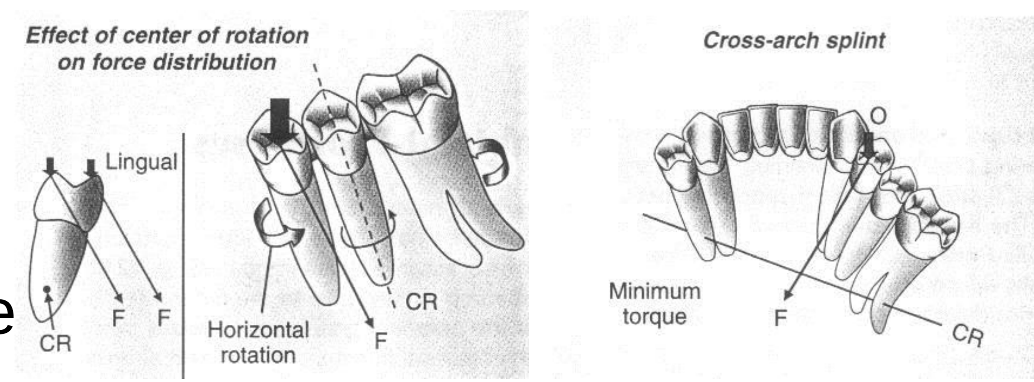
- A rough estimate: decrease of lateral forces>> Decrease of bending moment
- ***Bending moment arises* in axial *loading cases,***

  - inclinated cusp surfaces transform the load to lateral forces

  - the force creates torque around other abutments

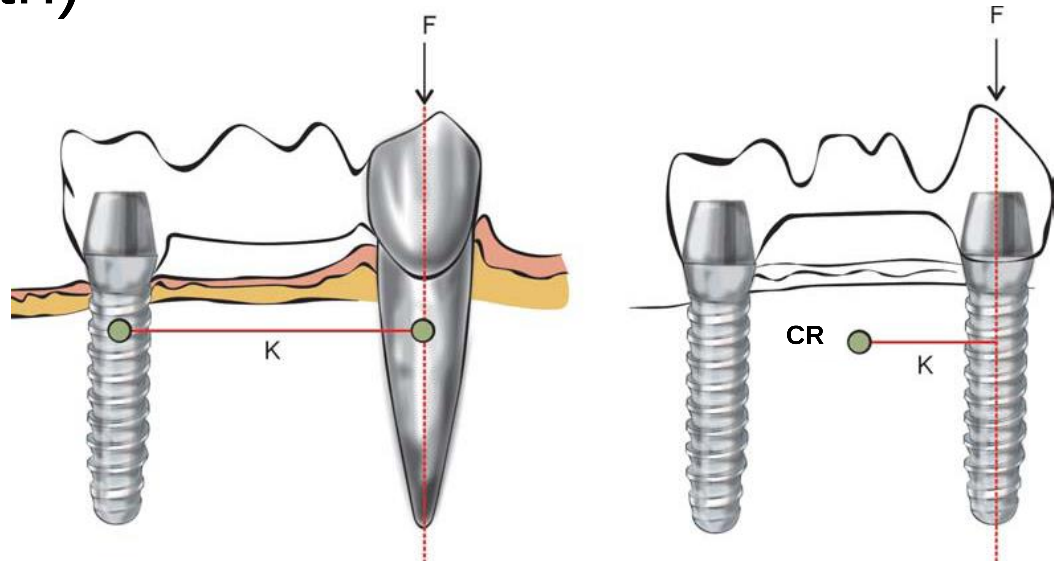
  - the prosthesis follows the bended dental arch





Decreasing bending moment II.

- Upon the rigid splinting of various abutments (implants and natural teeth) torque arises



Decreasing bending moment III.

Possibilities to decrease horizontal forces and bending moment:

- creating canine guidance when replacing lateral teeth,
- flat cusps, reducing the width of the masticatory surface,
- reducing the height of the suprastructure,
- dental support (with the help of special precision mechanical connectors, which allow some movement),
- rigid splinting (of implants),
- cantilever constructions only in exceptional cases.

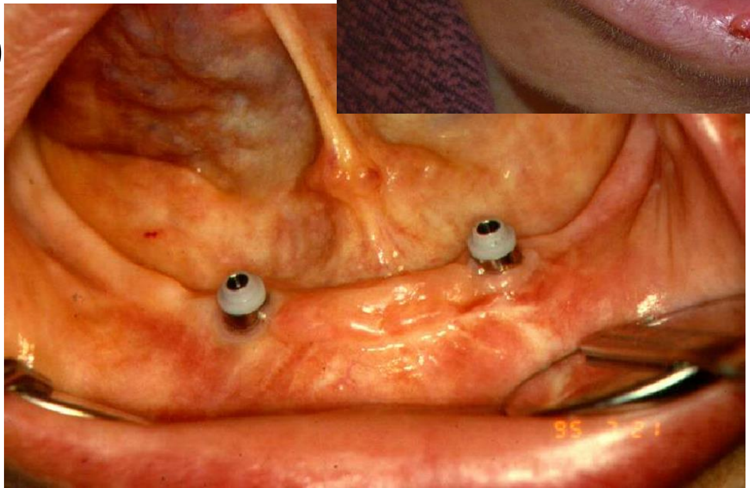
Stress breaking effect

Replacing the role of the periodontium:
An elastic element between the implant and the suprastructure
(mainly between the prosthetic abutment and the implant)

- to prolong in time sudden, shock-like forces
- to biomechanically harmonize osseointegrated implants and natural teeth

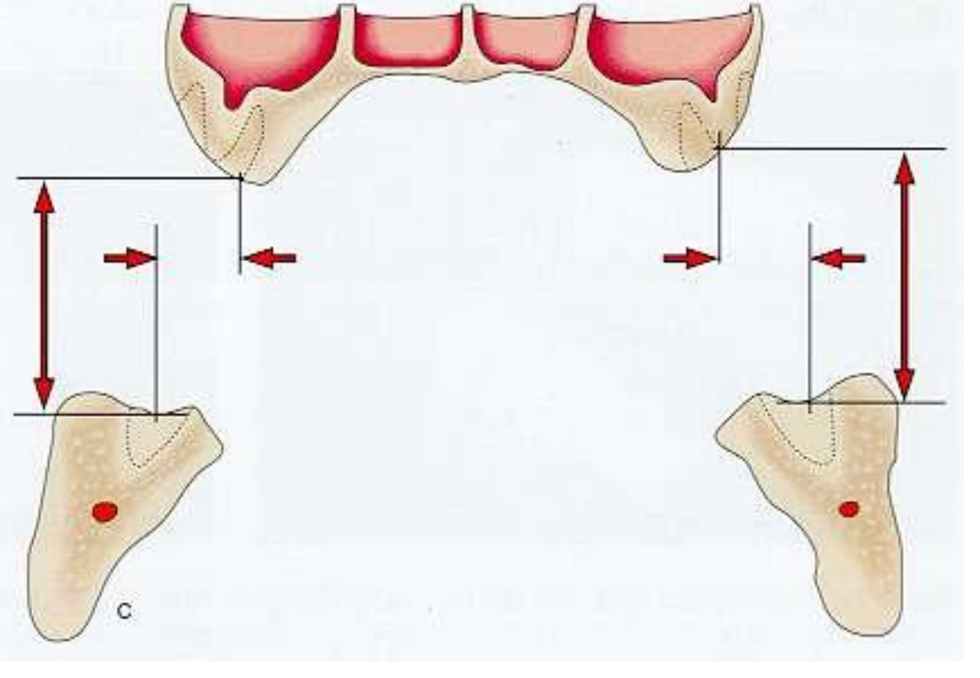
Plastics:
fatigue, plaque accumulation,
a single elasticity coefficient

-IMZ ®, Flexiroot ®, SIS® impl.
-restorations with a plastic
(or composite, e.g. Adoro-Ivoclar)
masticatory surface –
-prosthetic points??



Reactive biomechanics

- Interalveolar space grows as a consequence of the atrophy of the alveolar processes following the loss of teeth and due to the altered morphology of the jaws the implants can only be placed in a biomechanically unfavourable position. Due to these conditions implants are subjected to a high bending moment when the restoration is in place.



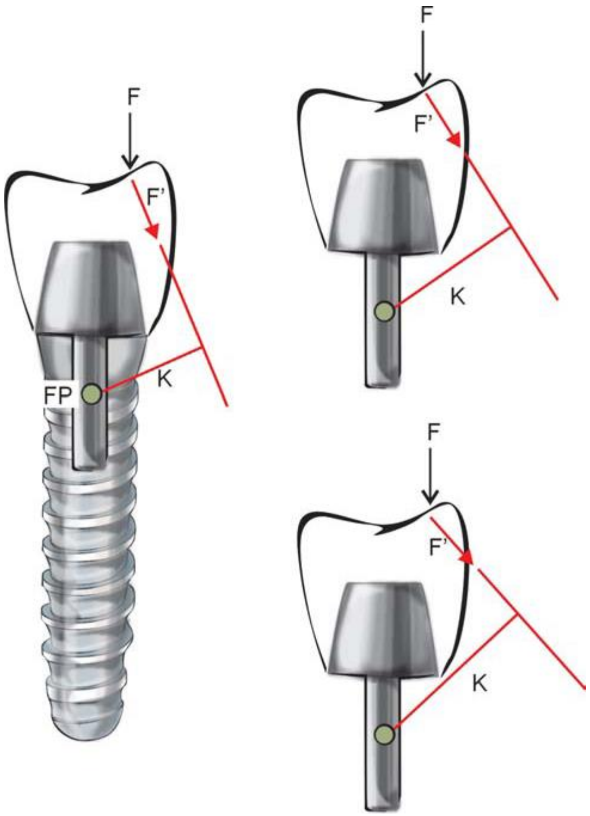
Therapeutic biomechanics

- The bending moment effecting final restorations can be decreased by a biomechanical thinking upon implant planning, by determining the position and direction of the implants and by a deliberate planning of articulation. This planning concept is so-called ‘**therapeutic biomechanics**’.

Therapeutic biomechanics II.

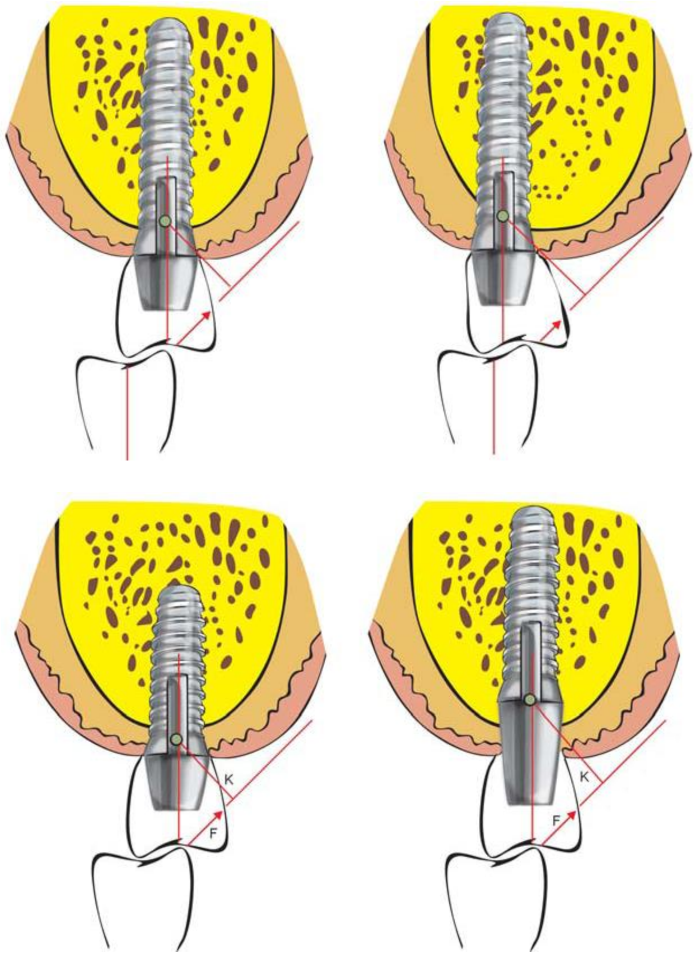
- Forces parallel with the implant axis evoke lateral forces on the restoration and thus create bending moment.

  Increasing the inclination of cusps by 10º will increase torque by about 30 %.



Therapeutic biomechanics III.

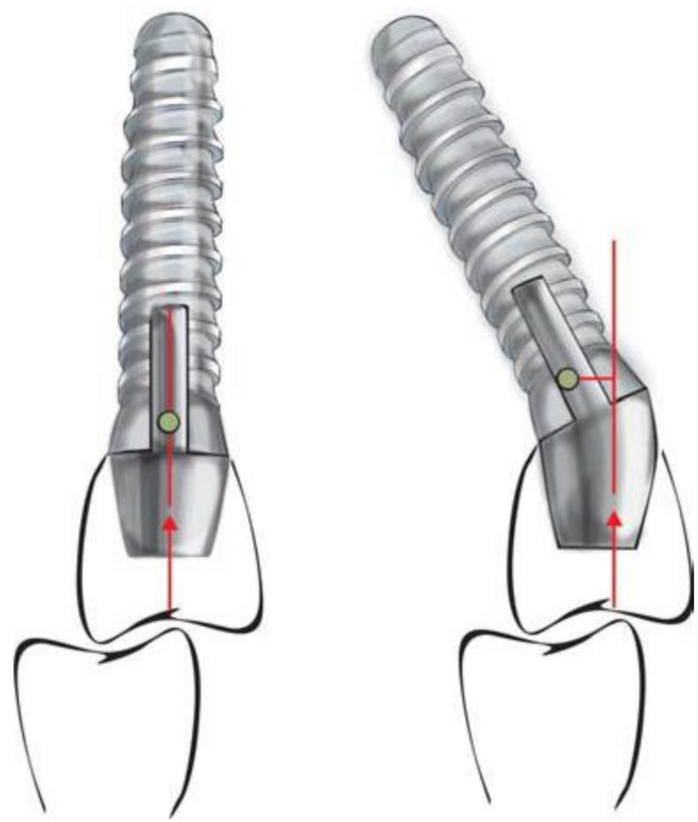
- Bending moment is also influenced by the vestibulo-oral and vertical placement of the implant.
- In the upper molar region moving the implant 1 mm buccaly results in an approximately 15% decrease in torque and positioning it 1mm apically (placing it deeper) increases torque by about 5%.



Therapeutic biomechanics IV.

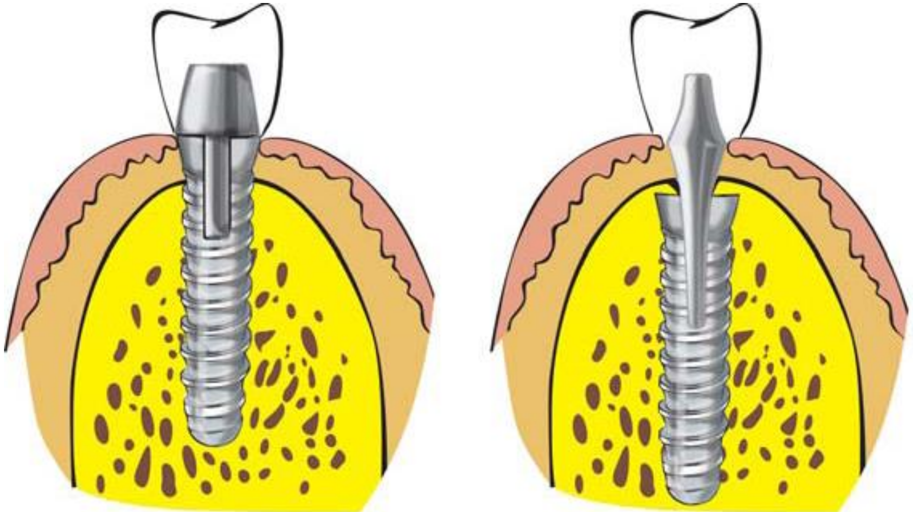
- The direction of the placement of the implant also influences bending moment: the higher the angle with the expected masticatory forces the higher the torque. A 10º difference in axis increases torque by about 5 %

- Theory - reality?



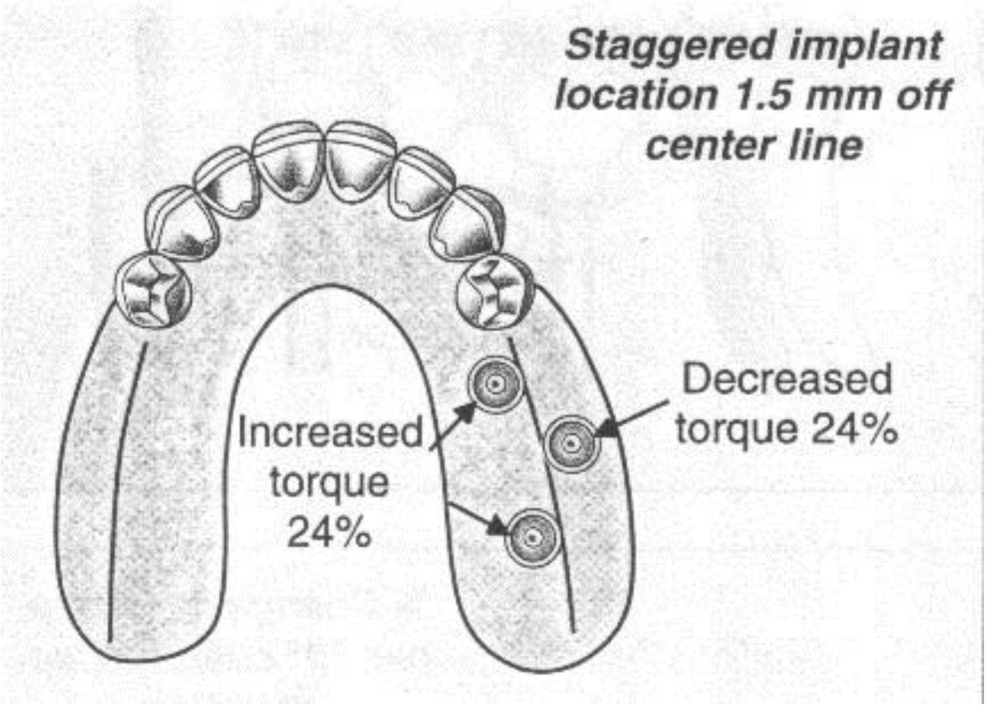
Platform switching

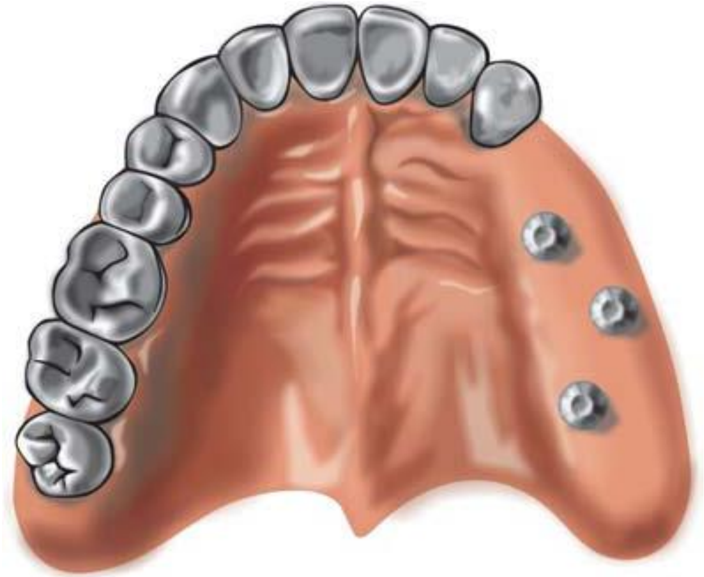
- In the case of two-phase implants placed in level with ridge or subcrestally, if the diameter of the prosthetic abutment is less than that of the implant, then the generally occurring marginal bone loss (the formation on biologic width) does not occur, or is less than ususal.



Implants placed in a tripodial configuration

- In the molar region implants can be placed in a staggered buccal and lingual offset to compensate the torque of lateral forces
- Different authors –different opinions concerning the biomechanical advantages of this method





Risk factors

- **Geometric:**

  number of implants<number of original root supports, unfavourable site &position of implants, excessive height of the restoration, prosthetic extension, implant connected to a natural tooth
- **Occlusal:**

  lateral contact in excursive jaw motions, parafunction
- **Bone/implant risk factors**

  lack of primary stability, disturbance of bony healing, narrow implants
- **Technical*:***

  lack of prosthetic fit, non-optimal screw joints or cementated prostheses

Wild geese above lake Tata