Biophysics – dentistry

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Surgery and Dentistry

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- Mechanics

  solving of technical problems by physical laws

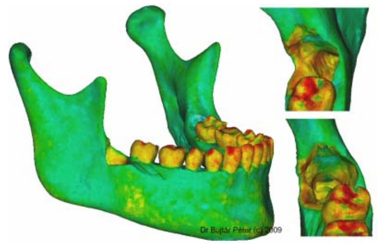
  »» investigation of prosthesis and the connection to abutments
- Biomechanics

  In vivo investigation of mechanical processes according to biological reactions

  »» Dynamic examination of the bone-implant connection

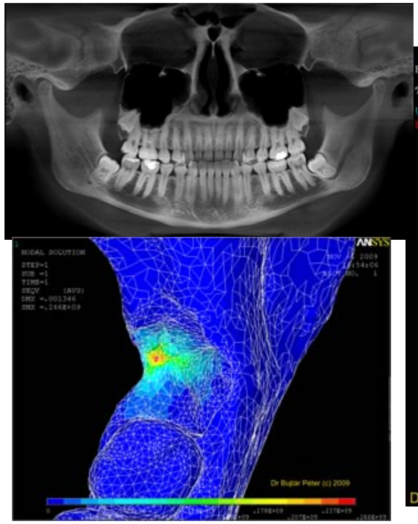
Biomechanical aspects in oral surgery

- Examination of jaws
  - Strength
    - Impacted teeth
    - Cleft palate
    - Predilected areas for jaw fracture
    - Therapy of jaw fractures - osteosynthesis plates
    - Planning of operations on the jaws
- Dental implants
  - Construction of new implant systems (shape, dimensions)
  - Mechanical stress transmission to the bone



3D Finite Element Analysis (FEA) model, based on CBCT scan

(female, 20 years old, impacted teeth 38, 48,18, 28)



Implantology

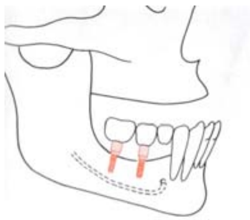
A compulsory subject in the 8th and 9th semesters

- Alloplastic artificial roots, implants can be placed into the jaw bones to support prosthetic devices to replace lost teeth.

- This is a complex biological and mechanical (biomechanical) problem. Implantology is nowadays one of the most dynamically developping branches of dentistry.

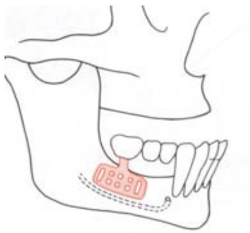
Various implant types

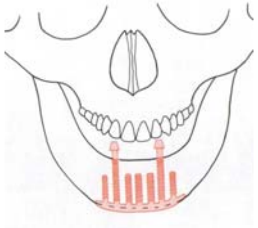
screw



Sub-periosteal

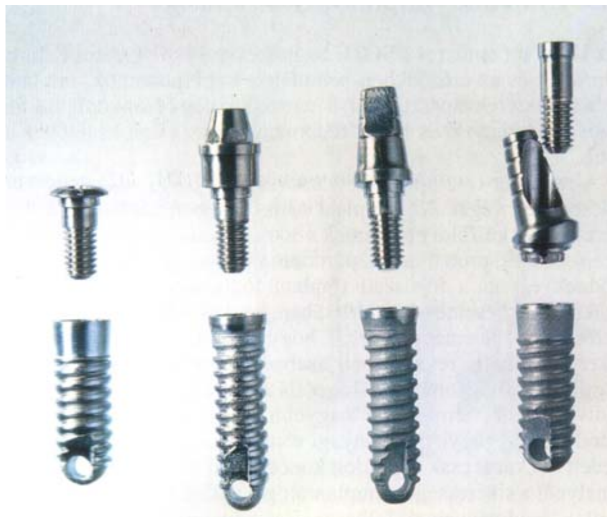
Blade-vent

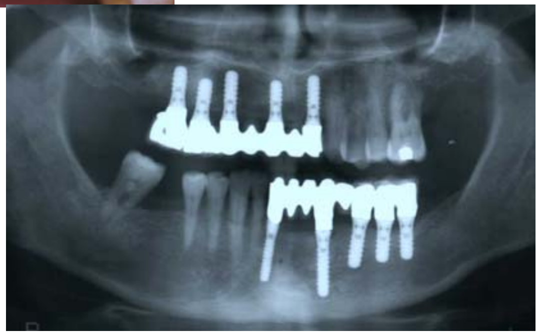




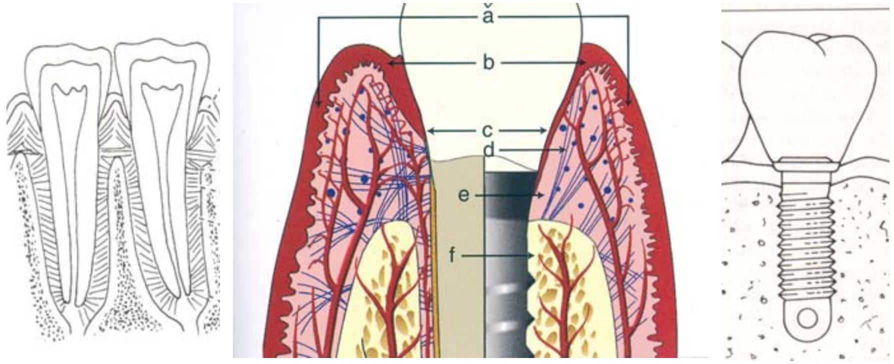
Trans-mandibular

Screw type implants





Anchoring of natural teeth and implants in the alveolar process



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 microdamages of bone
  - Importance of compressive and tensile stresses
  - Minimized shearing stresses

The implantological role of Biomechanics:

- Planning of implant systems
  - Task of bioengeneers
- Planning of implant prosthetics – treatment plan
  - Task of dentists
- Clinical examination of implants –
  - Task of dentists

Designing Implant Systems

- Ensuring proper mechanical stability of the implant and its parts
  - prevention of fractures, deformities
- Ensuring long term osseointegration and function of the implant
  - optimal force transmission

Co-operation between biomedical engineer and dentist

Planning of implant systems
Mechanical stresses in the bone around the implant

Model analysis

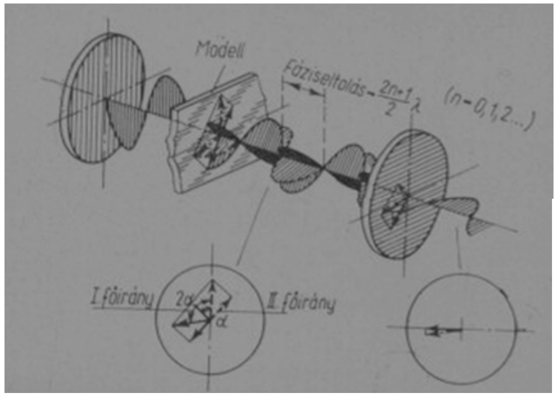
Photoelastic stress analysis — Finite element analysis

Biomechanical investigative methods, model simulations I.

Photoelastic stress analysis

-Direct modelling necessary

-result in relative units



Photoelastic stress analysis

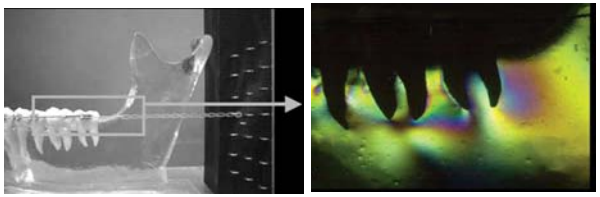
-Direct modelling necessary

-result in relative units

-Copying of individual anatomic conditions is difficult

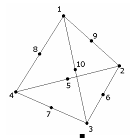
Gáspár, J, 2005

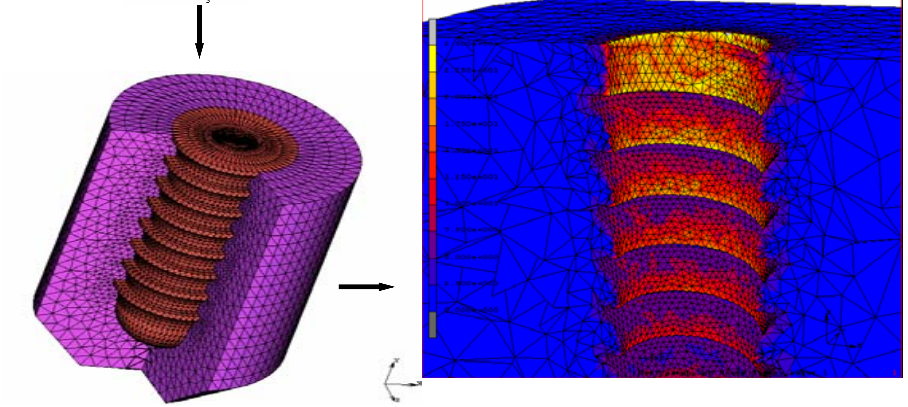
Nakamura, A, 2007



Finite element analysis

a computer based method – high accuracy, but dependent on input data (frequently uncertain)



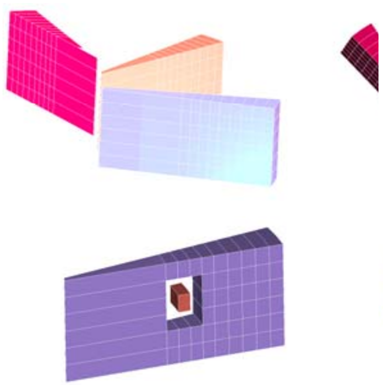


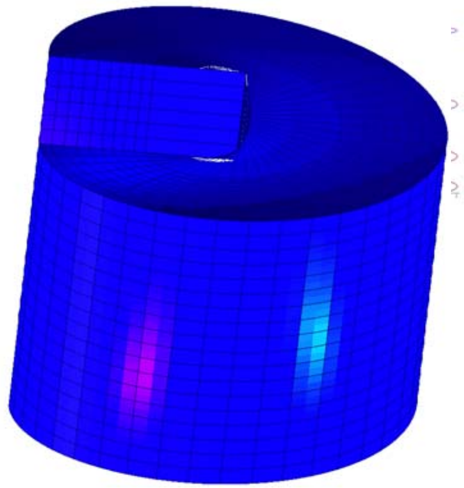
Finite Element Analysis (FEA)

- Computer based geometric modelling of the implant and surrounding bone (creating a 2D or 3D network)
- Choosing the point of support and force transmission
- Choosing mechanical material properties
- Defining loading parameters
- Running computer tests
- Evaluating the results and drawing conclusions

3D implant model

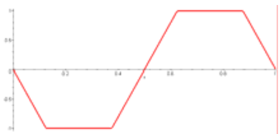
Parametric curve of the thread

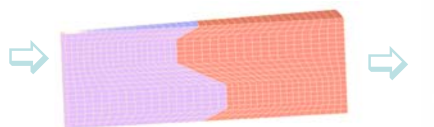


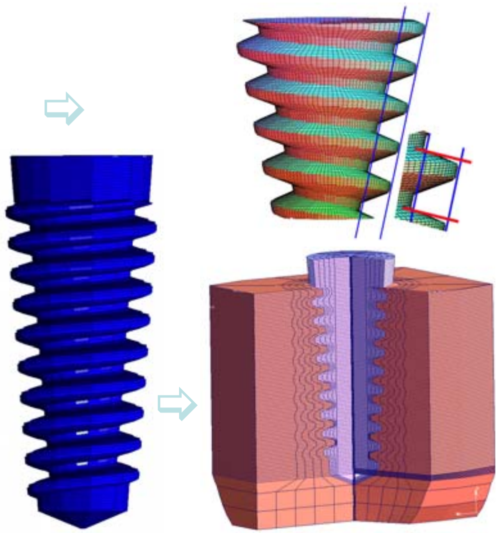


Creating the 3D geometric model

- Modelling the screw



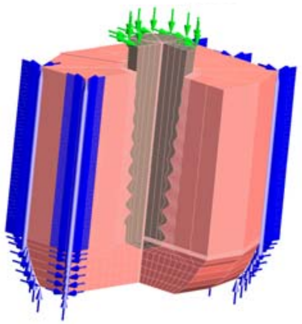




Study parameters

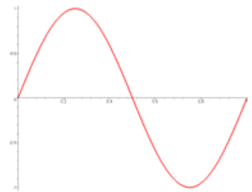
- Material properties (bone, titanium)
  - Homogeneous
  - Isotropic
  - Linear elasticity
- Geometric data, points of support and loading:

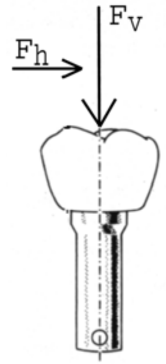
Material properties	Jaw, spongious bone	Titanium
E – Young modulus (MPa)	1340	137000
{ - Poisson coefficient	0.3	0.35

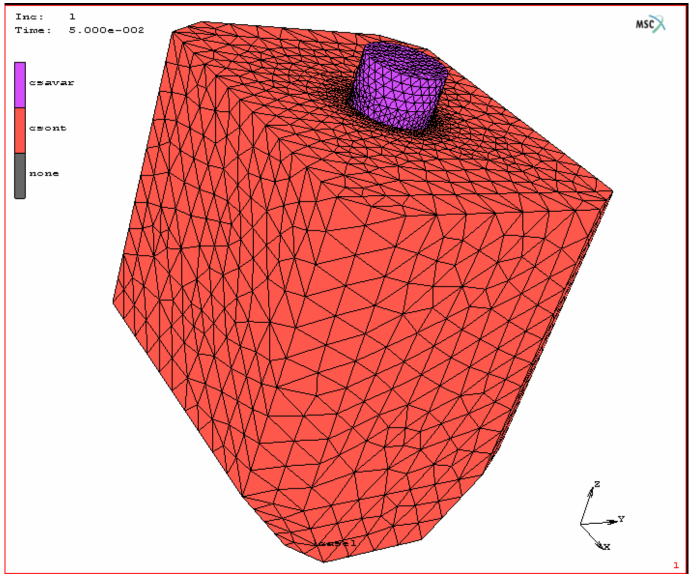


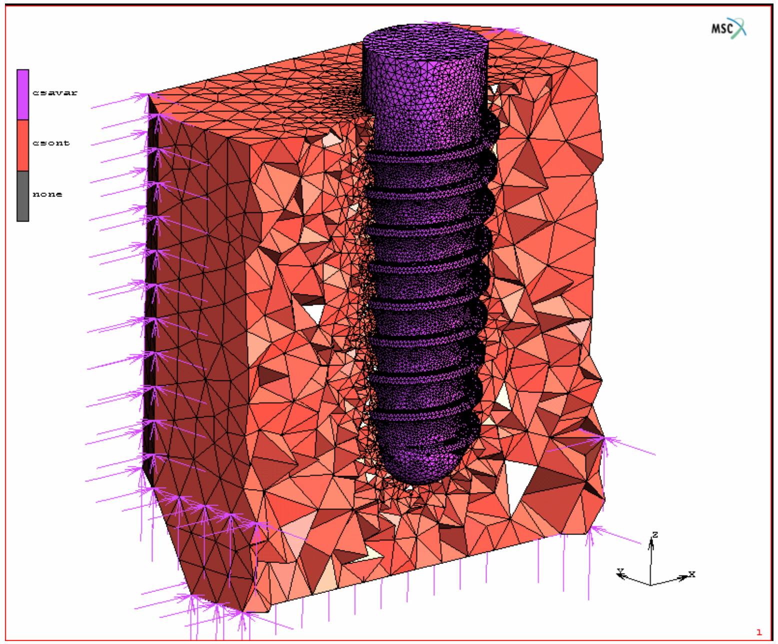
Static and dynamic loading

- Vertical load of a molar tooth: Fv = 250-650 N (loading force: 500 N)
- Vertical load of an incisive tooth: Fv = 225 N
- Horizontal load: Fh = 20 N
- Frequency: 1 Hz (sinus curve)

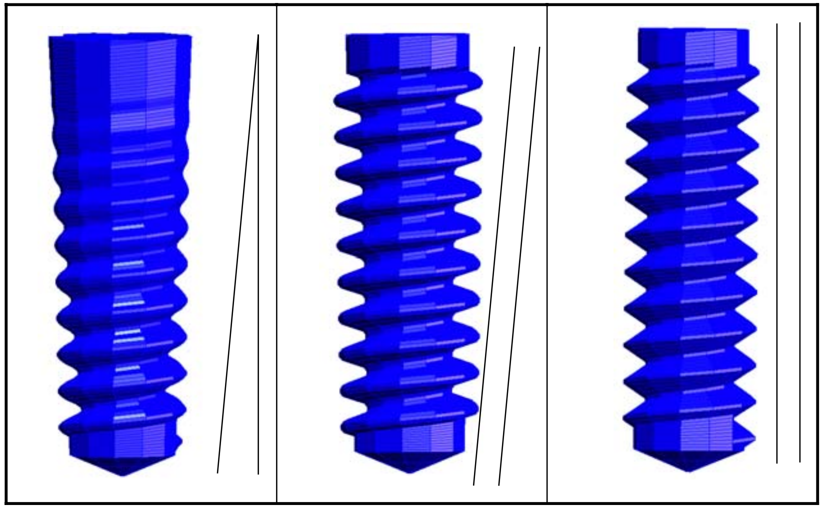


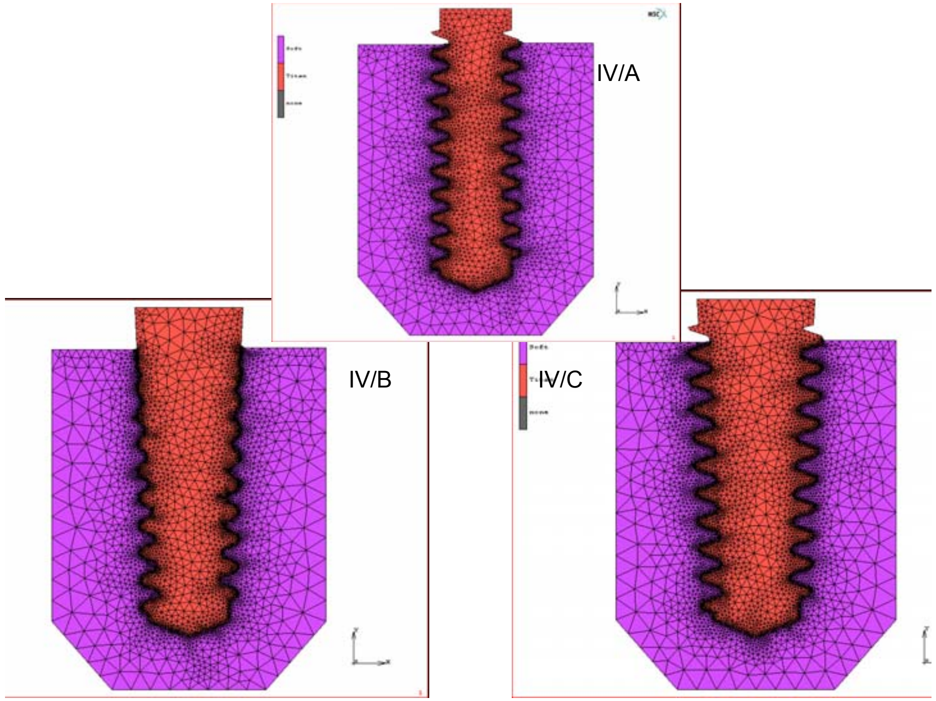






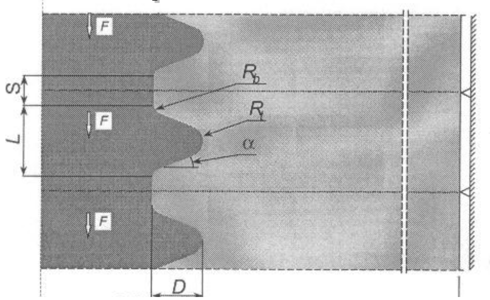
Implant shapes modelled

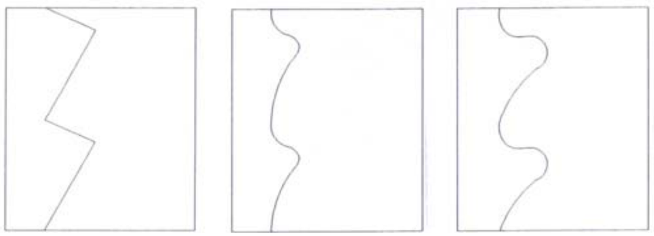




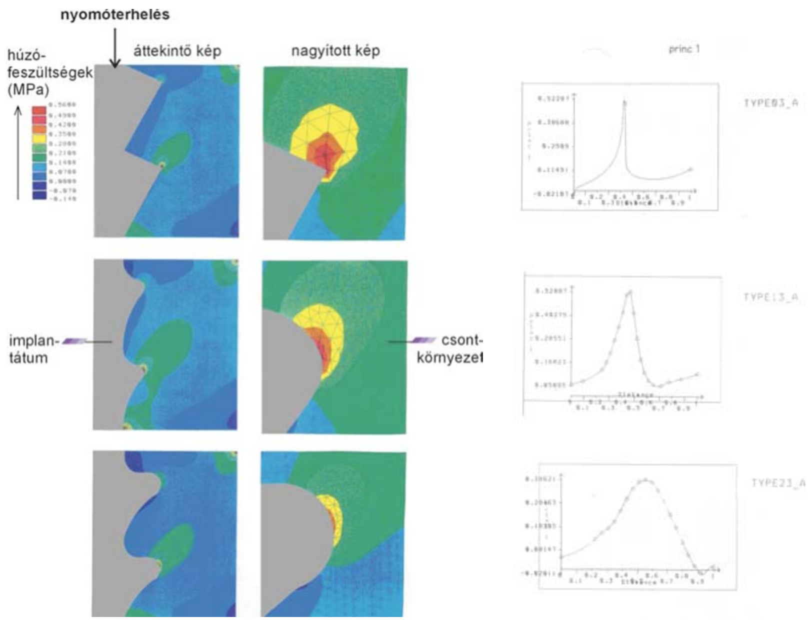
Thread shapes

- Thread parameters

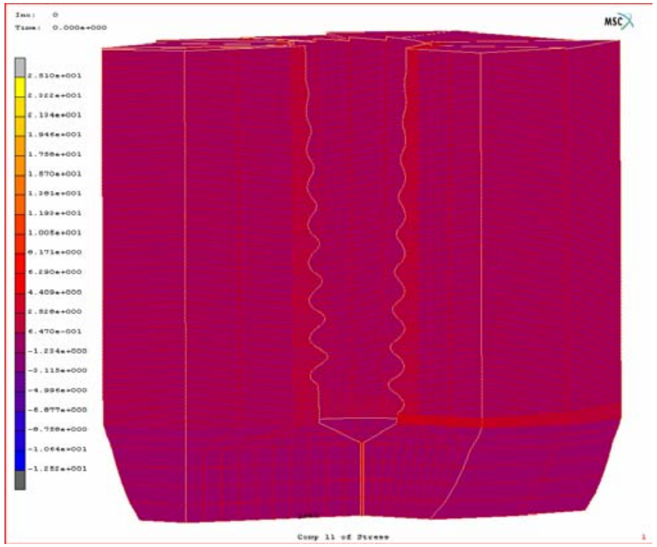


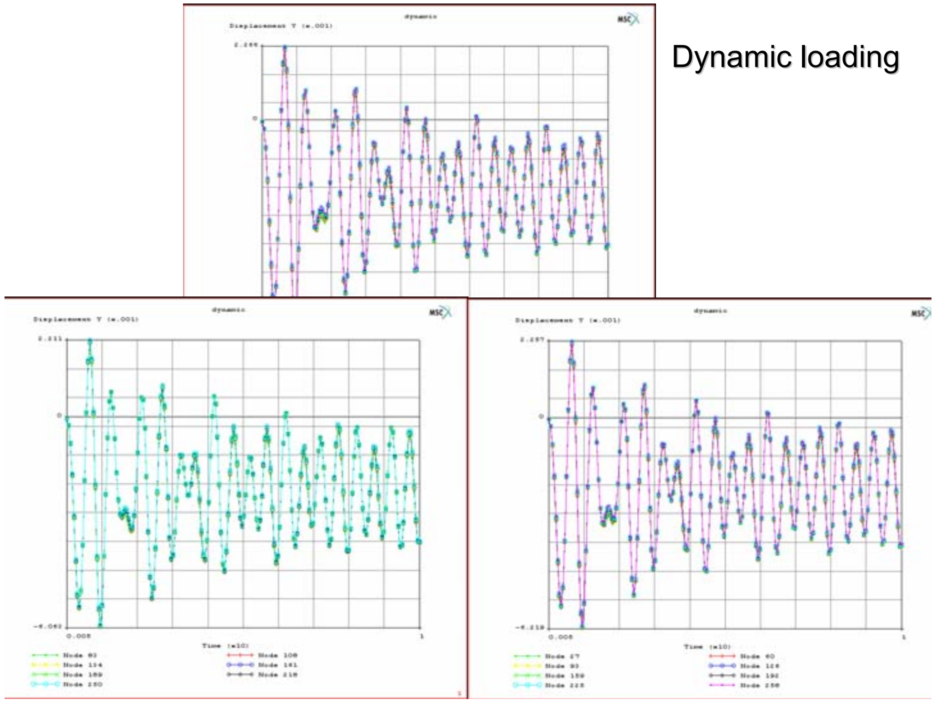


Stress distribution



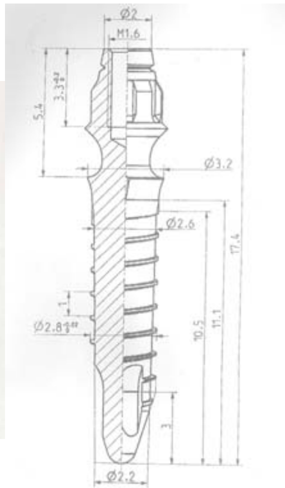
Dynamic animation

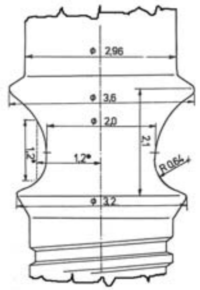




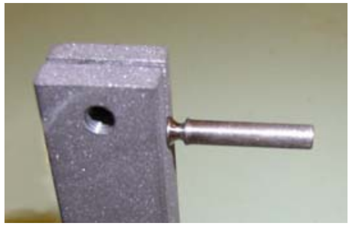
Dynamic loading

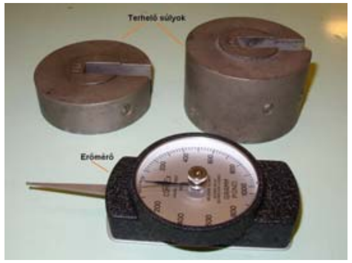
Direct model fabrication to study load and bending parameters

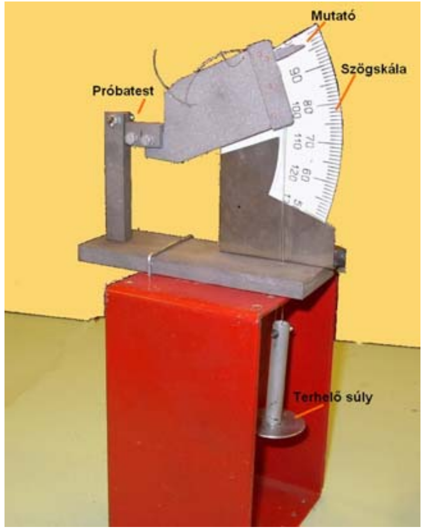




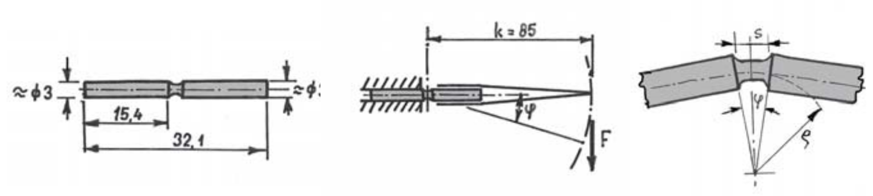
Study device

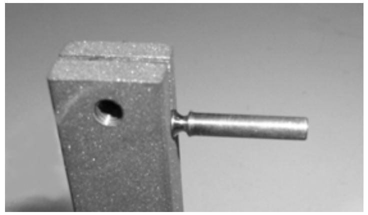


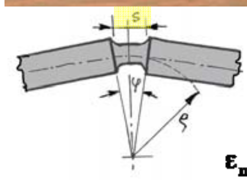




Study principle







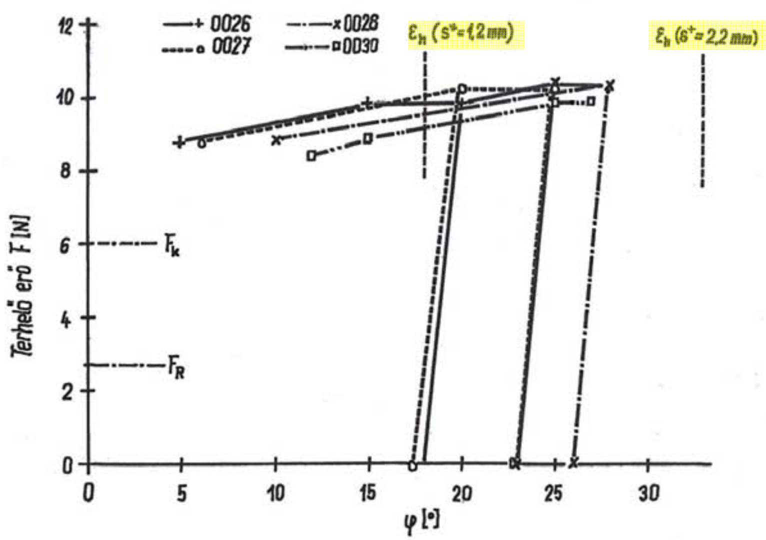
$$\varepsilon_{max} = \frac{r}{s}\varphi$$

Results

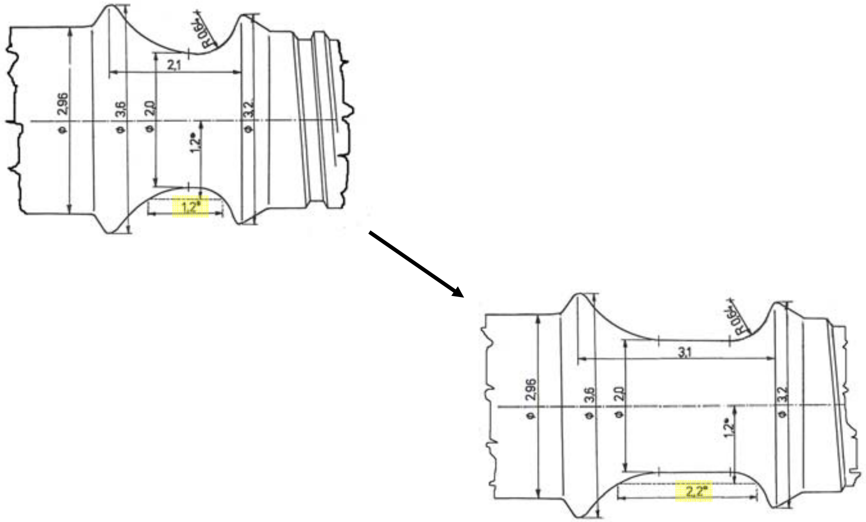
Material property	Factory value
Tearing strength	σ_B=535,7 MPa
Yield-point	σ_F=282,7 MPa
Tearing extension	Σ_B=31,4%

Π [°]	Π [l]	Σ [%]	
		s* = 1,2 mm	s* = 2,2 mm
5	0,08726	8,726	4,76
10	0,1745	17,45	9,52
15	0,2618	26,18	14,28
20	0,1490	34,90	19,04
25	0,4363	43,63	23,80
30	0,5236	52,36	28,56

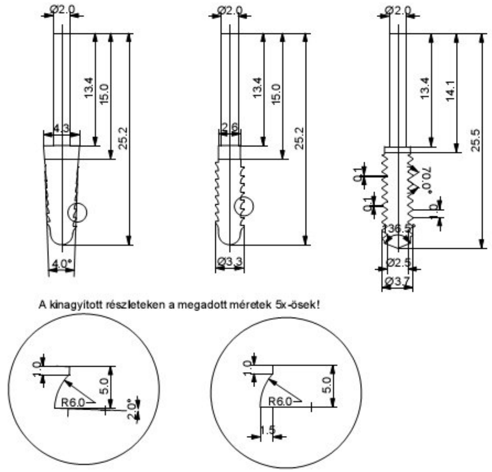
Results



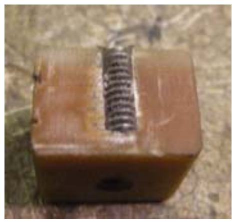
Conclusion



Direct model fabrication to study the thread design under cyclic load

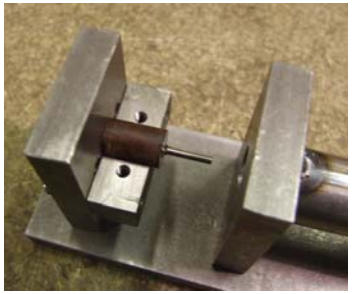


Models fixed into a textile bakelite cylinder with a resin based adhesive



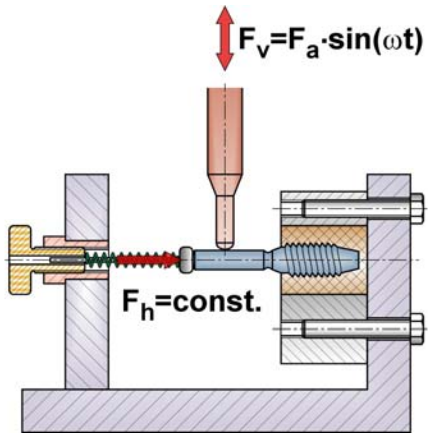
Holding unit fit for constant preload

Fixing the test objects in the holding unit

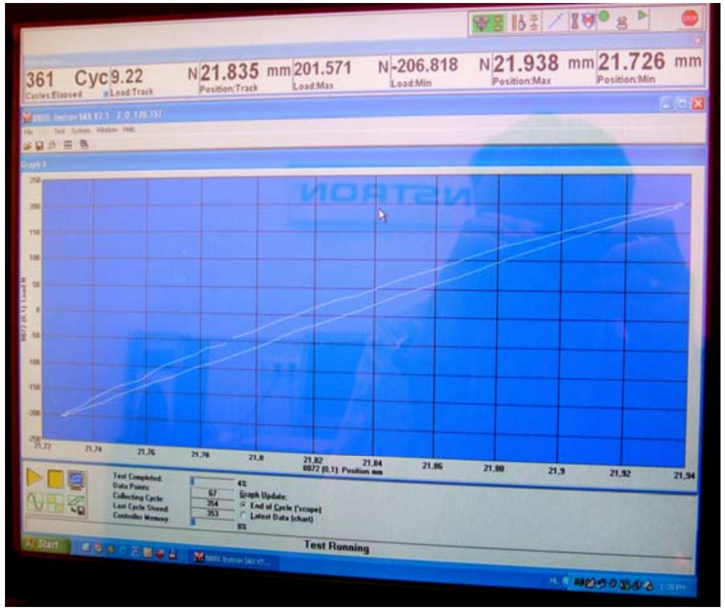


Loading the test objects

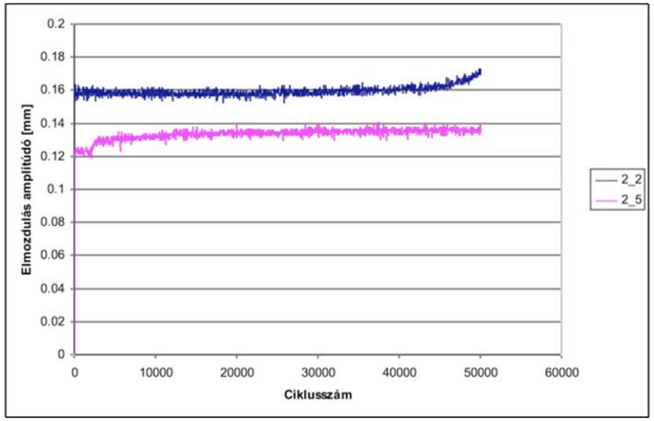
Loading the test objects



One loading cycle



Cyclic loading – fatigue characteristics



Fűrészfog kialakítású menetű modellek mérési eredményei

Biomechanical study methods in the clinical practice

- Measuring masticatory forces
  -dyamometric sensor between occlusal units
  -size +, direction ?, force distribution ? dynamic measurements ?,
  -standardisable, reproducability ?

- Measuring torque
  -Upon implant placement +
  torque wrench - primary stability
  -May be calculated hypothetically for prosthetic devices or implants ?

Biomechanical study methods in clinical practice

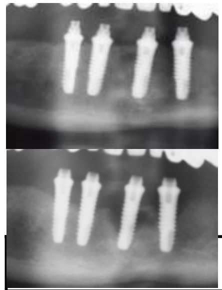
•Implant stability testing

– Implant stability
  - Primary stability - immediately after insertion
  - Secondary stability – osseointegration – following bone healing

– Prognostic sign for
  - (early) loading of implants and
  - long term function.

Implant stability testing

	Preop.	Intraop.	Postop.	Noninv.	Object.
Hystology	+	+	+	-	+++
X-ray	++	++	++	++	-
Insertion torque	-	+++	-	+	++
Removal torque	-	-	++	-	++
Mech. resonance					
Percussion	-	++	++	+	+
Periotest	-	++	++	++	++?
RFA	-	+++	+++	+++	++?



Implant stability testing

	Preop.	Intraop.	Postop.	Noninv.	Object.
X-ray	++	++	++	++	-
Insertion torque	-	+++	-	+	++
Removal torque	-	-	++	-	++

Percussion test

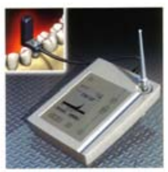
Preop.	Intraop.	Postop.	Noninv.	Object.
-	++	++	+	+

- „Model analysis”, experimental (direct)method
- Acoustic evaluation
  - „Clear vibrant” sound
  - „Dull” sound

Instrumental testing of mechanical resonance

	Preop.	Intraop	Postop.	Noninv.	Object.
RFA	-	+++	+++	+++	++?

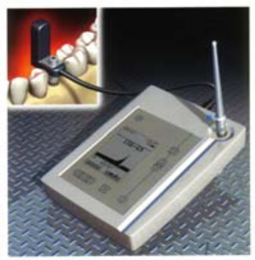
- Recording the interference of mechanical waves sent at the implant
  - Pulsed Oscillation Waveform (POWF) - (Japan) – acoustic resonance (1 kHz) is transmitted with a piezoelectric needle, results are displayed on an oscilloscope
  - Resonance Frequency Analysis (RFA)
    - Osstell device (Integration Diagnostics)
    - Implomates (Bio Tech One)
    - Individual RFA devices



Resonance Frequency Analysis (RFA)

Osstell® device

- Resonance is transmitted by way of a transducer. Based on the interference stability is indicated by an index number
- Result: ISQ index
  Implant Stability Quotient
  (relative unit)
- 15 years’ experience



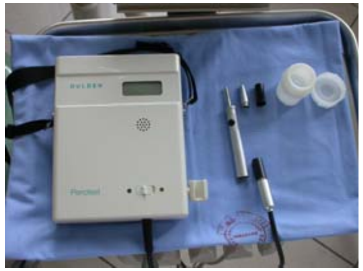
Instrumental testing of mechanical resonance

	Preop.	Intraop	Postop.	Noninv.	Object.
Periotest	-	++	++	++	++?

- Methods based on “tapping on” the implants
  - Dental Mobility Checker (J. Morita, Suita, Japan) – detecting acoustic signs
  - Periotest (Siemens, now Gulden)

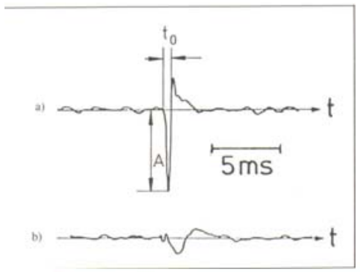
Periotest method

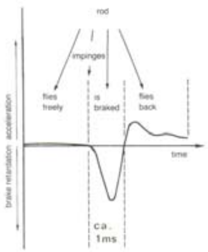
- Periotest® method to measure the stability of implants and teeth

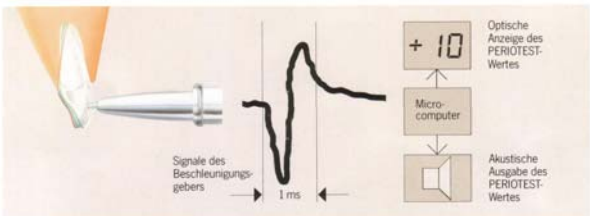


Periotest principle

-a little metal rod hits the object to be studied and based on the reflection parameters stability is shown by an index number





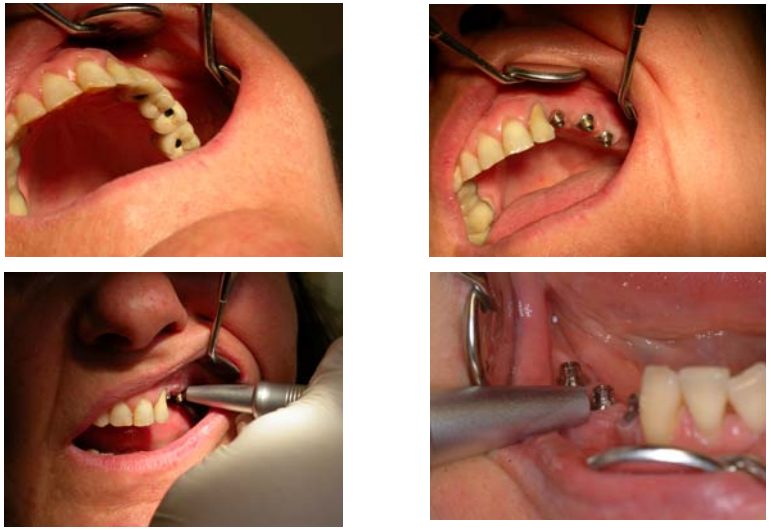


Periotest device

Result:
PTV index –
Periotest Value (relative unit)
full range: -8 to +50

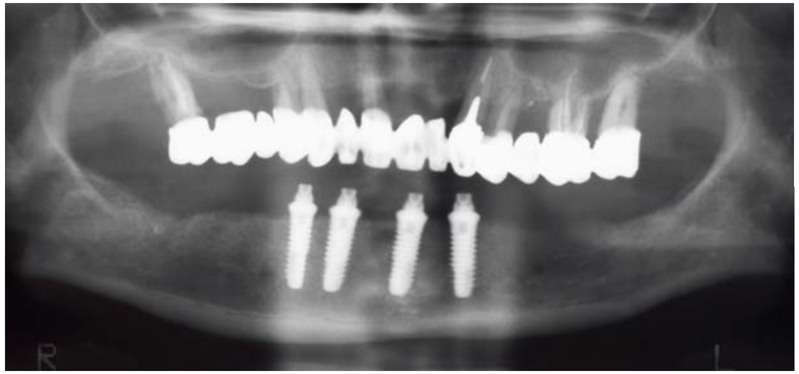
Periotest values of implants:
-8 ≤ PTV ≤ +5 (?) - good stability
+6 ≤ PTV ≤ +50 - inappropriate stability

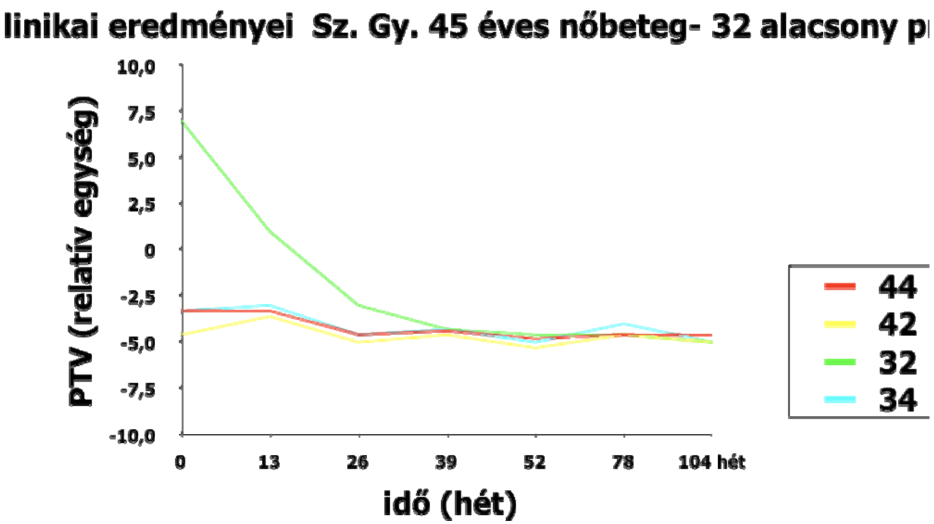
Periotest testing

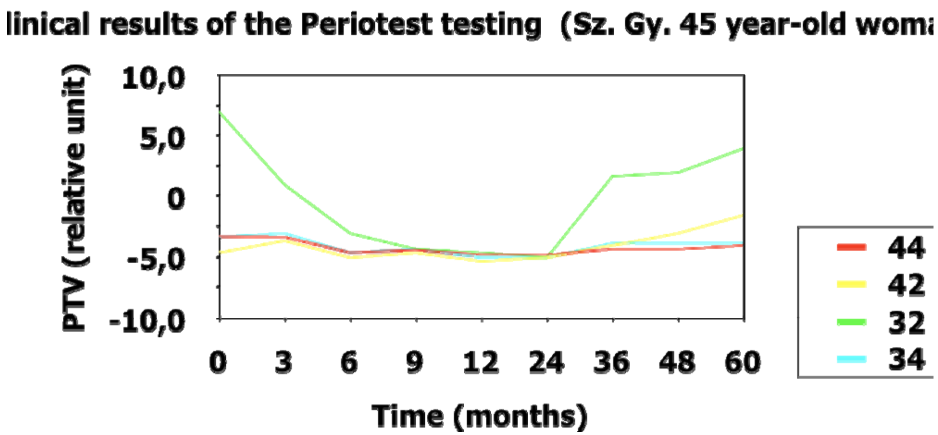


Sz. Gy. 45 year-old woman

32, 34, 42, 44 teeth replaced by one-piece Uniplant SP implants,
primary stability of the implant in position 32 is low

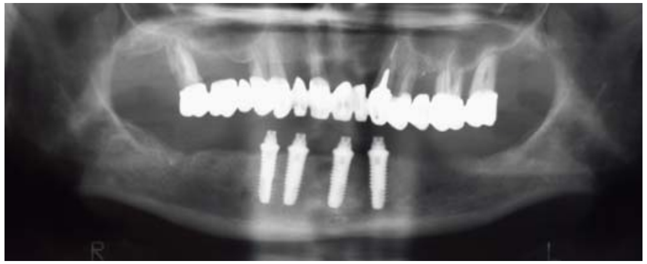




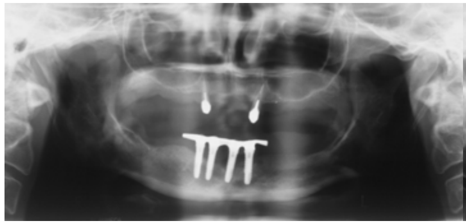


2004. 32, 34, 42, 44 teeth replaced by one-piece Uniplant SP implants
The buccal bone next to the implant in position 32 fractured during implant placement. Primary stability is low.
2007. Periimplantitis. The patient denies removal of the implant in position 42.
2008. Surgical exposure and autologous bone grafting around the implant in position 42.

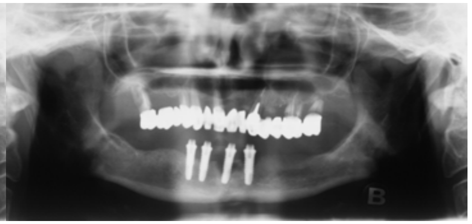
2004



2007



2008



Biomechanical principles of fabricationg implant-based prosthetic devices

• optimal load distribution
• reducing horizontal forces
• reducing torque
• force reduction

Biomechanical principles of fabricationg implant-based prosthetic devices

•Defining implant position (place and direction)

•Chosing the type of prosthetic solution

•Individual prosthetic design

• optimal load distribution
• reducing horizontal forces, minimising torque
• reducing shock-like forces

Reducing torque

Torque >>increased stress around the implant
-to determine it we (would) have to know the forces + the axis

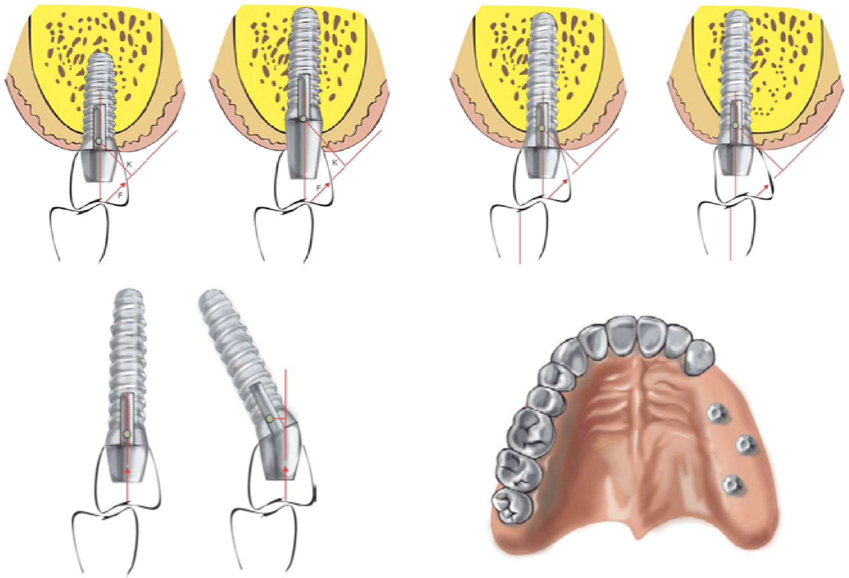
Axis position
- Close to the border between the cervical and middle third of the implant, or
- somewhere else along the implant, or
- outside of the implant in the bone (?)

The real position of the axis is determined by
- bone anatomy, quality, the ratio of cortical to cancellous bone
- the prosthesis

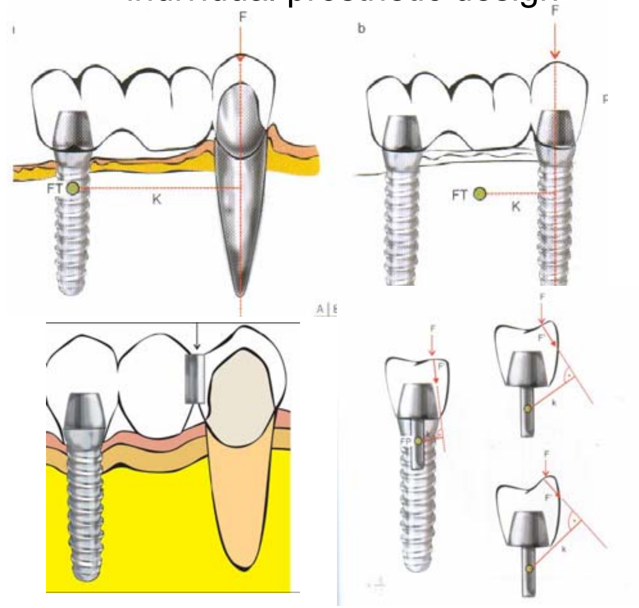
Forces
- they may be measured approximately, their distribution may only be supposed

>> Uncertainty – theory – reality ?

Possiblities of reducing torque - defining implant position



Possibilities of reducing torque - individual prosthetic design



Natural biomechanics

Thank you for your kind attention