"International symposium dedicated to the 20th anniversary of first publications on nanoSPD "Towards innovation application of BNM"

Ufa State Aviation Technical University

23 - 27.06.2008

NANOSTRUCTURED TITANIUM FOR DENTAL IMPLANTS

Dr.Ing. Luděk DLUHOŠ

Czech Republic

Timplant® – dental implants

1980 - 1984 University of chemistry technology - engineer
1984 - 1996 Iron and Steel Research Institute – researcher
1992 - 1996 VSB-Technical University – doctor
1993 - Company Timplant – research, development and production of Dental Implant System Timplant® - owner
2005 - Nanostructured dental implant Nanoimplant® - first in the world

Nanoimplant®s
RESEARCH NANOTEAM

- Jarmila SOCHOVÁ – Timplant® ,assistent, final inspection, marketing, ISO Systems, Ostrava, Czech Republic
- prof. Ing. Jiří Petruželka,CSc. – Head of Institute of Metal Forming, VŠB – Technical university of Ostrava, Czech Republic
- MUDr. Daniel HRUŠÁK,PhD. - Head of medical staf and Senior assistant: Department of Stomatology, University Hospital, Charles University Prague, Medical Faculty Pilsen, Czech Republic
- Prof.Dr. Ruslan Z. Valiev – Scientific Director of IPAM USATU, Russia
- Terry C. Lowe – Chief executive officer, Metallicum Inc., USA

Property Requirements for Dental Implants Material

- metalic or nonmetalic (ceramic)
- bio-inert or biocompatibility or bio-active surface
- not contains neither even potentially toxic nor allergenetic additives
- optimal specific strength properties
- availability, shape, diameter, lenght, roundness, straightness, machinability (CNC)
- acceptable price

ASTM F67-95 and following

The most frequently used material in the world for dental implants

Designation: F 67 – 95

Standard Specification for
Unalloyed Titanium for Surgical Implant Applications[1]

F 67

TABLE 1 Chemical Requirements

Element	Composition,[A] %							
	Grade 1		Grade 2		Grade 3		Grade 4	
	Flat Product	Bar and Billet	Flat Product	Bar and Billet	Flat Product	Bar and Billet	Flat Product	Bar and Billet
Nitrogen, max	0.03	0.03	0.03	0.03	0.05	0.05	0.05	0.05
Carbon, max	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Hydrogen, max	0.015	0.0125[B]	0.015	0.0125[B]	0.015	0.0125[B]	0.015	0.0125[B]
Iron, max	0.20	0.20	0.30	0.30	0.30	0.30	0.50	0.50
Oxygen, max	0.18	0.18	0.25	0.25	0.35	0.35	0.40	0.40
Titanium	balance	balance	balance	balance	balance	balance	balance	balance

[A] Forgings are designated Grade F-1, F-2, F-3, or F-4 respectively. Forging compositions are identical to those specified for flat product.
[B] Bar only; maximum hydrogen content for billet is 0.0100 %.

TABLE 2 Product Analysis Tolerances[A]

Element	Limit or Maximum of Specified Range, %	Tolerance Under the Minimum or Over the Maximum Limit[B]
Nitrogen	up to 0.05	0.02
Carbon	0.10	0.02
Hydrogen	up to 0.015	0.0020
Iron	up to 0.25	0.10
Iron	over 0.25	0.15
Oxygen	up to 0.20	0.02
Oxygen	over 0.20	0.03

[A] Refer to AMS 2249C.

TABLE 3 Mechanical Requirements—Bar, Billet, and Forging[A]

Grade	Tensile Strength, min		Yield Strength, 0.2 % Offset, min		Elongation in 4*D*, min, %	Reduction of Area, min, %
	ksi	MPa	ksi	MPa		
1	35	240	25	170	24	30
2	50	345	40	275	20	30
3	65	450	55	380	18	30
4	80	550	70	483	15	25

[A] These properties apply to forgings having a maximum cross section not greater than 3 in.^{2} (1935 mm^2). Mechanical properties of forgings having greater cross sections shall be negotiated between the manufacturer and the purchaser.

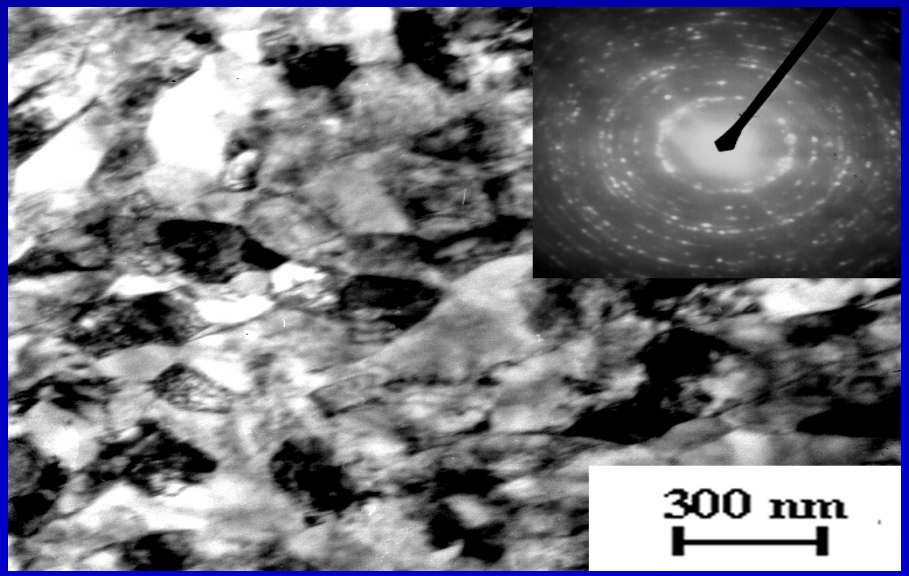
Titanium used in period 1992-1996 for implants Timplant® - GOST 27265-87, VT 1-00

NEW: Nanostructured titanium

The first samples of nanostructured titanium – were produced the first implants

Material	State	UTS(MPa)	YS(MPa)	Elong(%)	RA (%)
Grade 2	TiECAP 4 passes + rolling	1030	845	12.0	51.0
Grade 4	TiECAP 4 passes + rolling	1143	864	15.4	47.4

Ultrafine grain Grade 2 commercial purity titanium:
TEM of cross section



Ultrafine grain Grade 4 commercial purity titanium:
TEM of cross section

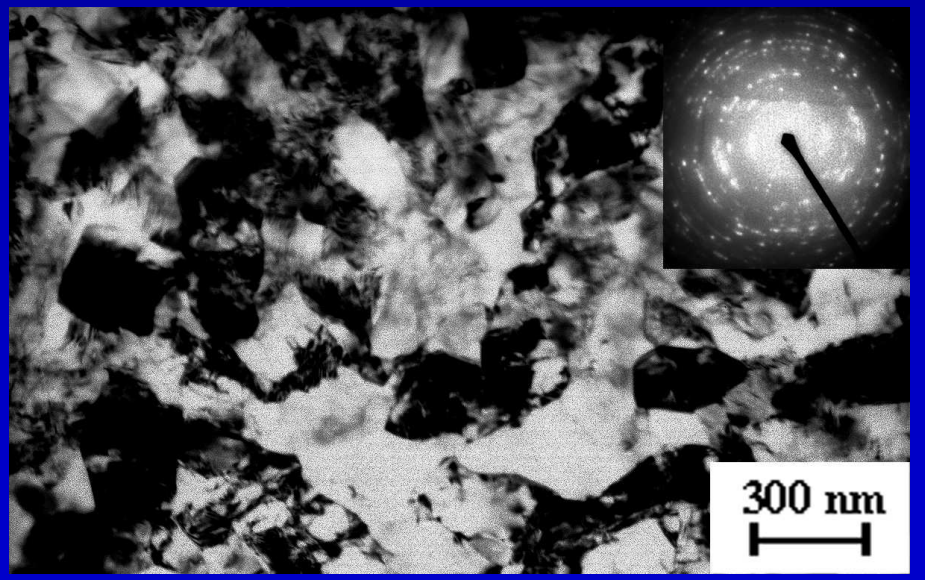


Photo: TEM USATU

Nanostructured titanium II.

The second delivery of 40 nTi rods ø 8 mm – improved UTS

Room temperature tensile tests (ISO 6892 – 84, ST SEV 471-88)

Sample ID	YS	UTS	Elong.	RA
	MPa		%	
IPAM-TCP4-8DEC05-B02-016	1100	1240	13.7	53
IPAM-TCP4-8DEC05-B02-017	1100	1226	12.0	51
IPAM-TCP4-8DEC05-B02-018	1050	1236	12.7	50

USATU Laboratory Report No. 6, Dec 10, 2006

Nanostructure in Nature?

GECKO - *Saurodactylus auritanicus*

Sucking tentacular finger – size of tentacle about 150 ηm, that is why gecko is able to walk on the glass top wall

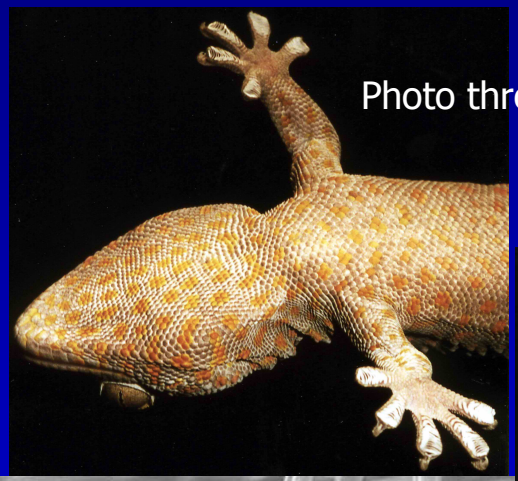
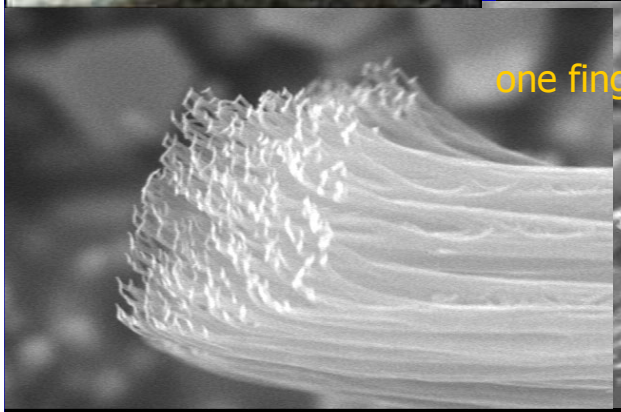
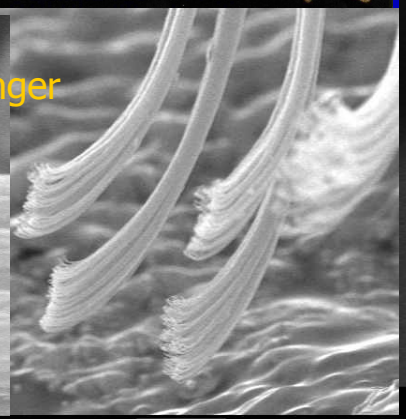
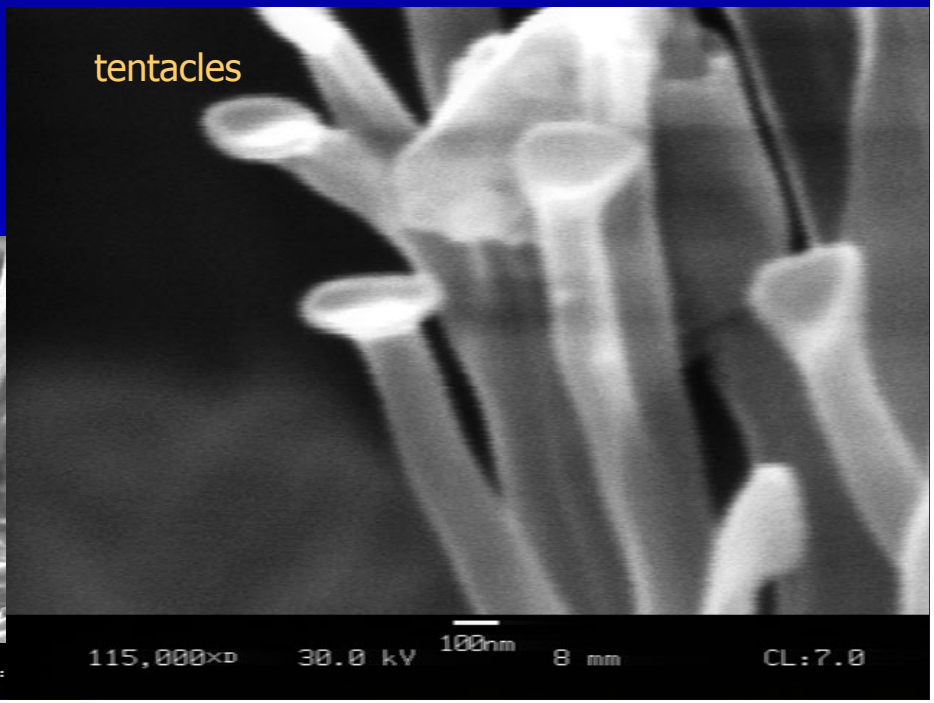


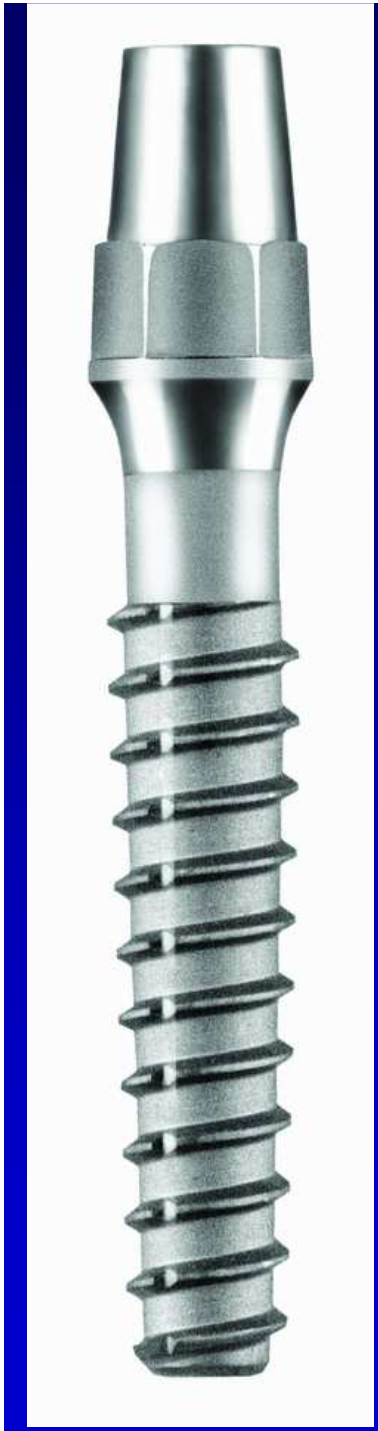
Photo through glass



one finger







Nanoimplant® first in the world

1. Size of particles of nanostructured titanium about 100 ηm size of biological virus 75 -100 ηm, protein 5-50 ηm

2. Tensile strength - 2.8 x higher than cpTi Gr.2
2.3 x higher than cpTi Gr.4

3. Theoretical calculation of strength of flexure in VSB-Technical University of Ostrava

Nanoimplant® ø2,4 mm = Timplant® ø3,5 mm

Dental implants Timplant® dia 3,5 are more than 15 years inserted to the human body without fracture

4. Purity grade – 99% titanium, no alloy, without toxic or potentially toxic elements (Ti6Al4V)

5. Length of intraosseal part – 10, 12 and 14 mm – optimal length for thin implants

6. Etched surface - clean surface, 2.4 x higher roughness – better biological properties – higher cells adhesion [4]

7. Self taping conical thread – high primary retention and optimal bone condensation

STRENGTH

of flexure

ø2,4

=

ø3,5

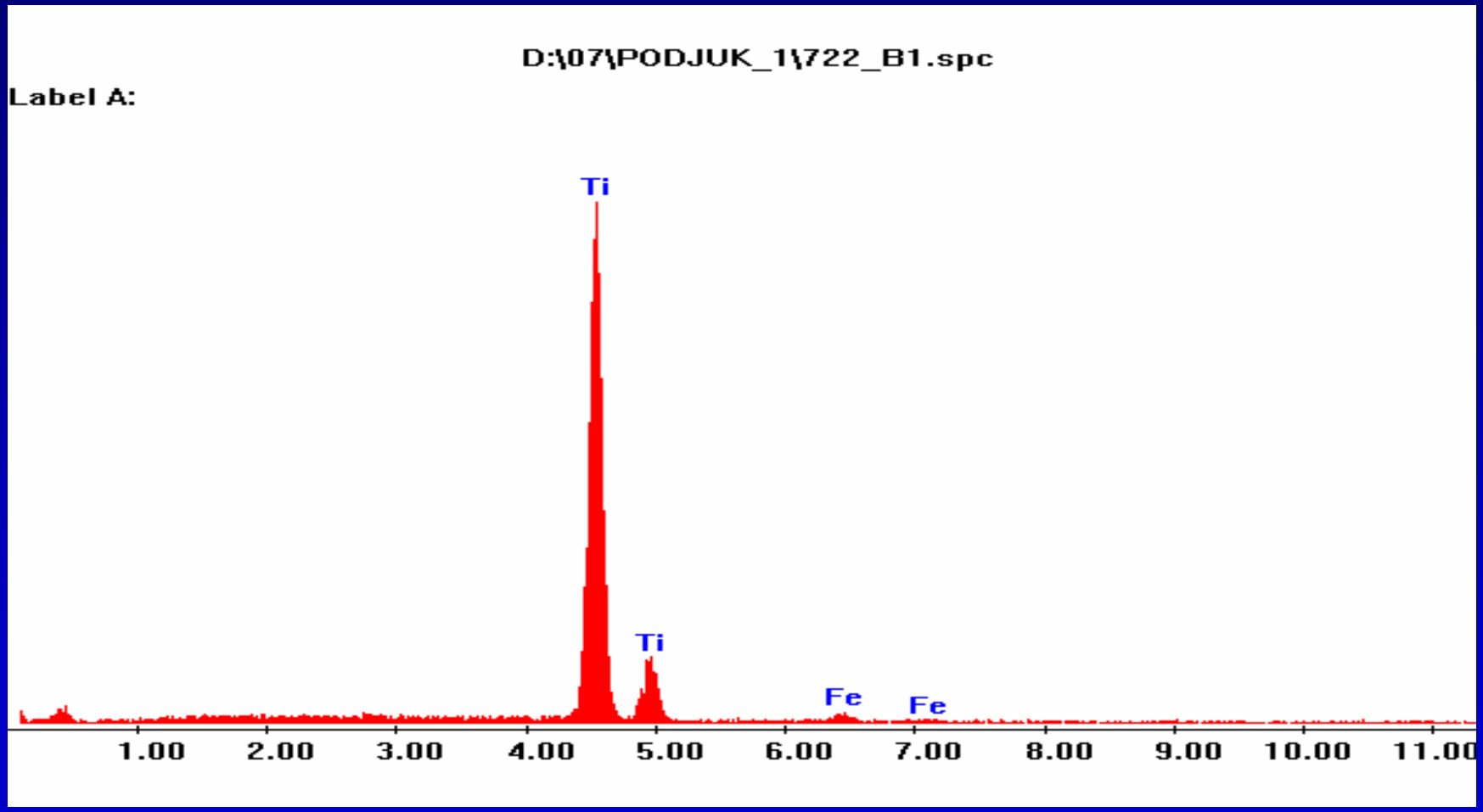
AREA

of intraosseal part

12 mm ≈ **10 mm**

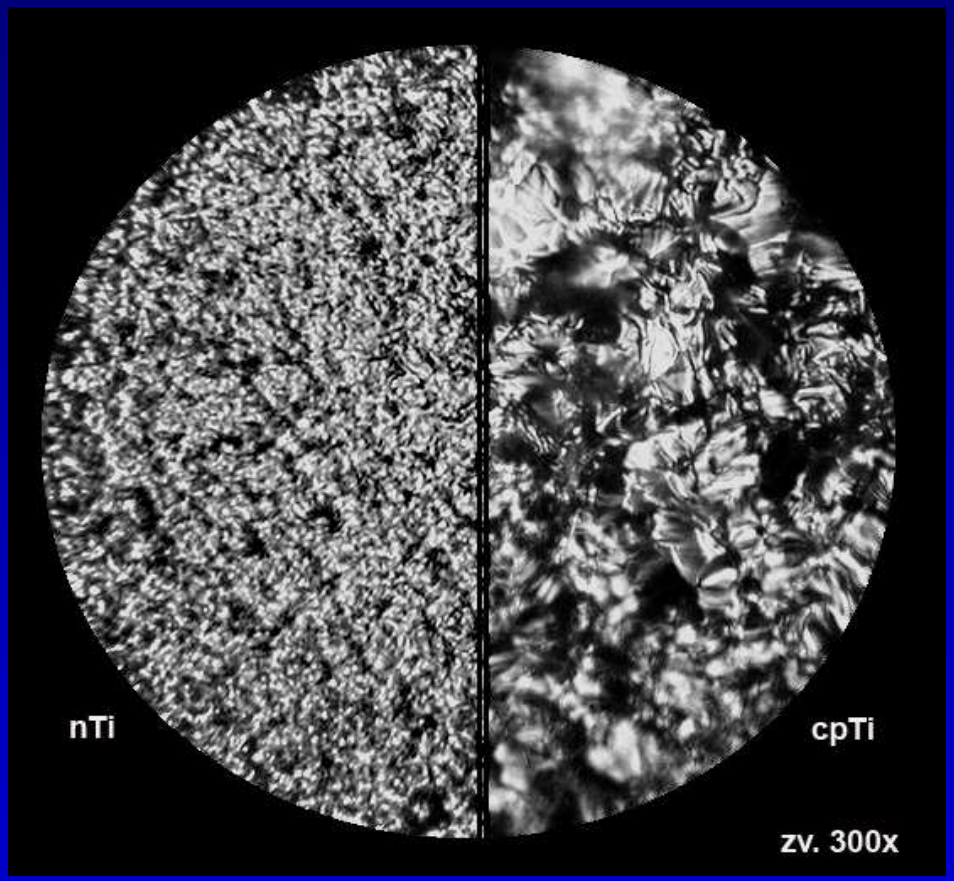
Nanostructured titanium Gr.4

list of peaks of chemical elements (etched surface)



Picture: EDAX- Dept. of Nanotechnology – VSB -Technical University of Ostrava

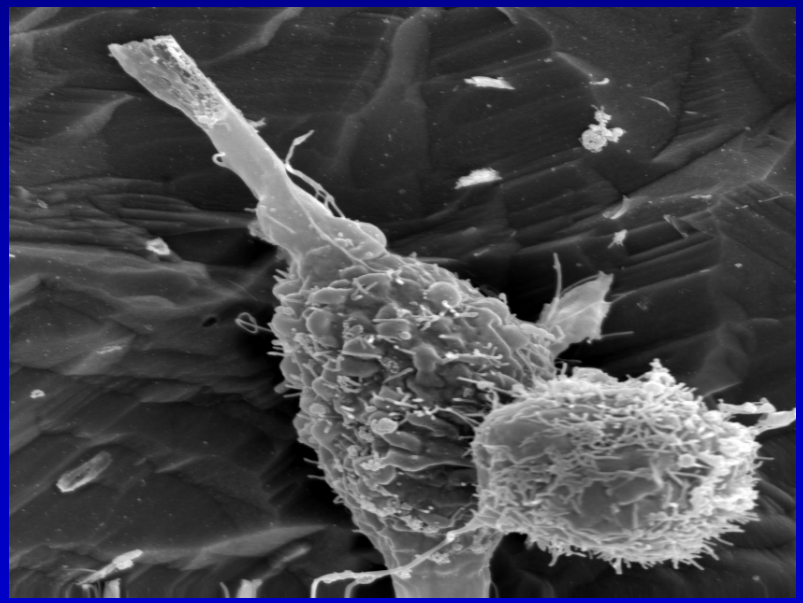
Etched surface nanoTi & cpTi



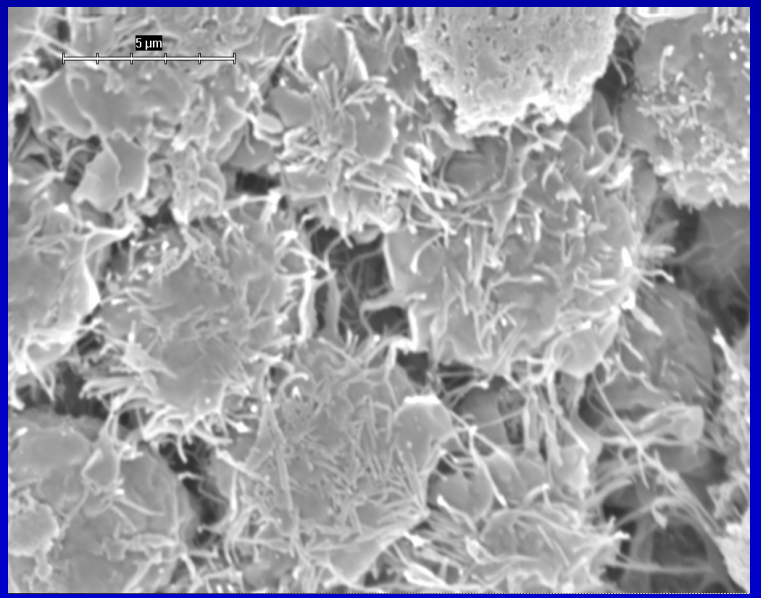
Optical microscope / photo Timplant

Cytocompatibility of nanostructured titanium surface

Cell attachement on nanomaterial (sample N4) in early phase 12h



Cell layer on nanomaterial treated HF etching (sample N3) in early phase 24h



Photos SEM:Institute of Physical Biology
Cell line L929

Cells occupation on the different surface

After 72 hours

MATERIAL	surface	finishing	% of occupied surface
ASTM F67-00	A1	Turning	**49,07**
ASTM F67-00	A2	Turning & plasma	**53,11**
ASTM F67-00	A3	Turning & HF-etching	**53,01**
ASTM F67-00	A4	Turning & HF & plasma	**54,16**
NANOMATERIAL	N1	Turning	**68,76**
NANOMATERIAL	N2	Turning & plasma	**65,41**
NANOMATERIAL	N3	Turning & HF-etching	**87,22**
NANOMATERIAL	N4	Turning & HF &plasma	**86,96**

Nanomaterial has a significance to quickly cell adherence

The First Inserted Nanoimplant®

14. November 2005

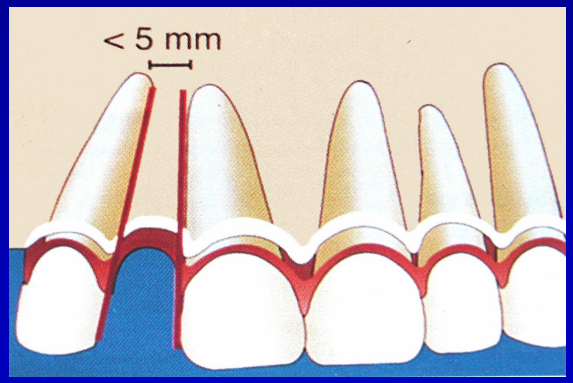
Photo: MUDr. Daniel HRUŠÁK,PhD.- surgeon, Department of Stomatology, University Hospital, Pilsen

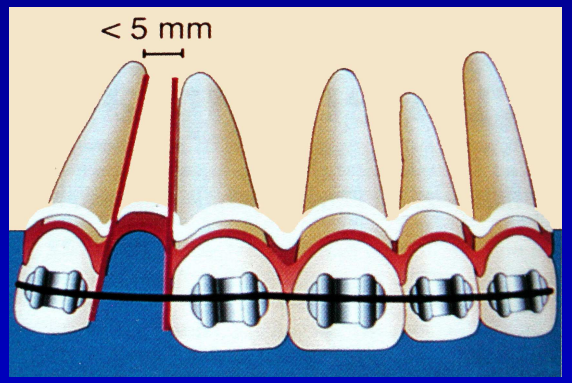
INDICATIONS of Nanoimplant®

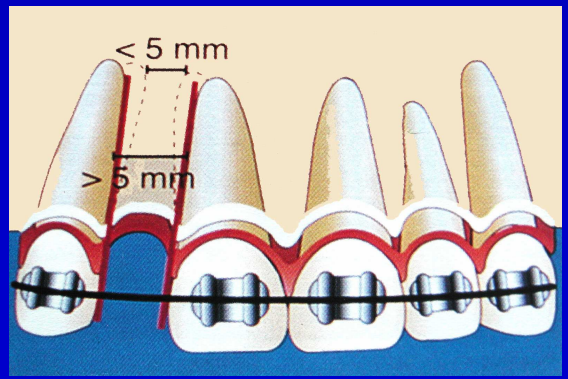
INSUFFICIENT OF TRANSVERSAL BONE 'S SIZE 4,5-6 mm

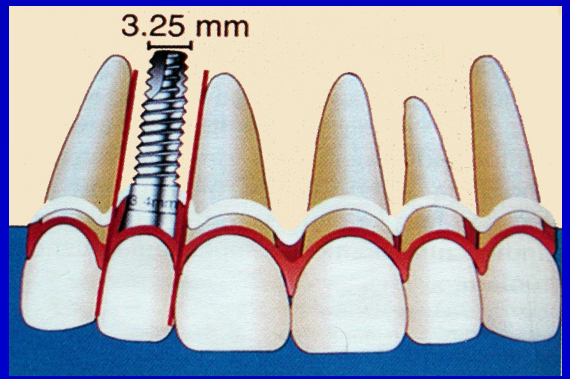
- above 6 mm – classical implants ø >3.5mm
- under 6 mm - Nanoimplant®
- under 4,5 mm - alveolar split + Nanoimplant®

INSUFFICIENT OF INTERDENTAL SPACE









EXAMPLES OF SURGICAL SOLVING INSUFFICIENT OF TRANSVERSAL BONE 'S SIZE

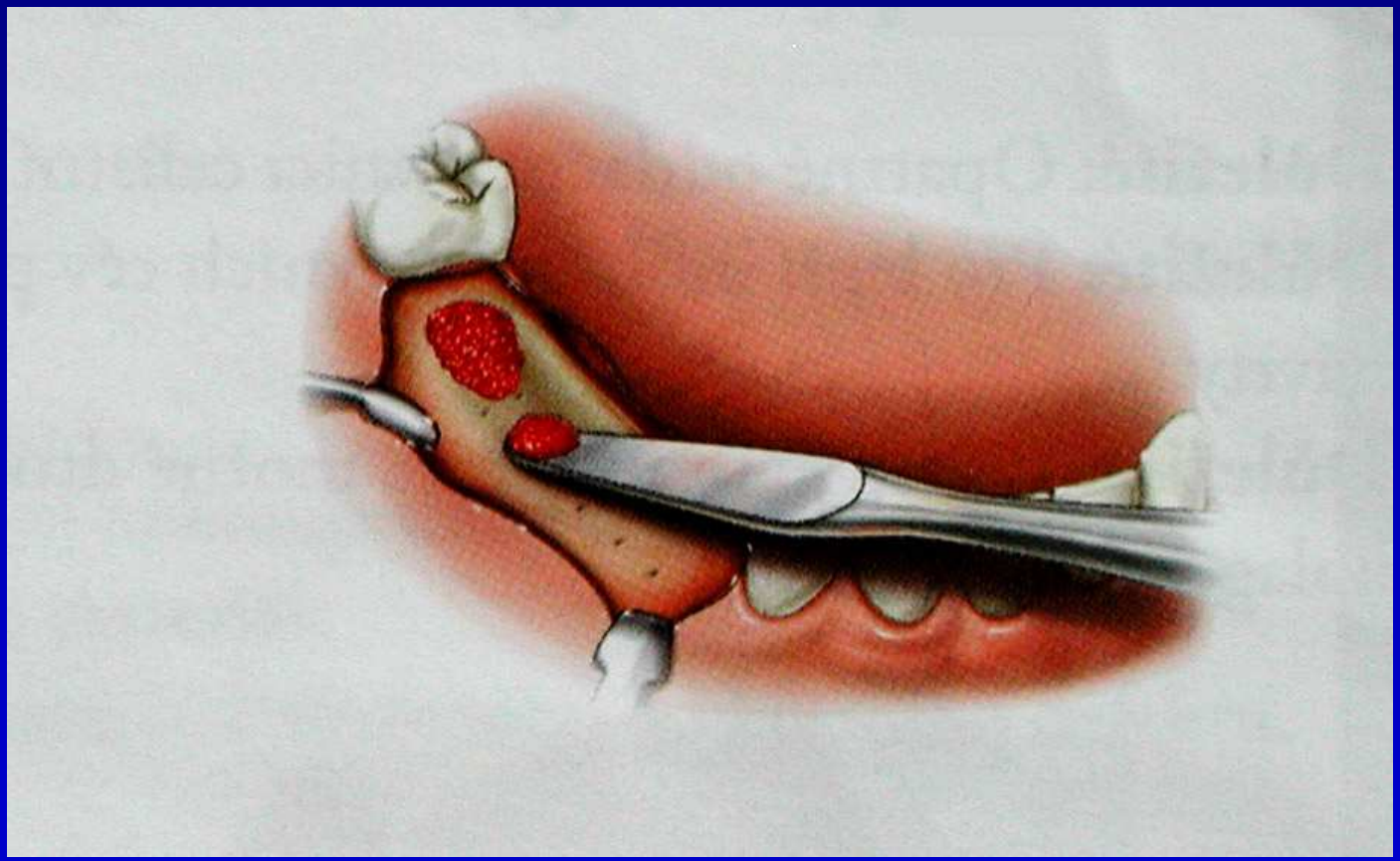
(narrow bone)

- GUIDED BONE REGENERATION
- BONE SPLITTING
- ONLEY AUGMENTATION
- OSTEODISTRACTION – by Timplant® distractor

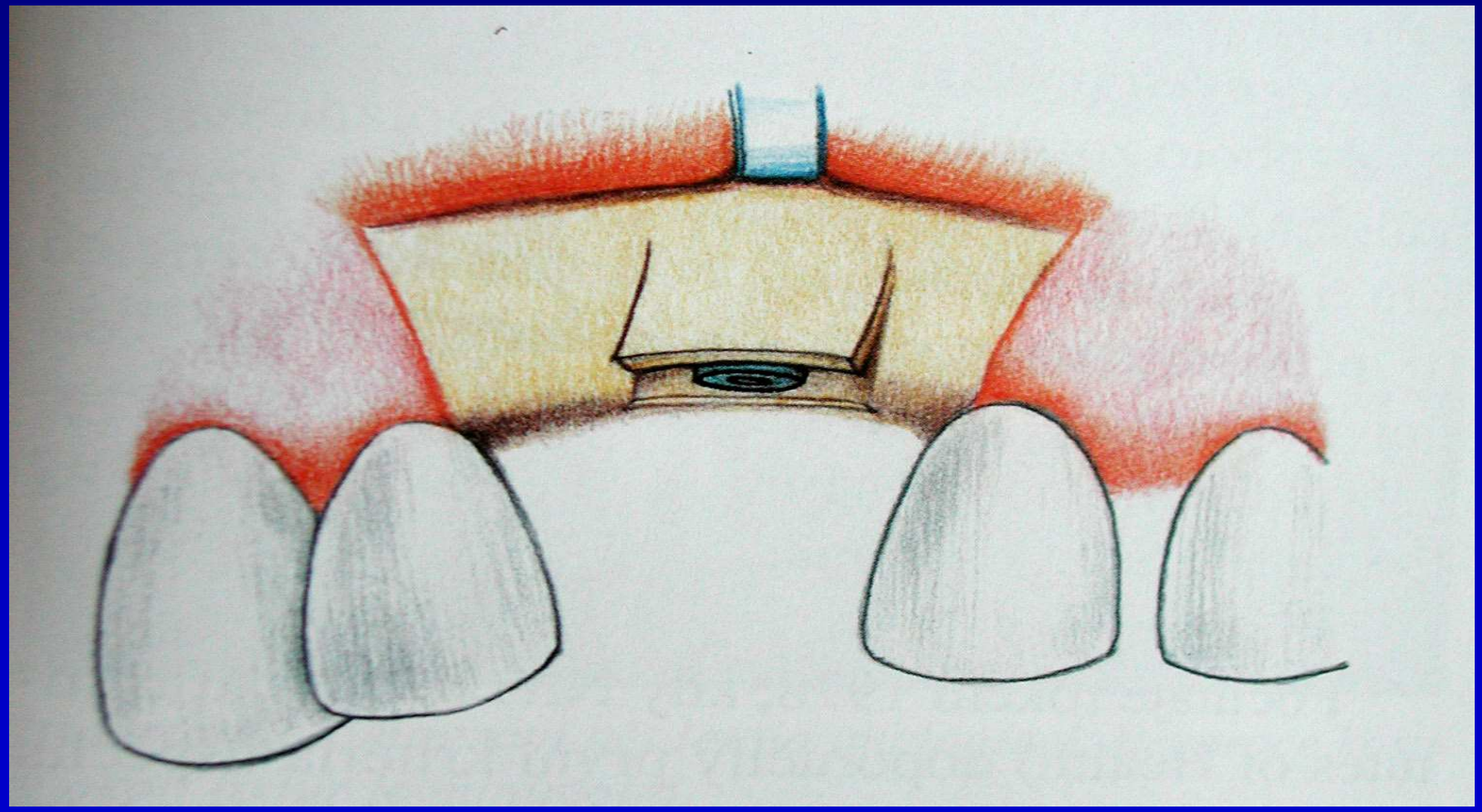
OR MORE SIMPLY METHOD IS

INSERTING OF THIN IMPLANT - Nanoimplant®

GUIDED BONE REGENERATION



BONE SPLITTING



ONLEY AUGMENTATION

by bone graft

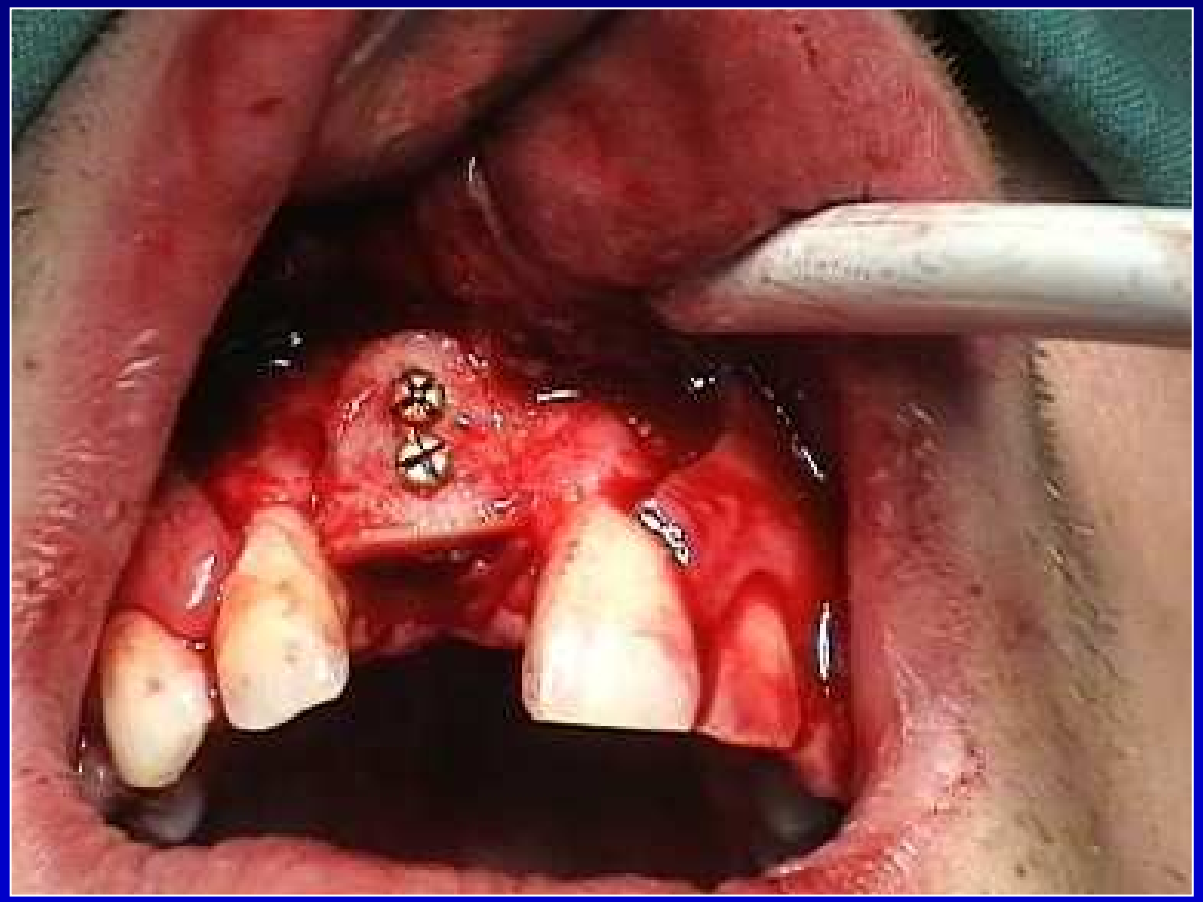


Photo: MUDr. Daniel Hrušák, PhD. - surgeon

OSTEODISTRACTION

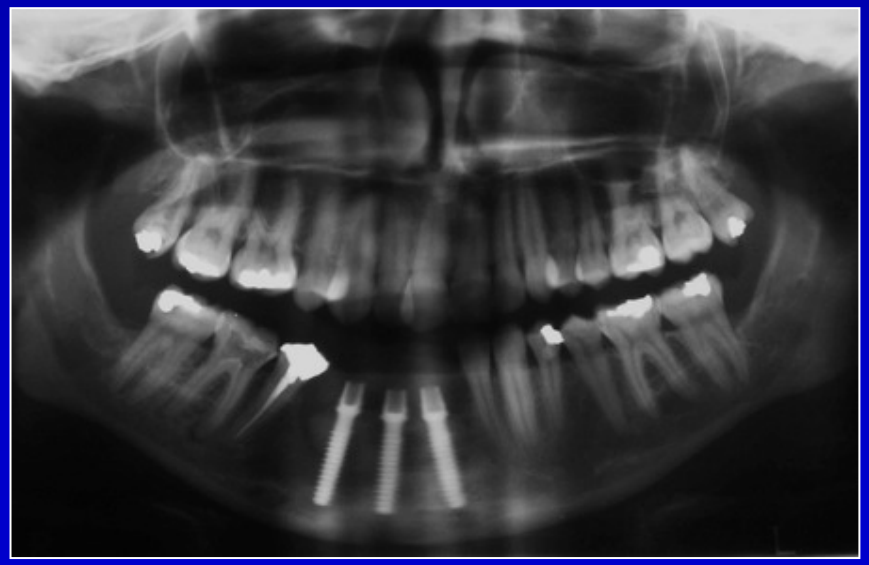


Photo: MUDr. Daniel Hrušák,PhD - surgeon

The Most Frequently Used Applications Of Inserting Dental Implants Nanoimplant®

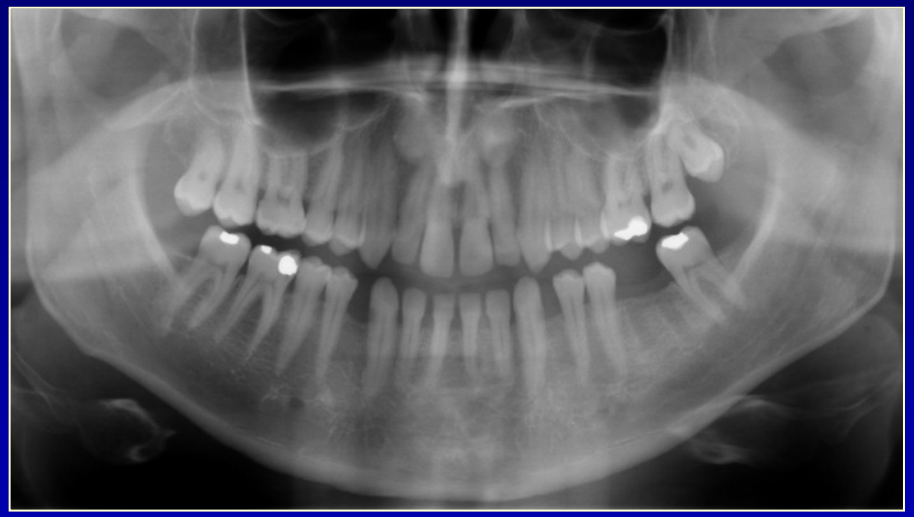
- Replacement of solo tooth
- Missing molar teeth
- Combination of different types of implants and Nanoimplant®
- Combination of dental implants with own teeth
- Immediatelly loaded implants

All followed clinical pictures are from clinical praxis of MUDr. Ctibor Arnold, stomatosurgeon, Teplice, Czech Republic

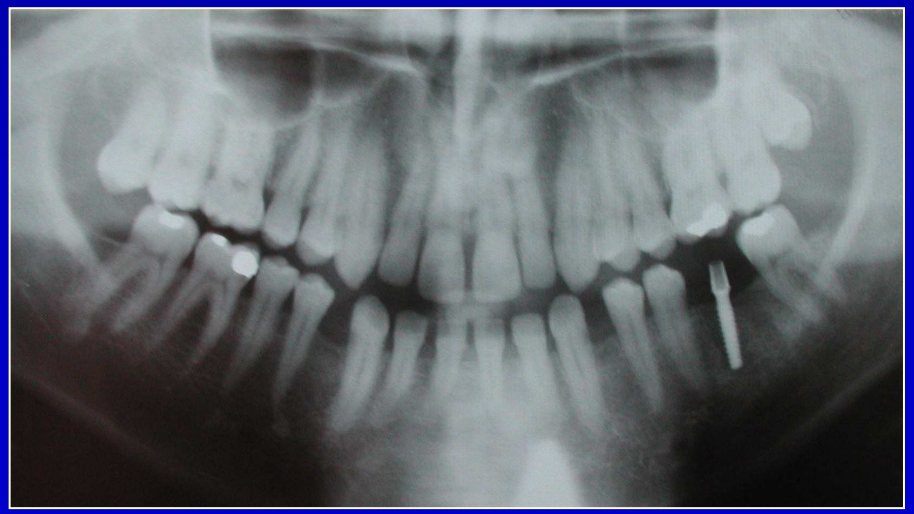
Case Report No.1

Replacement of solo tooth

- Ztráta zubu 36 – pacient r. 1975, odmítl fixní můstek, žádal řešení implantáty
- Zaveden Nanoimplant A11 a metalkeramická korunka

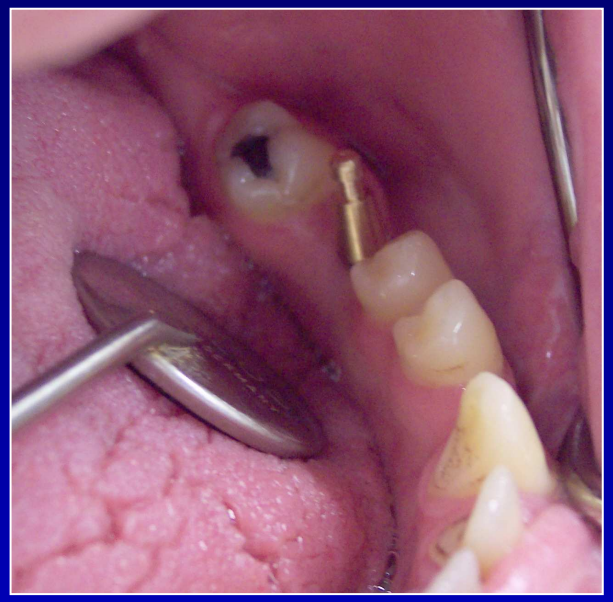


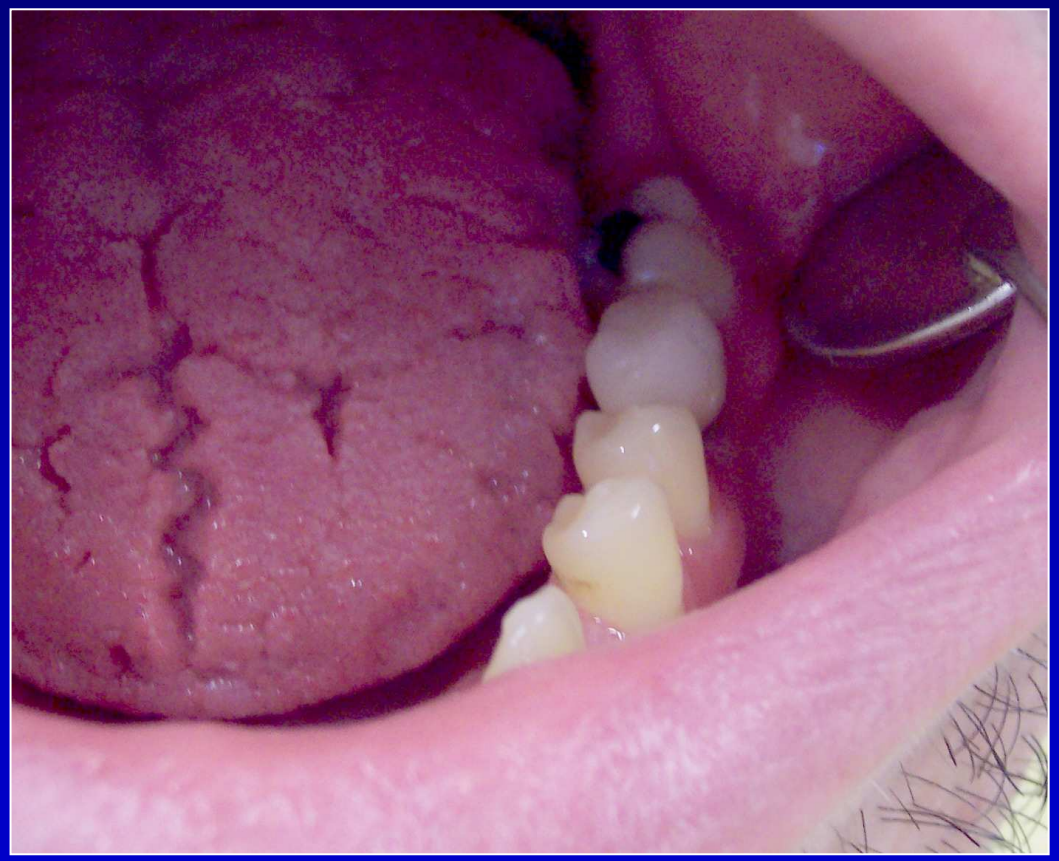
Dva roky ve funkci



Case Report No. 1

Replacement of solo tooth

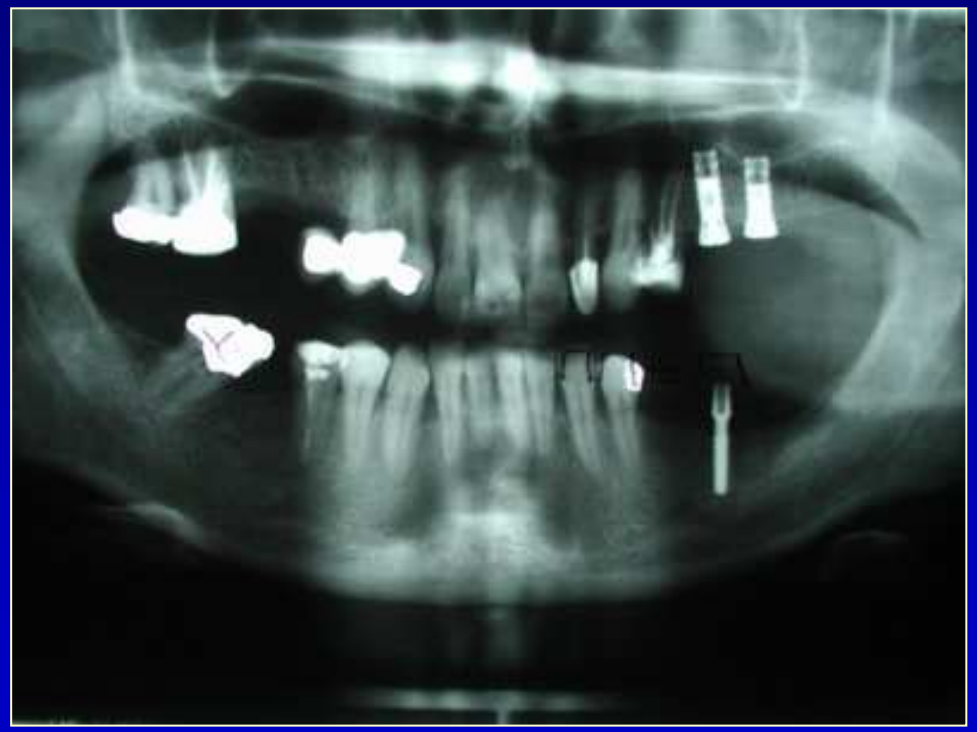




Case Report No.2

Missing molar teeth

- Zkrácený zubní oblouk – pacientka r. 1959
- HČ dobrý transverzální rozměr, suprastruktura 3 metalkeramické spojené korunky
- DČ – alveol pod 6 mm, Nanoimplant A11, metalkeramický most 33, 34–36



Case Report No.2

Missing molar teeth

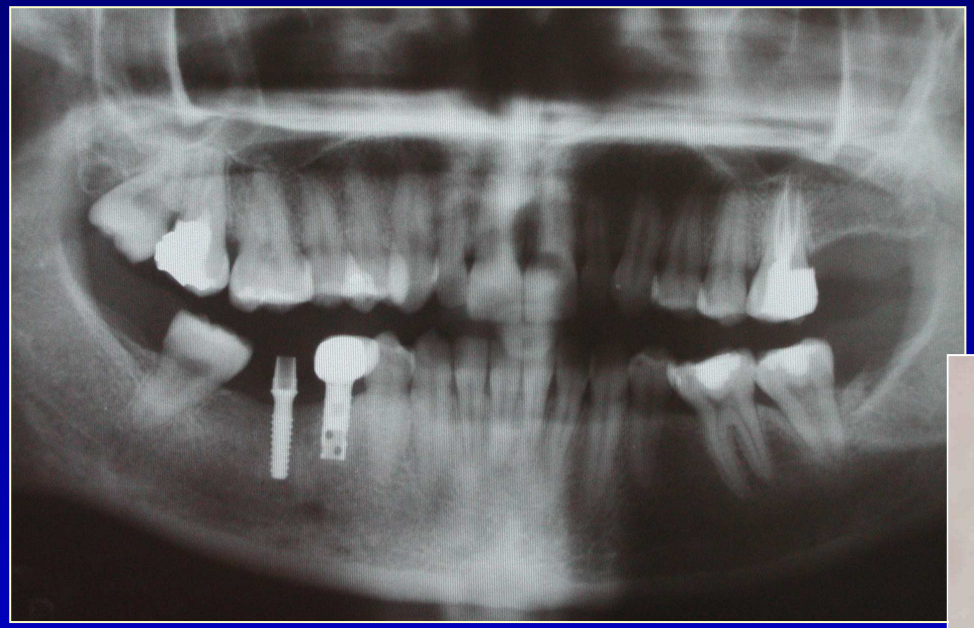
Case Report No.3

Combination of classical implant Timplant a Nanoimplant

- pacientka r. 1977
- Před 5 lety náhrada zubu 45 implantátem B22 + metalokeramická korunka.
- V cizině extrakce 46. Atrofie alveolu v transverzálním rozměru.
- Zaveden Nanoimplant A12 + 2 spojené metalkeramické korunky kotvené na B22 a A12.

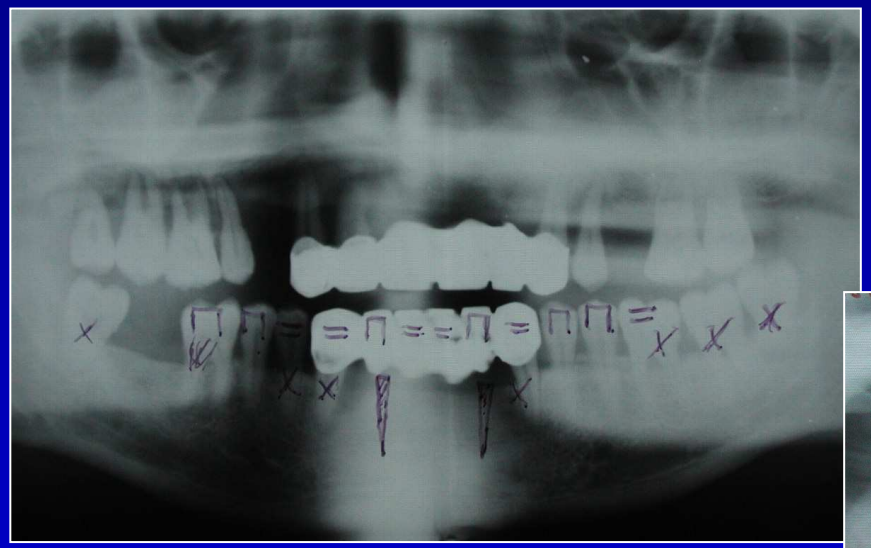
Case Report No.3

Combination of classical implant Timplant ® a Nanoimplant®

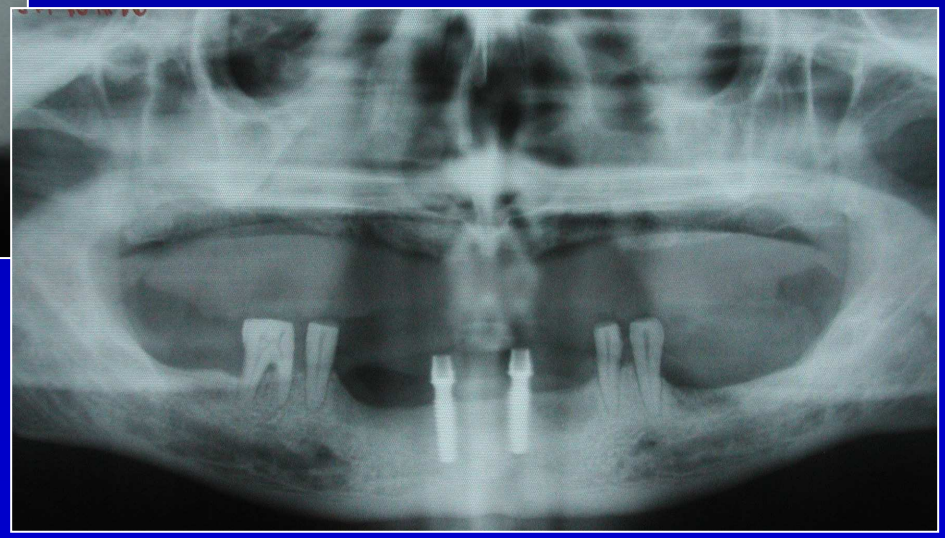


Case Report No.4

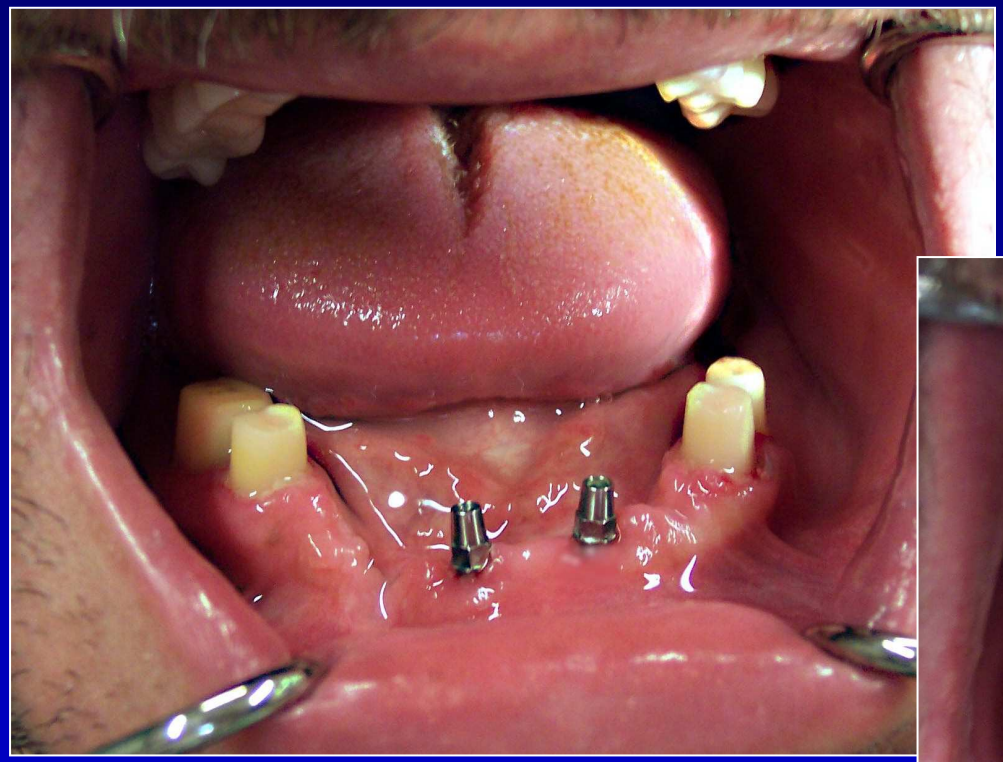
Combination of dental implants with own teeth



Ročník 1965
HTP
DPP



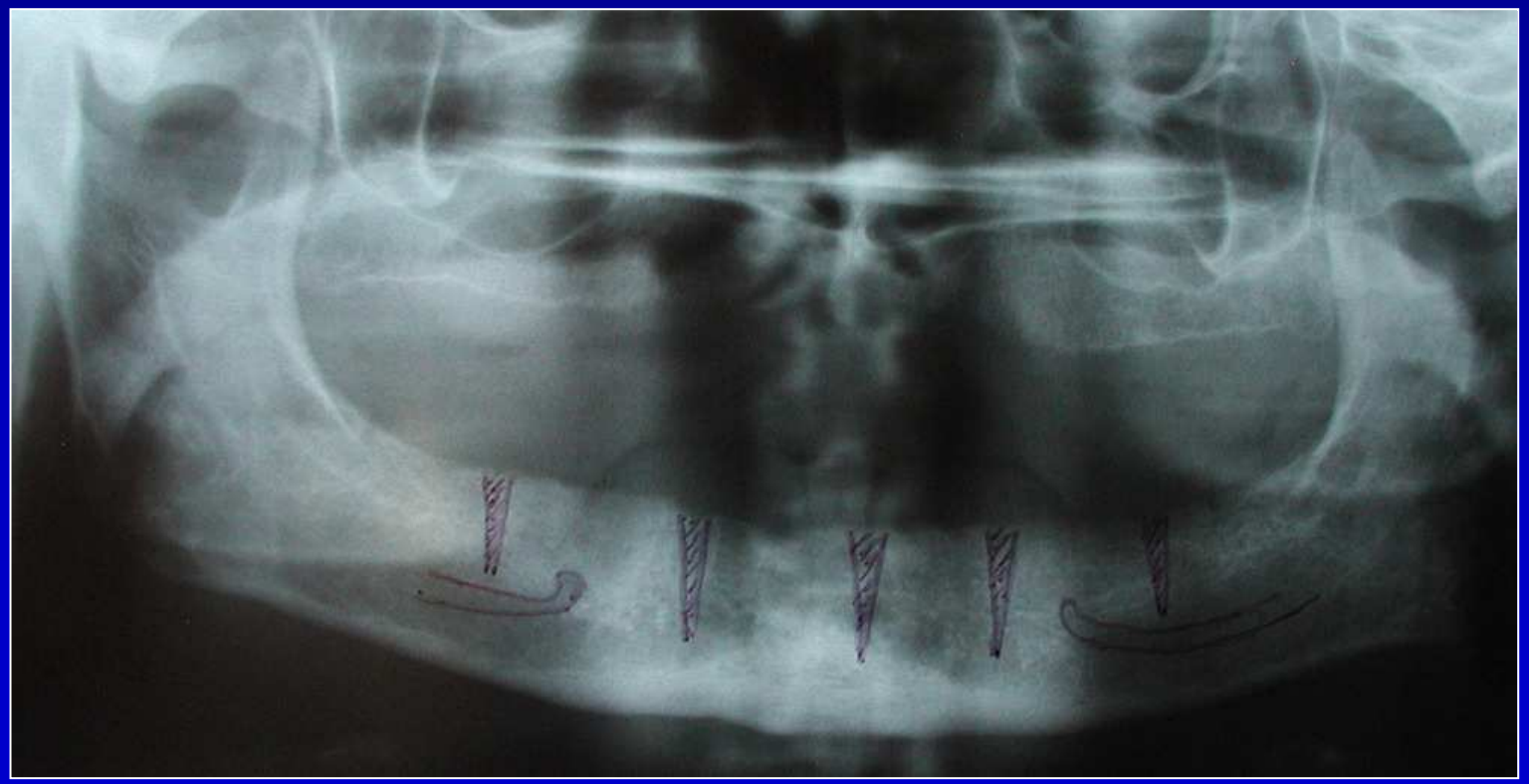
Case Report No.4



Case Report No.5

Immediately loaded implants

- Totální defekt DČ - pacientka r. 1947
- Dva roky HTP a DTP.
- Implantace 5 ks Nanoimplantů - v místě 36,46 – A10, 33, 43, 41 – A12.
- Ihned otisky. Provizorní suprastruktura do 2 hodin od operace.
- Po 3 měsících otisky na definitivní plošný metalkeramický most.

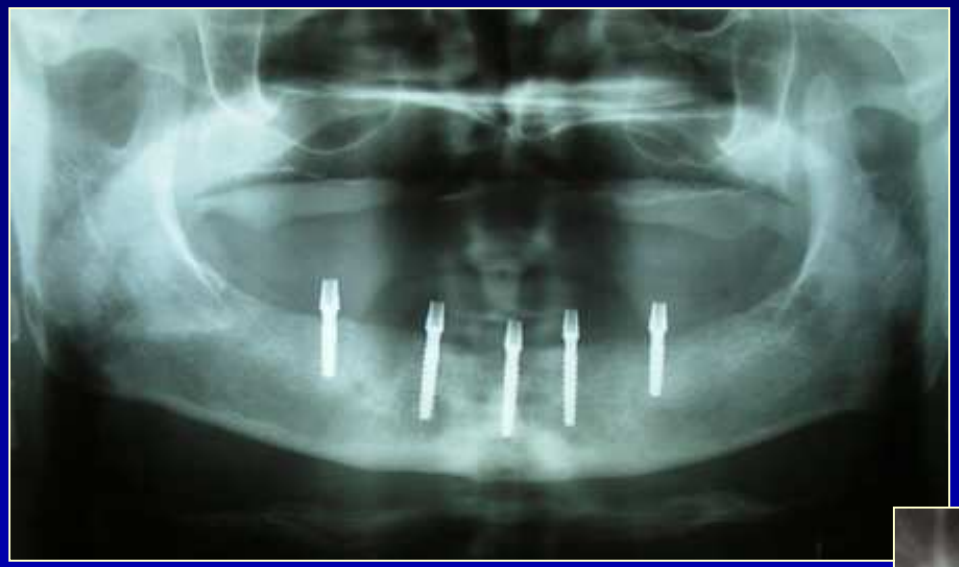


Case Report No.5

Immediately loaded implants

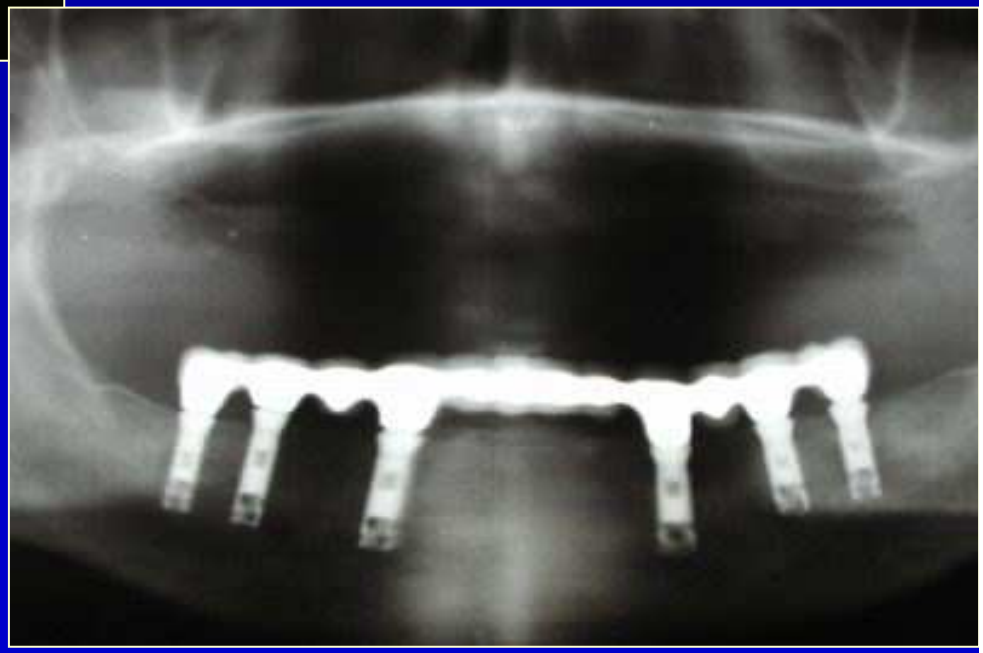
Case Report No.5

Immediately loaded implants



RTG kontrola po zavedení

Three years loaded classical implants – comparative x-ray ilustrate good size of bone



Case Report No.5

Immediately loaded implants

Case Report No.5

Immediately loaded implants

Temporary bridge

Case Report No.5

Immediately loaded implants – final situation

Literature

- 1. Davarpanah, M.- Martínéz, H.:Manuel d'implantologie clinigue
- 2. Hrušák, D. – Dluhoš,L. – Petruželka, J.: Nanoimplantát – implantát 3. tisíciletí. StomaTeam CZ 2/2006, ISSN 1214-147X, s. 2-3
- 3. Petruželka,J. – Dluhoš,L. – Hrušák,D. – Sochová,J.: Nanostrukturní titan – nový materiál pro dentální implantáty. Česká stomatologie a praktické zubní lékařství, 3/2006, ISSN 1213-0613, s. 72 – 77
- 4. Thomas J. Webster, Jeremiah U. Ejiofor: Increased osteoblast adhesion on nanophase metals:Ti, Ti6Al4V, and CoCrMo. Biomaterials 25 (2004) 4731–4739
- 5. Pictures: PerioGlas®; Davarpanah M. a kol.: Praktická impantologie, Praha 2005; Šimůnek, A. a kol.:Dentální implantologie, Hradec Králové 2001; web sites : www.youtube.com/watch?v=fXdKGwI0CYA, www.timplant.cz

Thank you for your attention