

Izzivi sodobne kolčne in kolenske endoprotetike

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BIOMATERIALI

- So v ospredju pomembnih napredkov v zdravstvenih vedah.
- Glede na starajoče se prebivalstvo in naraščajoče število kroničnih bolezni – glavni izzivi za sektor javnega zdravja.
- Povpraševanje po bolj sofisticiranih medicinskih izdelkih, se bo v prihodnjih letih pričakovano povečalo.
- Potreba po neprekinjenem raziskovanju.
- **Najsodobnejše tehnologije.**

Biomateriali so lahko sestavljeni iz kovin, keramike, polimerov ali naravnih materialov. Obstaja veliko primerov teh aplikacij:

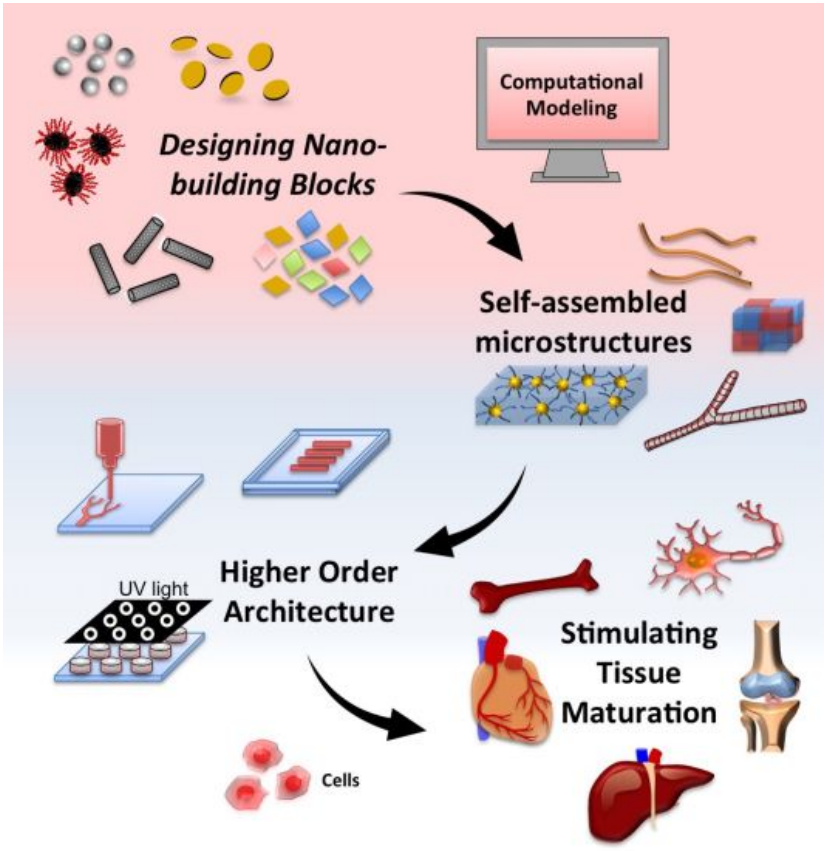
BIOMATERIAL

- The Materials Which are used for structural applications in the fields of medicine are known as biomaterials
- These materials are used to make devices to replace damaged or diseased body parts in human and animal bodies
- A variety of devices and materials are used in the treatment of disease or injury. Commonplace examples include suture needles, plates, tooth fillings, etc.

Biomaterial, Bio-implant / Bio-medical device:

Overview-

- Replace a missing biological structure
- Support a damaged biological structure
- Enhance an existing biological structure

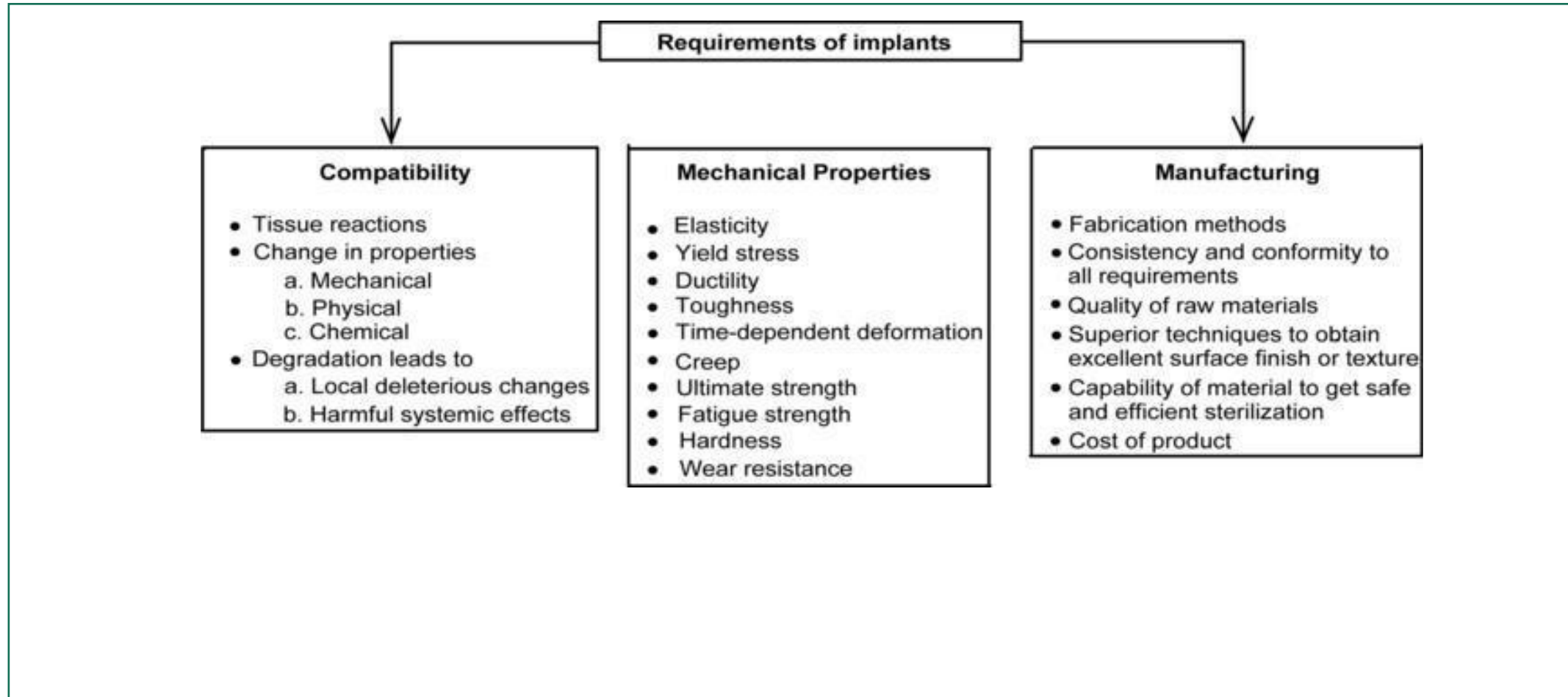


Finger joint silicone rubber	Breast implant silicones	Heart valve polyester, stainless steel
Hip joint titanium	Artificial heart polyurethane, metal	Intraocular lens (IOL) poly(methyl methacrylate)

Numbers of Medical Devices/yr. Worldwide	
intraocular lens	7,000,000
contact lens	75,000,000
vascular graft	400,000
hip and knee prostheses	1,000,000
catheter	300,000,000
heart valve	200,000
stent (cardiovascular)	>2,000,000
breast implant	300,000
dental implant	500,000
pacemaker	200,000
renal dialyzer	25,000,000
left ventricular assist devices	100,000

Millions of lives saved. The quality of life improved for millions more.
A \$100 billion industry

ZAHTEV ZA VSADKE



ENDOPROTETIKA

- Popolne zamenjave kolčnih in kolenskih sklepov so **trenutno najpogostejša in najuspešnejša metoda v napredni kirurgiji za zdravljenje degenerativnih boleznih sklepov**, lajšanje bolečin in odpravljanje deformacij.
- Približno 10% vsadkov odpove predčasno.

KOLČNA IN KOLENSKA ENDOPROTEZA

GLAVNI PROBLEM:

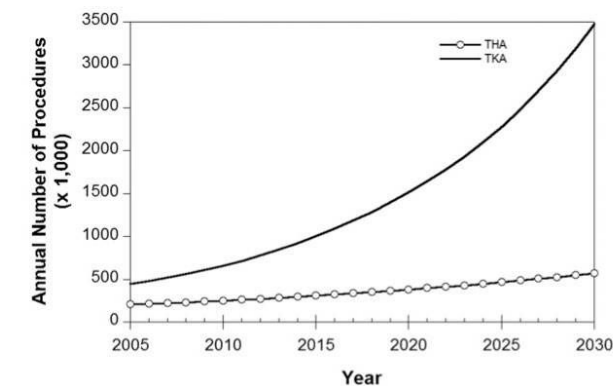
- bolečina
- omejen obseg gibanja
- šepanje
- deformacija
- razlika v dolžini nog



POJAVNOST:

- 200 do 300 tha/leto/ 100.000 prebivalcev (starih 50-90 let).
- 1m tha and 2m tka/ leto

The projected number of primary total hip arthroplasty (THA) and total knee arthroplasty (TKA) procedures in the United States from 2005 to 2030.



Kurtz S et al. J Bone Joint Surg Am 2007;89:780-785

KOLČNA ENDOPROTEZA

CILJI

- Zamenjava bolečega degenerativnega sklepa z biomateriali je doseči dolgoročno funkcionalno dobro delujoč kolčni sklep, s čim manj trenja med zgibnimi površinami.

PROBLEM TRENJA

- Obrabni delci in bolezen zaradi delcev.



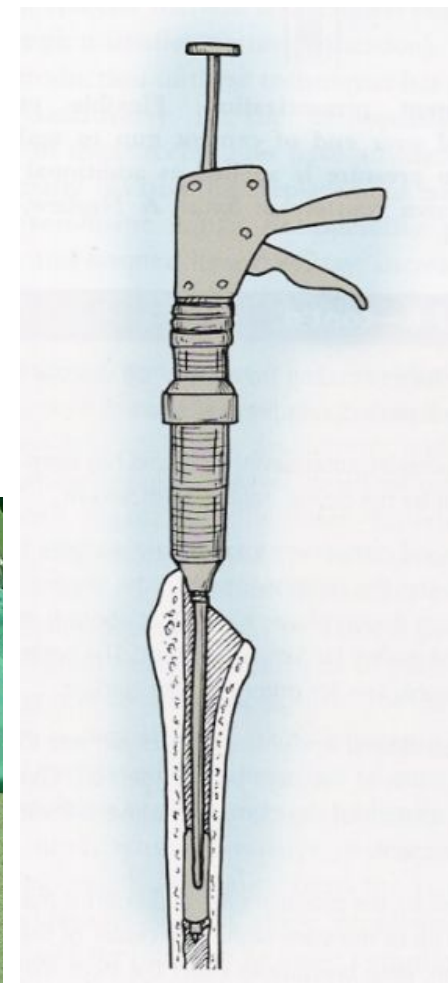
ZLATI STANDARD – Charnley THA

- Polietilenska ponvica.
- Nerjavna jeklena glava 22 mm.
- Nerjavno jekleno deblo.
- Pmma-polymethyl methacrylate.
- 77 % do 81 % preživetje po 25 letih spremljanja.



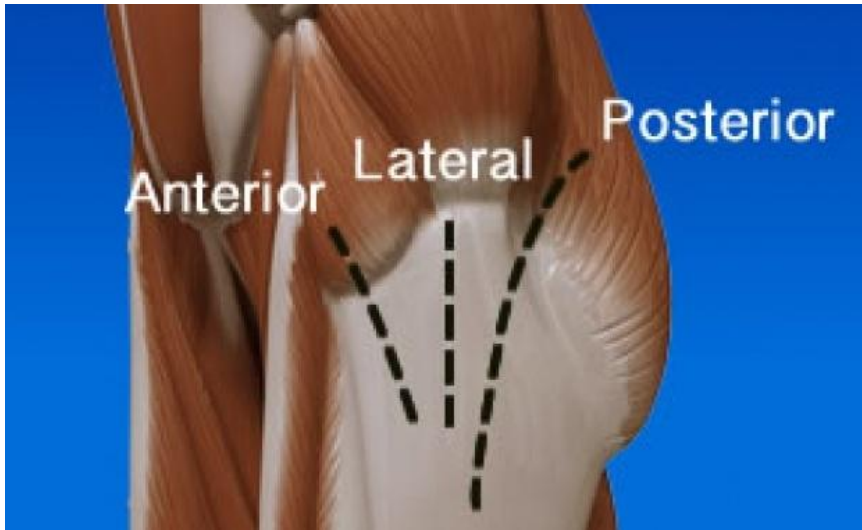
ALTERNATIVNE MOŽNOSTI, IZBOLJŠAVE

- Fiksacija komponent brez cementa v zgodnjih 80-ih.
- Izboljšan polietilen.
- Uporaba keramičnih materialov.
- Izboljšane tehnike cementiranja.
- Izboljšan cement z antibiotikom (gentamicin).

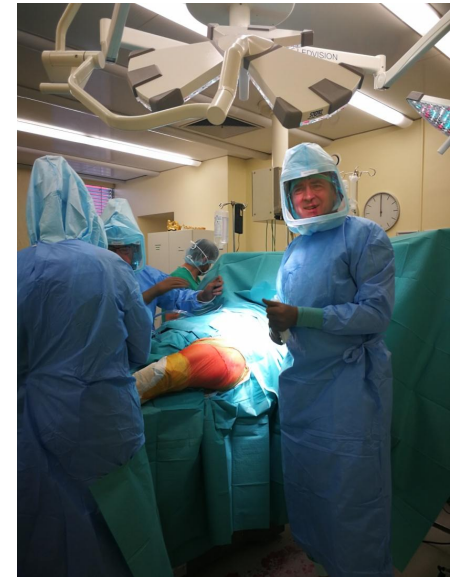


THA

- Izboljšana operativna tehnika



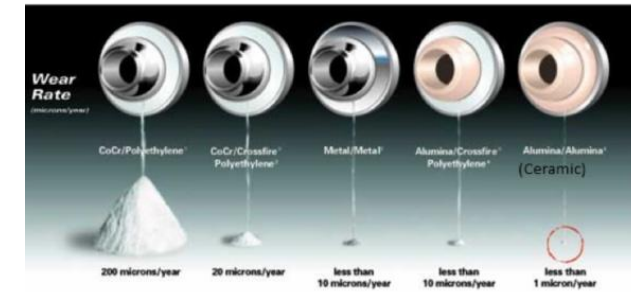
- Sodobne operativne zmogljivosti



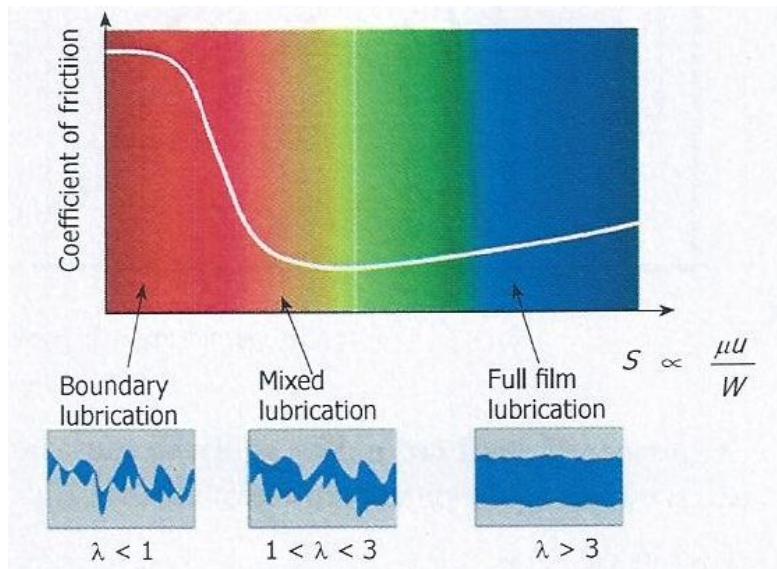
OBRABA, TRENJE, MAZANJE

Obraba glavni razlog za odpoved kolčnega vsadka (vnetne reakcije, osteoliza, omajanje vsadka).

- Mejno mazanje (neugodno glede na obrabo).
- Mešano mazanje.
- Mazanje s tekočinskim filmom (ugodno glede na obrabo).



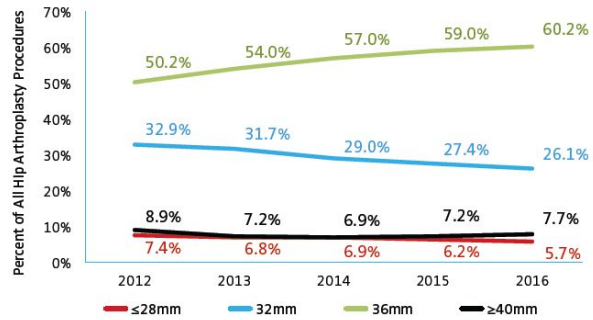
Puccio FD, WJO, 2015



Head/cup	h_{min} (μm)	R_a (μm)	λ	Lubrication regime
MoP	0.065-0.144 (0.105)	0.1-2	0.1-1	Boundary to Mixed
CoP	0.076-0.107 (0.092)	0.1-2	0.05-0.9	Boundary to Mixed
MoM	0.020-0.061 (0.041)	0.014-0.071	0.6-2.9	Boundary to Mixed
MoM _{RHR}	0.082-0.049 (0.066)	0.014-0.071	0.9-4.6	Boundary to Fluid-film
CoC	0.035-0.045 (0.04)	0.0014-0.0071	5.7-28.3	Fluid-film

OBRABA, TRENJE, MAZANJE

Figure 21: Femoral Head Sizes Implanted by Year
(N=251,324)

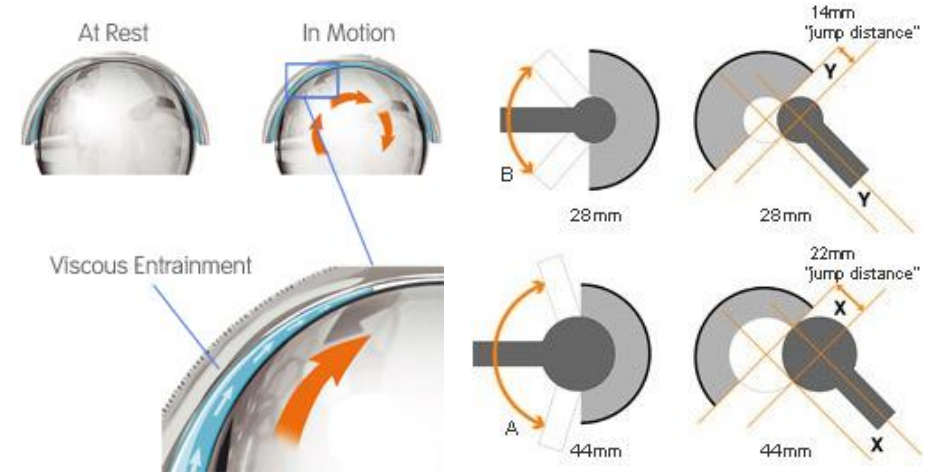


* Femoral head analyses do not include unipolar or bipolar heads used in hemiarthroplasty.

American Joint Replacement
Registry

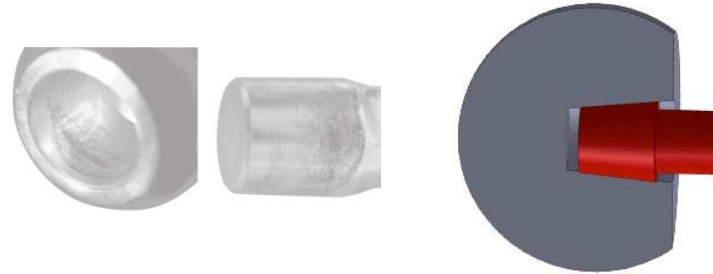
2017 Annual Report Figures

Published November 2017



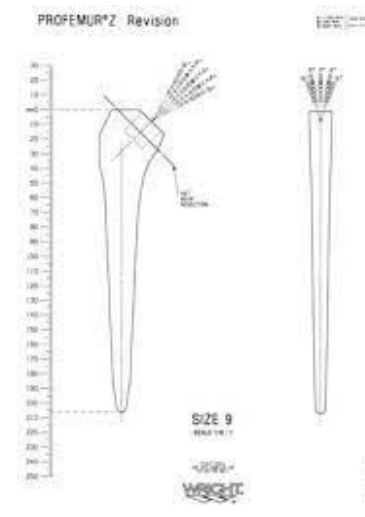
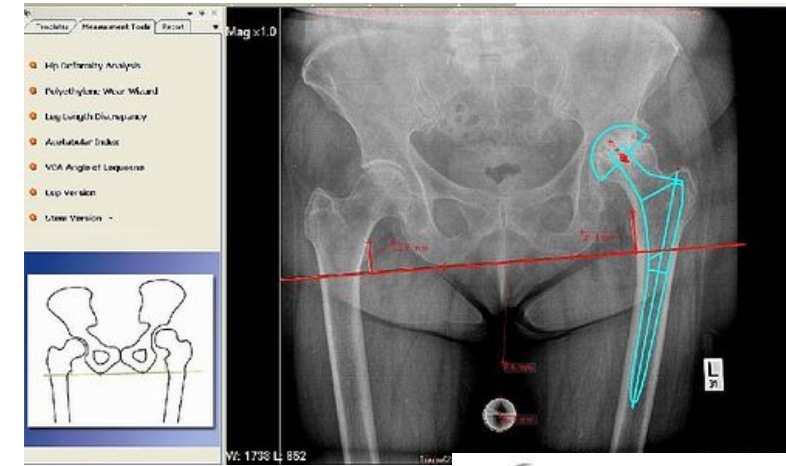
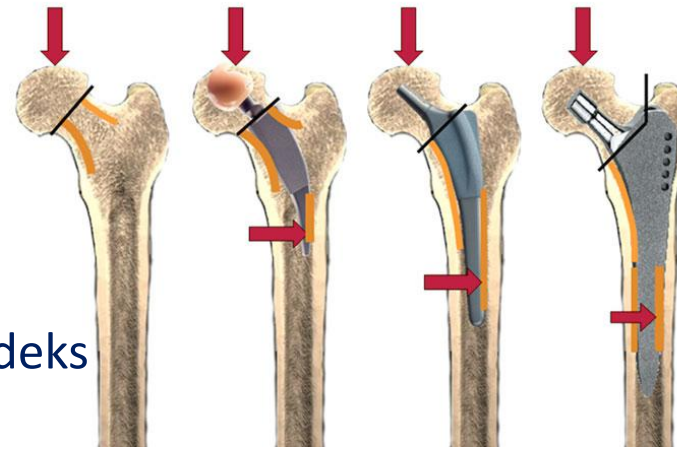
POVEČANJE VELIKOSTI GLAVE:

- ↑ Mazanje, rom, stabilnost
- ↑ Torzija zaradi trenja > ↑ obremenitve na konusnih in stiku vsadka s kostjo
- ↑ Obraba polietilena zaradi daljše drsne razdalje na korak

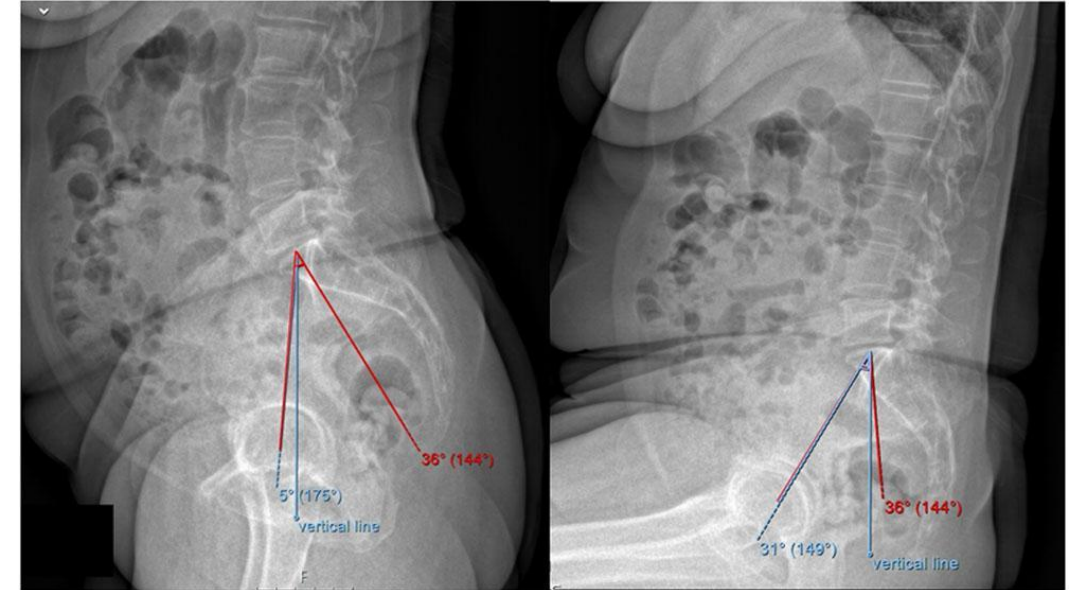
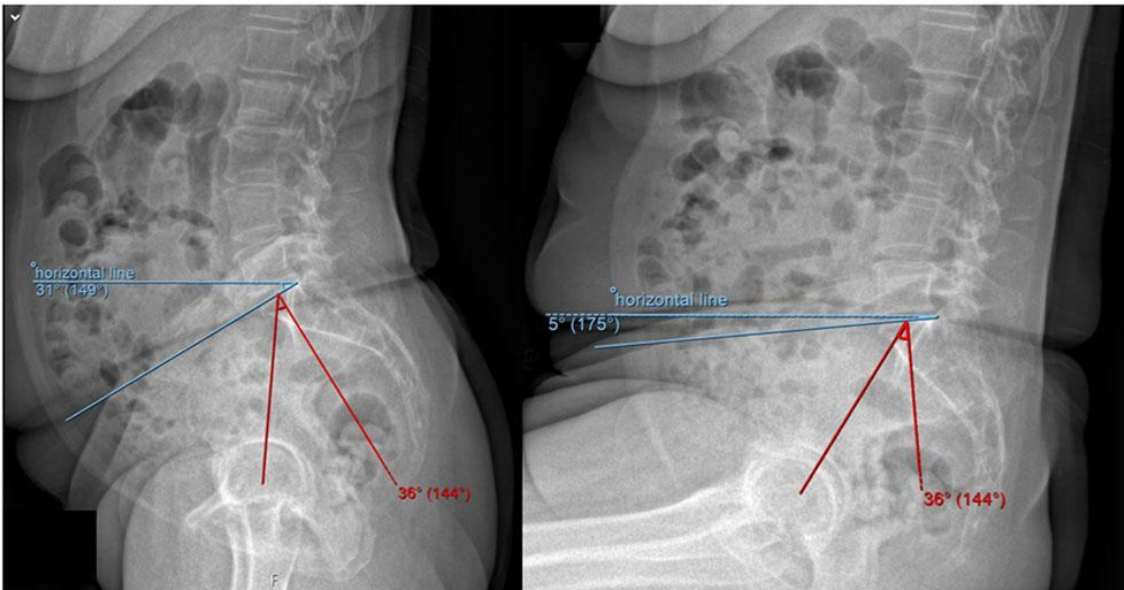
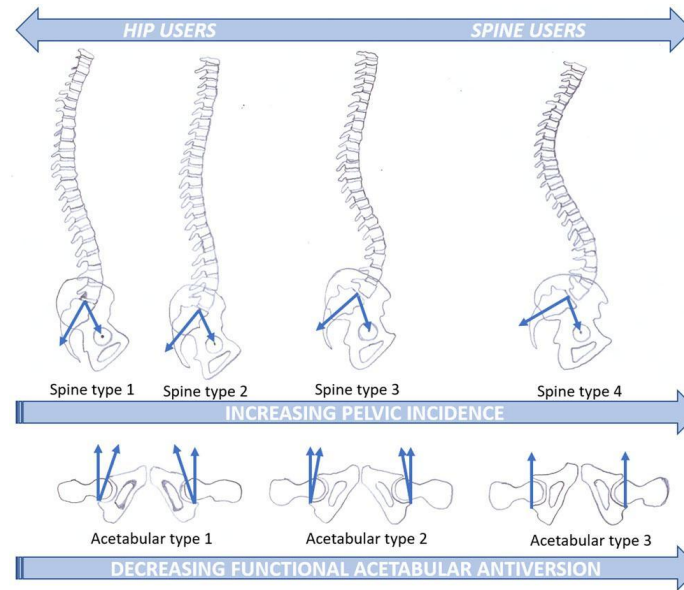


THA – OBNOVA NORMALNE ANATOMIJE KOLKA

- Središče rotacije.
- Femoralni odmik.
- Izbira vsadka (najboljše prileganje stegneničnega in acetabularnega dela) – indeks polnjenja kanala.
- Izenačitev dolžine okončin.



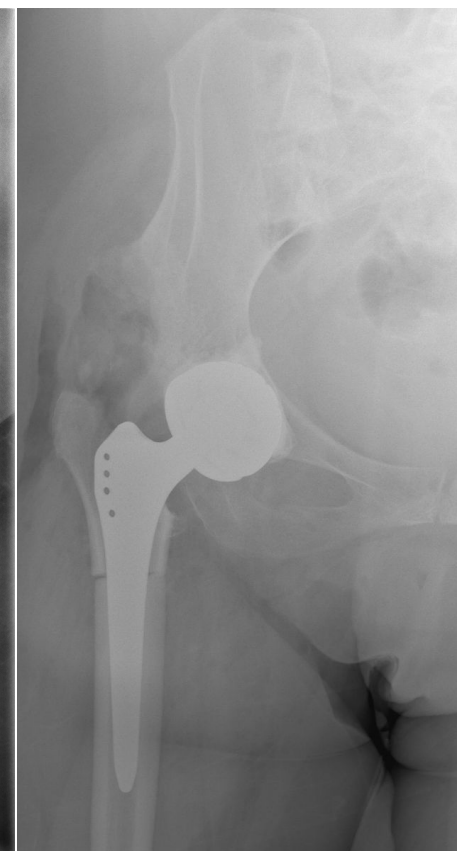
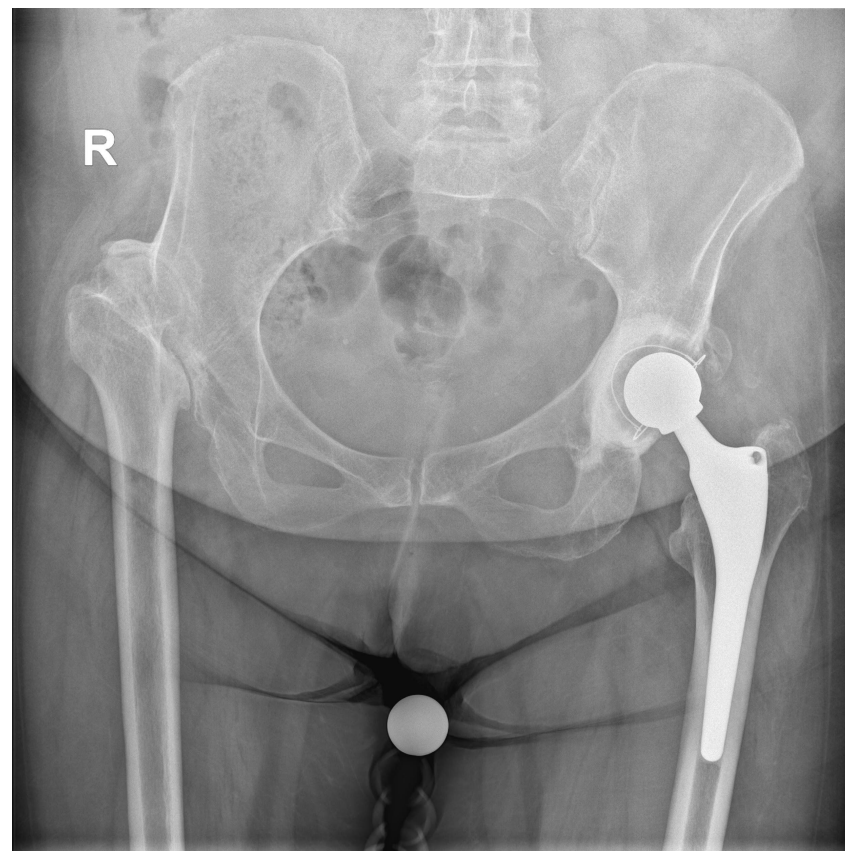
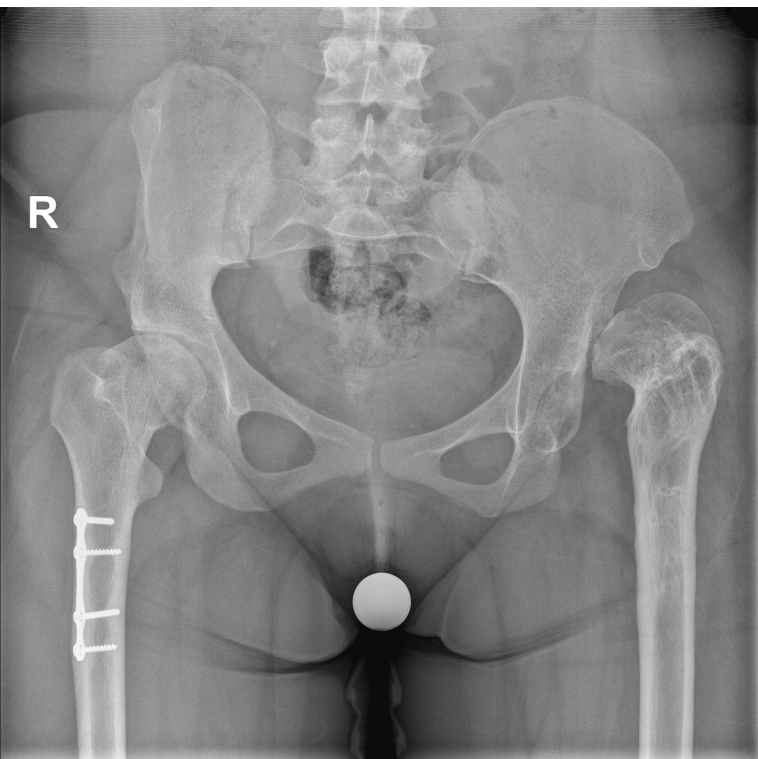
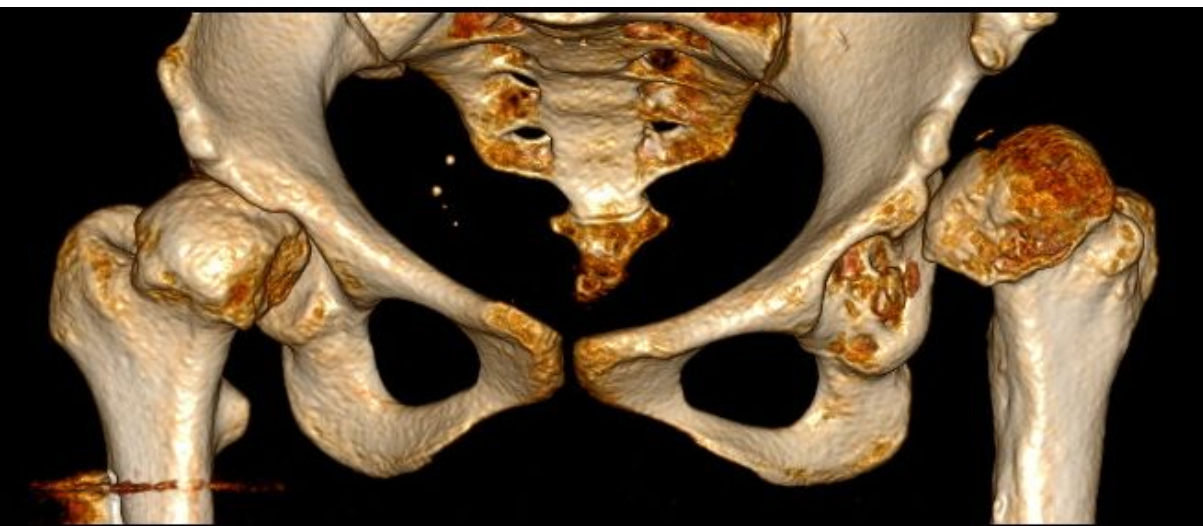
Pomen Spino - pelvično razmerja na vgradnjo kolčne endoproteze

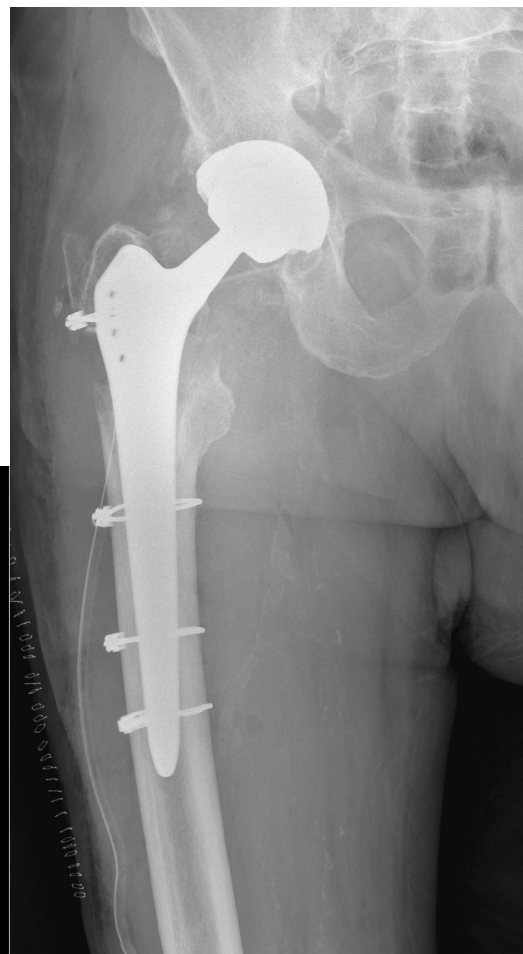
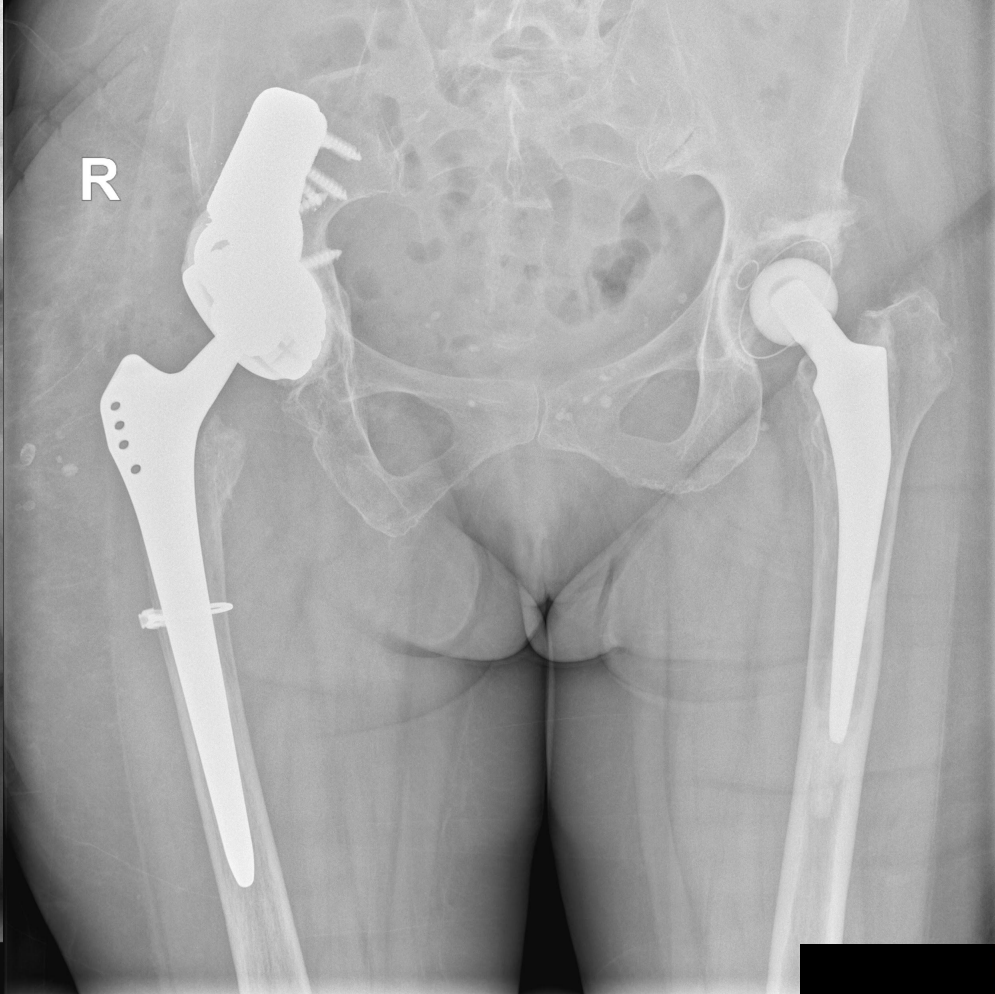


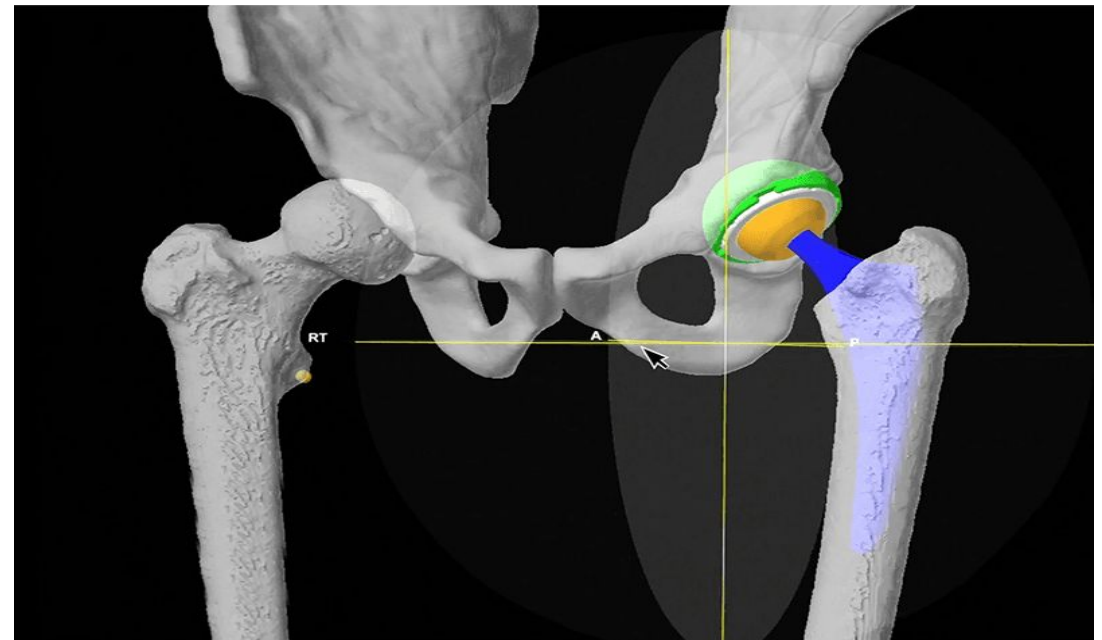
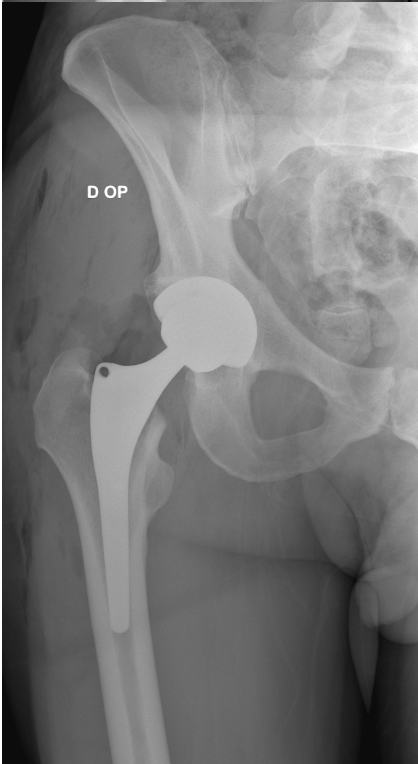
BIOMEHANSKI VIDIKI



- 1-2 milijona korakov na leto.
- 3-6x telesna teža zaradi abduktorjev → 7-8x pri športnih aktivnostih.
- Spuščanje po stopnicah povzroči najvišjo reakcijsko silo v sklepu (jrf).
- Abduktorji zagotavljajo dve tretjini sile kolčnega sklepa, vzporedno z dolgo osjo stegenice.
- Povečanje stegneničnega odmika in medializacija čašice zmanjšujeta reakcijsko silo sklepa s povečanjem vzvodne ročice abduktorjev.

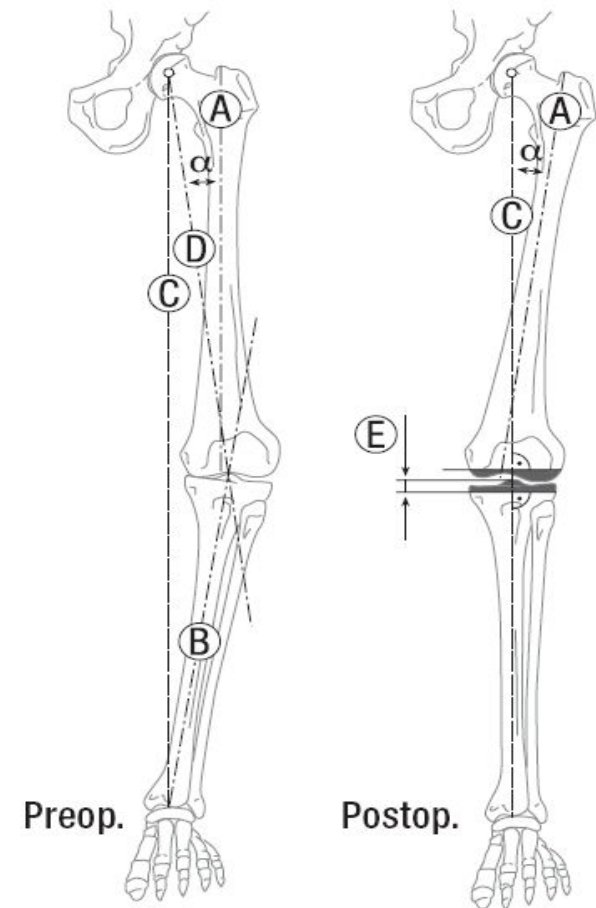
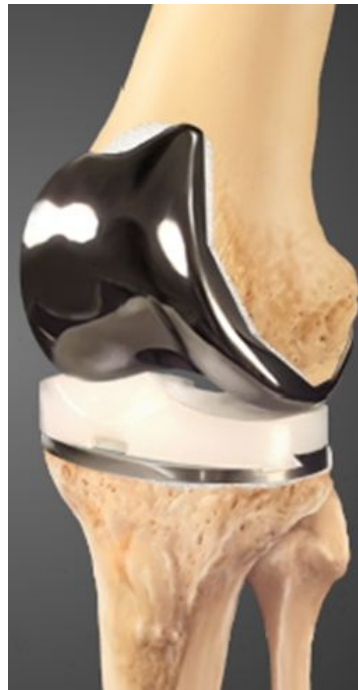
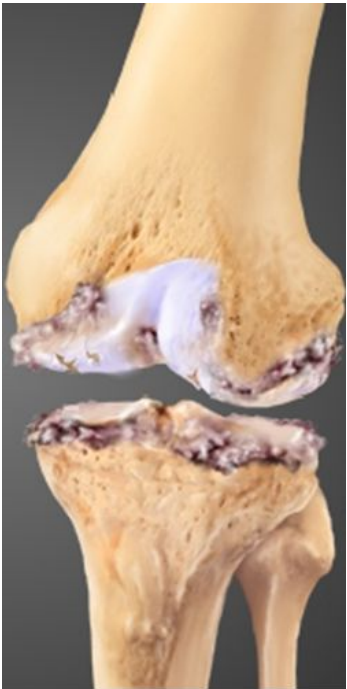






Kolenska endoproteza

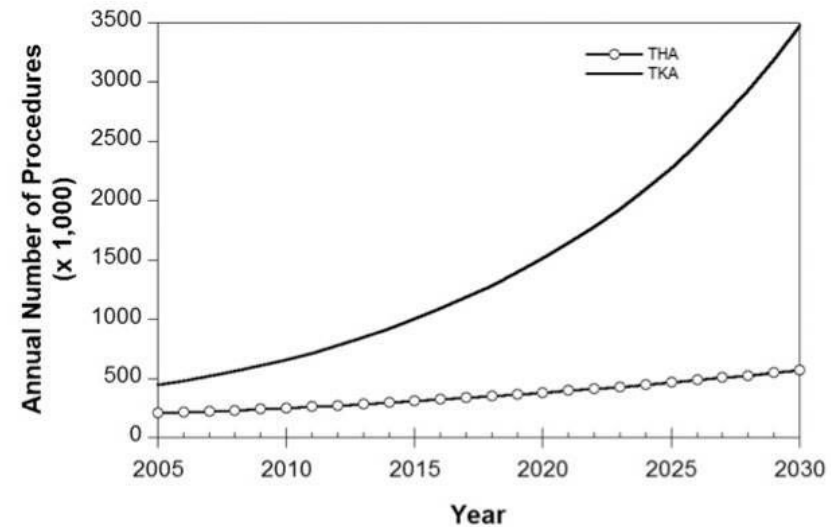
- Rekonstrukcija mehanske osi kolena.
- Uravnoteženje ligamentov, stabilno koleno v fleksiji in ekstenziji, brez bolečin pri gibanju.
- Gibljivost od 0 do 120°.



- G. John n insall, v zgodnjih 70-ih letih utemeljitelj sodobne kolenske endoprotetike.
- **10 letno** preživetje **95%** (graves et al. 2013, njr 2013) število vstavljenih tep kolena se večja **kolk : koleno= 5 : 4** (v slo leta 2019 vgrajenih 2841 tep in 358 pep kolena).
- Najprimernejša starost med 60 in 80 let.



The projected number of primary total hip arthroplasty (THA) and total knee arthroplasty (TKA) procedures in the United States from 2005 to 2030.

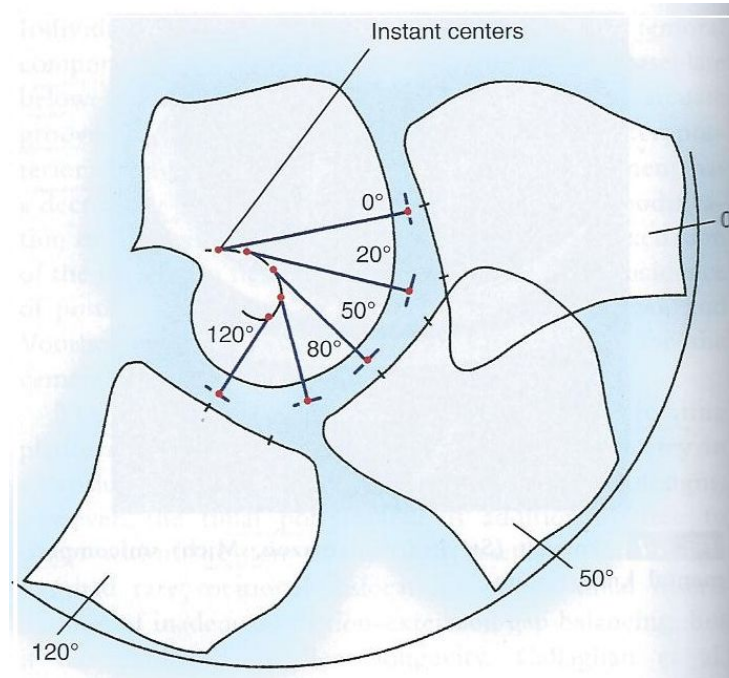
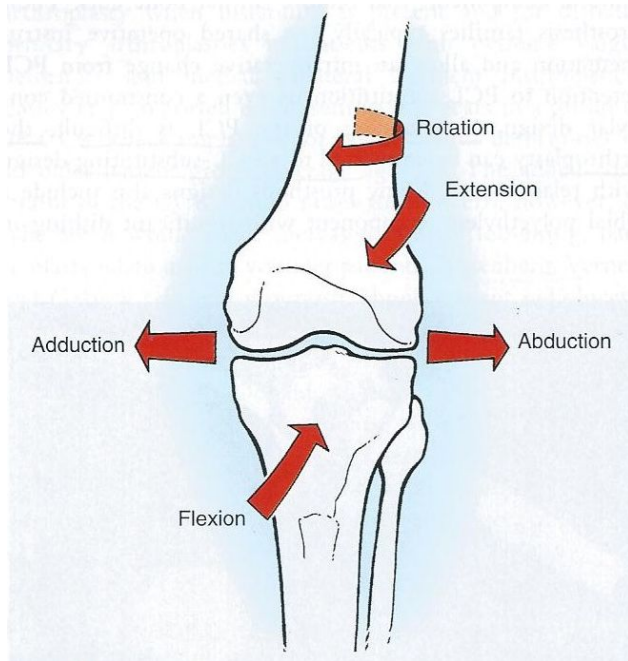


Kurtz S et al. J Bone Joint Surg Am 2007;89:780-785

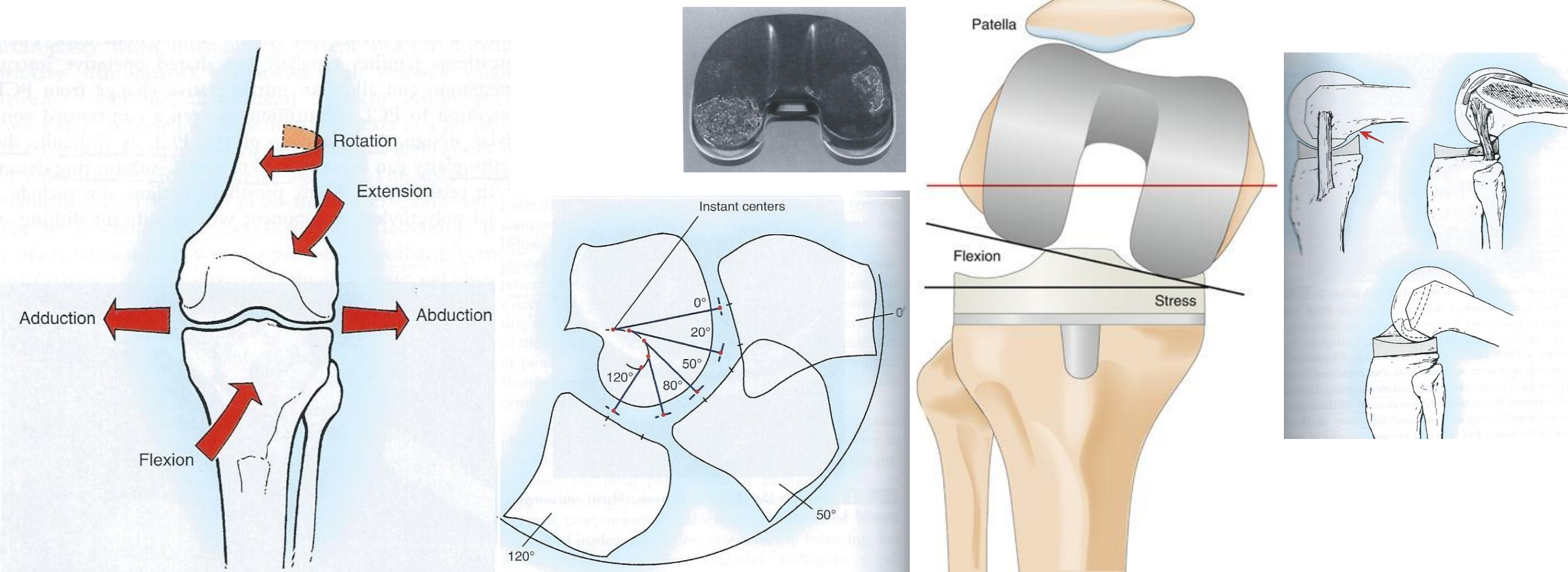
ANATOMIJA IN BIOMEHANIKA KOLENA

Gibanje kolena med hojo: veliko bolj zapleteno kot preprosta fleksija in ekstenzija.

Biomehanika kolena: veliko bolj zapletena kot pri kolčnem sklepu.

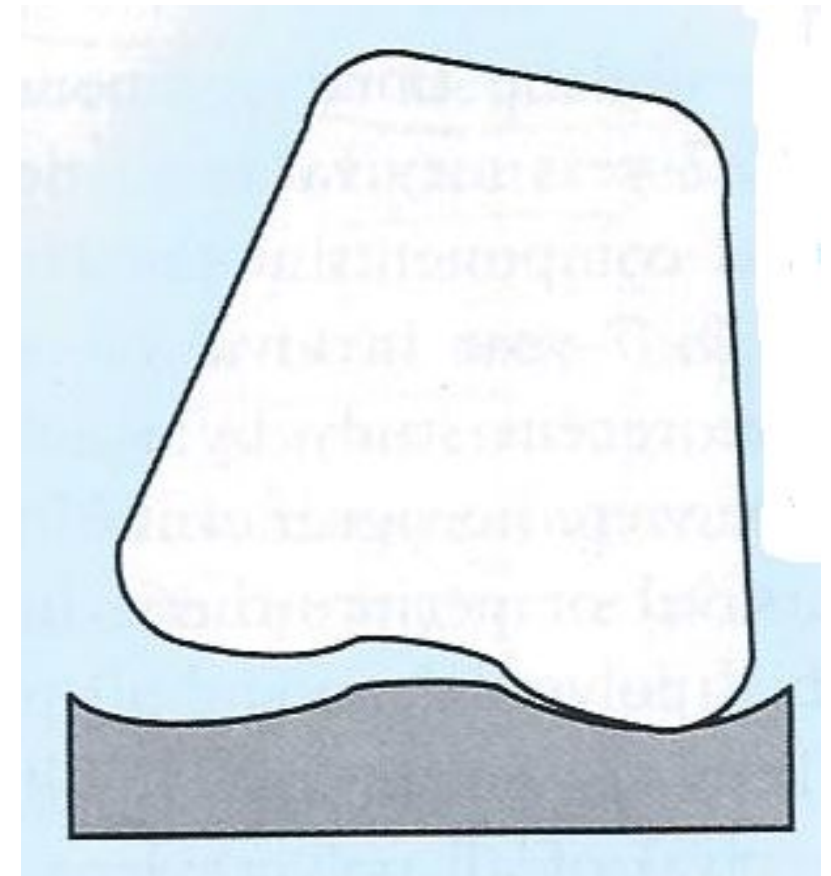
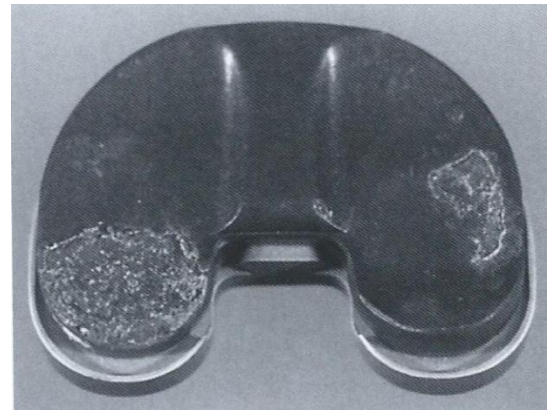
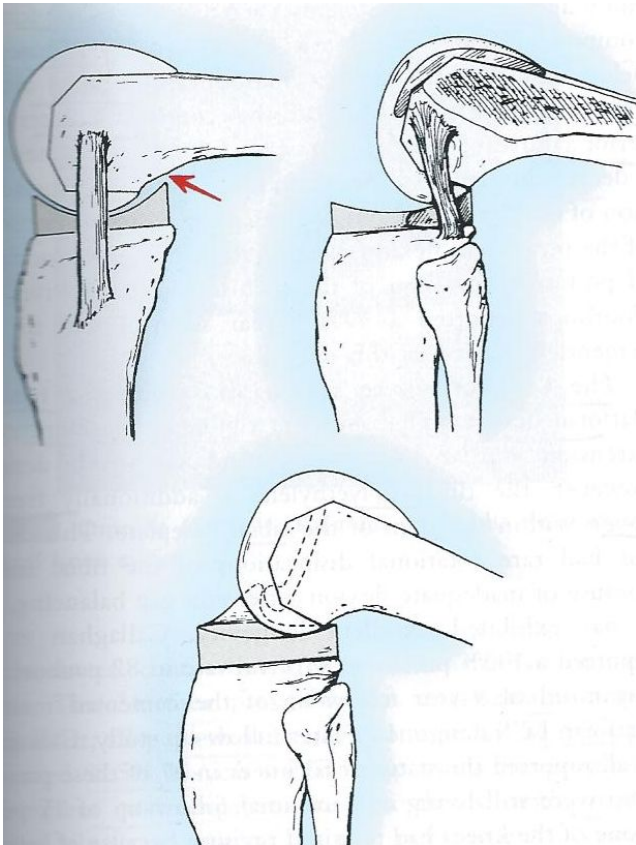


- Do **20% bolnikov** ni zadovoljnih z izidom posega **1 leto po op** (*bourne et al. 2010, klit et al. 2014*).
- Natančna uravnava položaja komponent TKE v frontalni, sagitalni in transverzalni ravnini.



OBRABA IN KLINIČNE TEŽAVE PRI TKA

Pogosto v povezavi z nepravilno kirurško tehniko in neustreznim mehkovtkivnim uravnoteženjem.



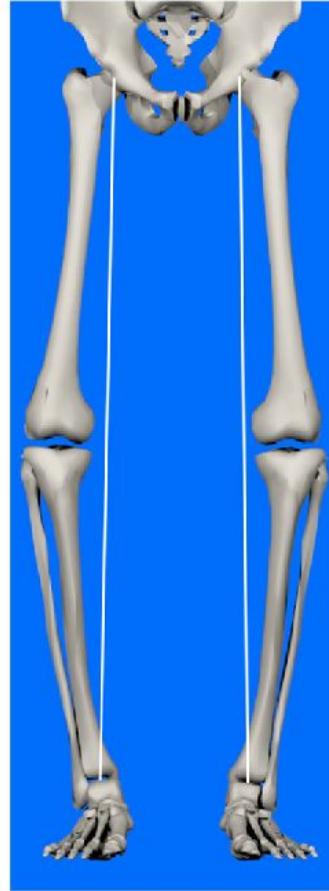
Tehnike uravnave komponent TKE

Constitutional alignment



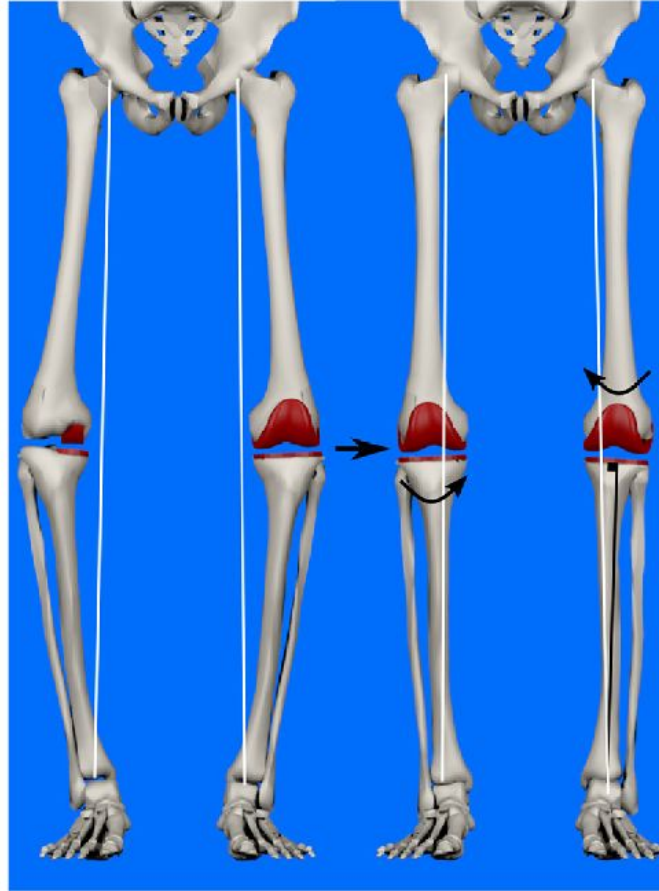
Patient-specific
Alignment techniques

UKA KA



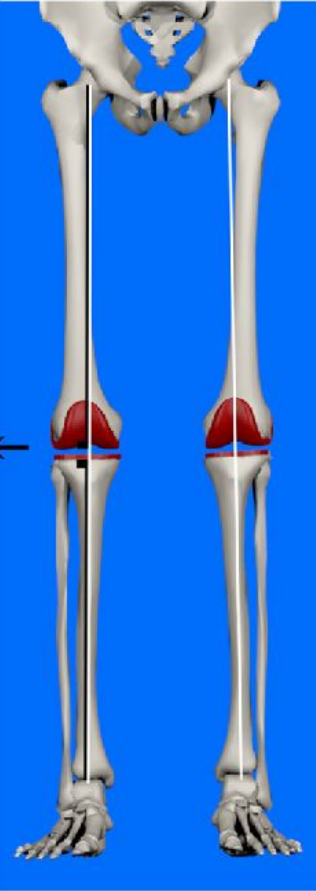
Hybrid
Alignment techniques

rKA aMA



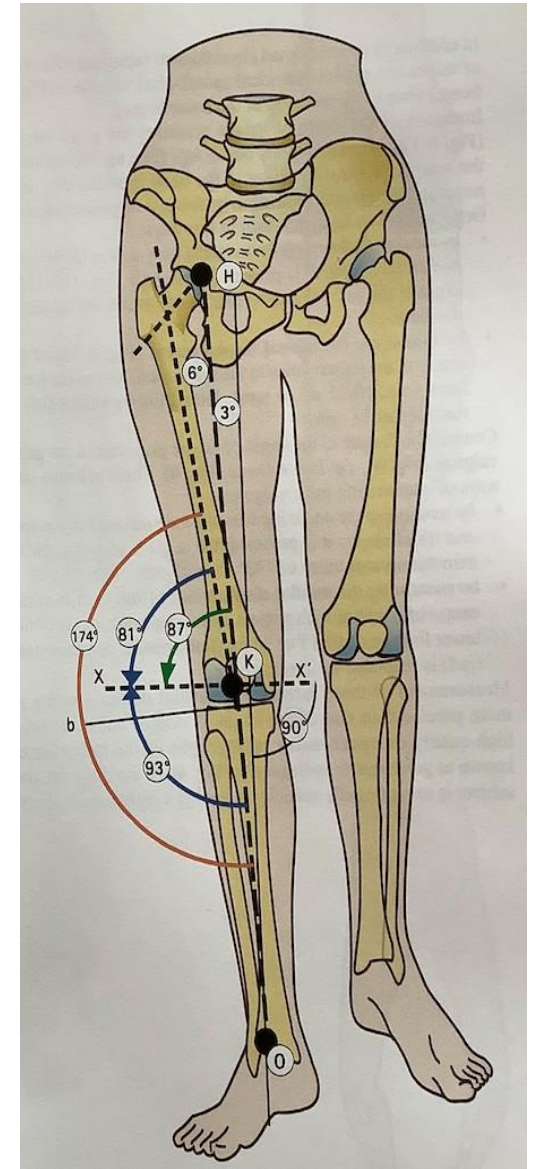
Systematic
Alignment techniques

MA AA



Tehnike uravnave komponent TKE

Systematic alignment	Mechanical (standard) MA	<p>Coronal plane: neutral mechanical axis, extension gap</p> <p>Sagittal plane: Femur (extension/flexion), Tibial slope (flexion gap)</p> <p>Axial plane: aligning the femoral component with the TEA</p>
	Anatomical AA	<p>Systematic oblique joint line (2-3° valgus) relative to mechanical axis</p> <p>Promotion of a better load distribution on the tibial component</p>
Patient-specific alignment	Kinematic KA	<p>„True knee resurfacing“ (fully anatomic positioning of implants)</p> <p>Patient specific and ligament sparing</p>
Hybrid alignment	Adjusted mechanical (constitutional residual malalignment) aMA	Adaption of conventional mechanical with the goal to under-correct the constitutional frontal deformity (varus/valgus) to a maximum of 3°
	Restricted	Use of computer navigation or PSI to assess limb and femoral and tibial components frontal alignment for



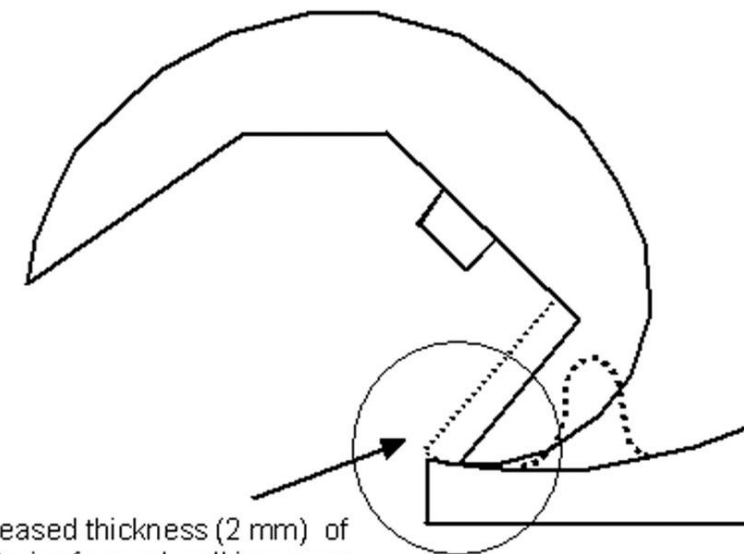


GIBLJIVOST (konstrukt proteze)

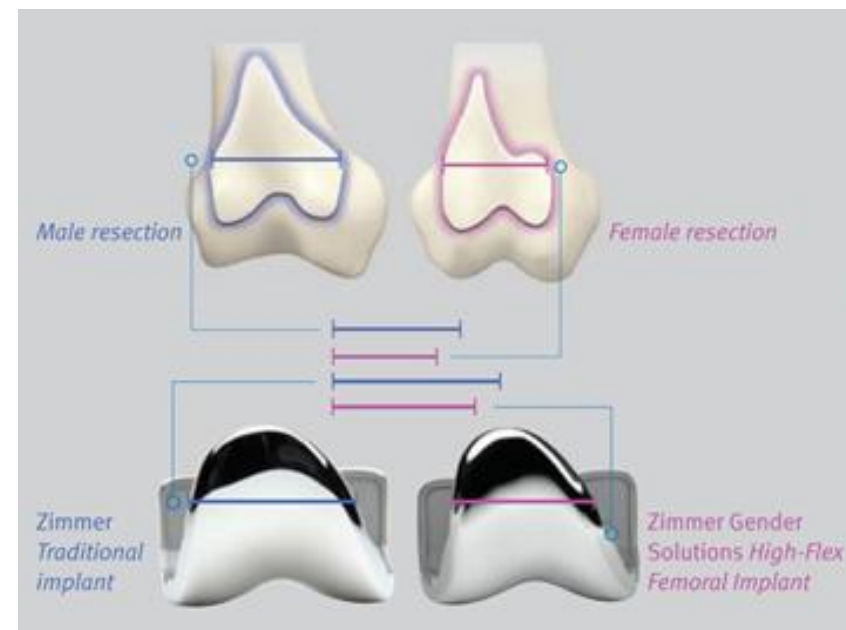
- stopnice 90-120 °
- kopalna kad 135 °
- počep 165 °
- klečanje pri molitvi 150 °

VLOGA SPOLA

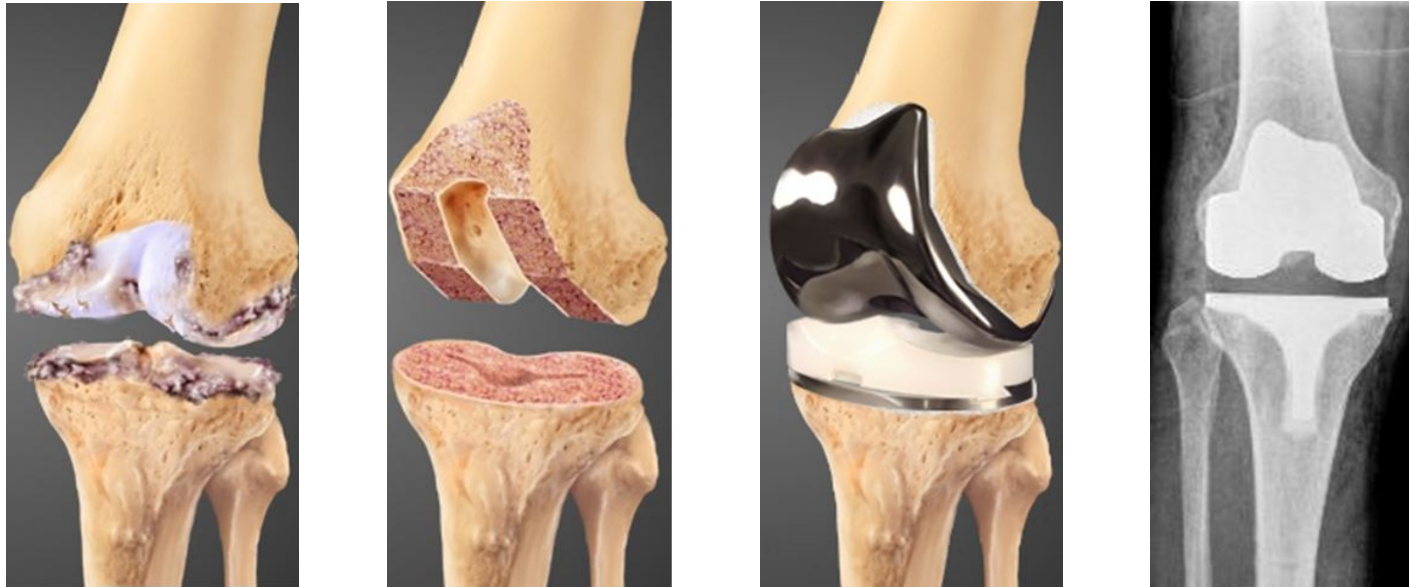
- 75% pacientov so ženske (Slo 2019 65%)
- femur manjše razmerje m/l in a/p
- večji q kot



Increased thickness (2 mm) of posterior femoral wall improves tibiofemoral contact at high flexion



ZLATI STANDARD

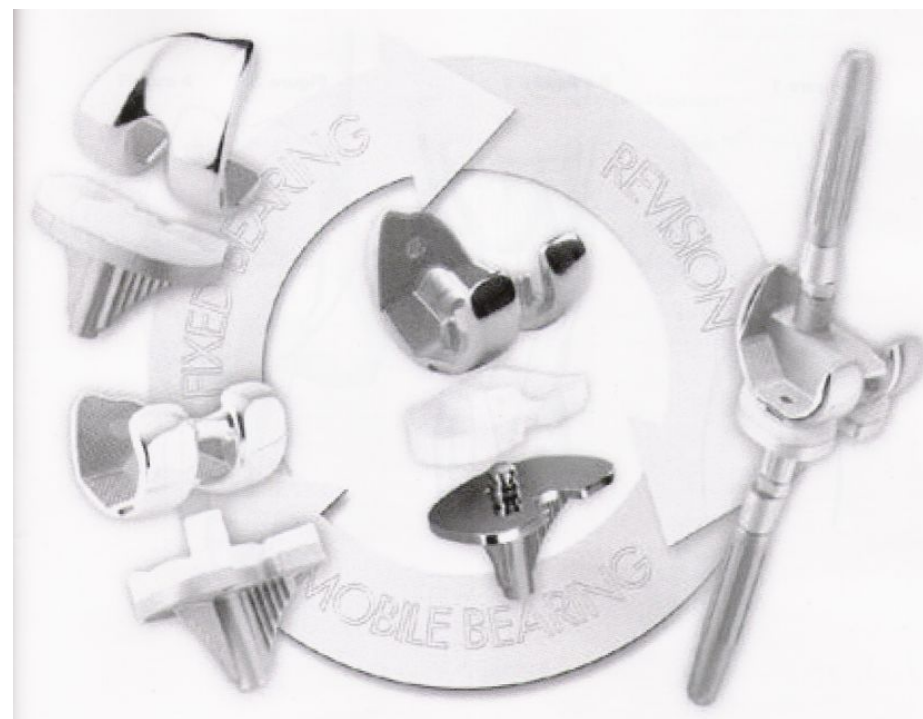


Sodobna cementna kolenska endoproteza:

- **Chrome cobalt femoralna komponenta** s sprednjim žlebom za artikulacijo pogačice.
- **Dvojno zaobljena sklepna površina tibijalnega polietilenskega vložka** skladna s femoralno komponento.
- **Tibiajalna komponenta:** metafizno deblo, prvotno v celoti poli, sedaj kovinska (titan ali CoCr zlitina), ki omogoča enakomernejši prenos obremenitev na metafizno kost.
- **Prvotna zasnova:** preživetje 94% pri 15-letnem spremljanju.

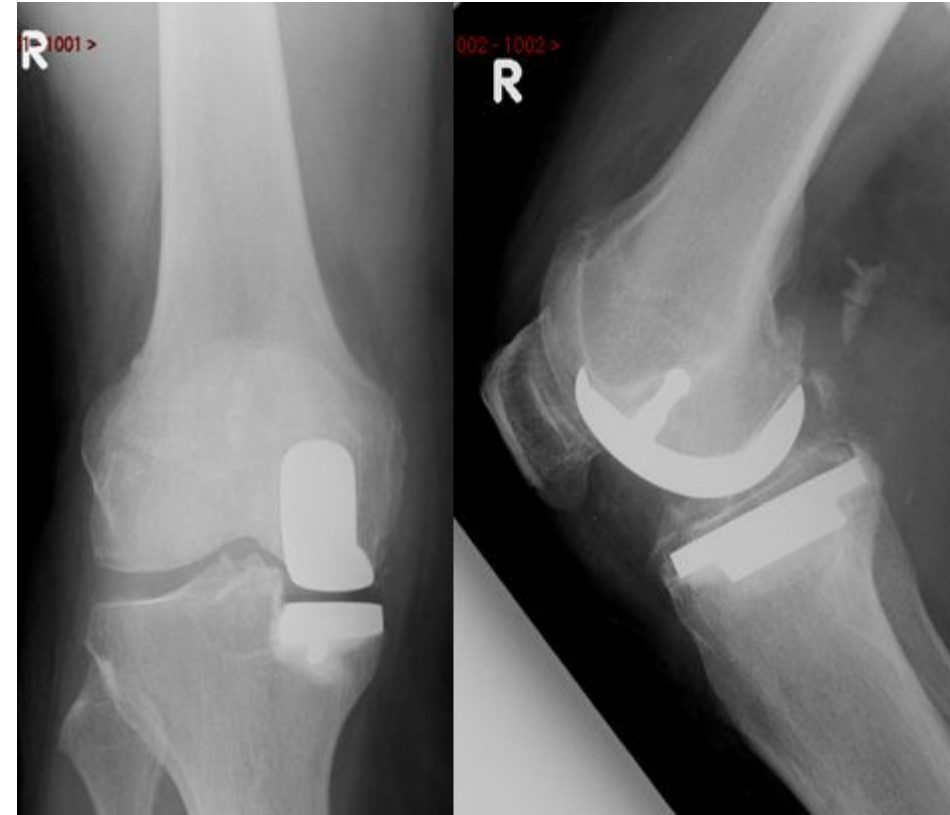
Kolenske endoproteze

Z izpopolnjenimi modeli kolenskih endoprotez se približujemo idealnemu modelu vsadka, ki mora zagotoviti **normalen** ali **skoraj normalen obseg gibljivosti v vseh treh oseh** (prosto drseča endoproteza), obseg gibov pa naj bi bil omejen z mehкими tkivi, posebno vezmi.



Sankasta ali enostranska endoproteza (unikondilarna)

- Prosto drseča (unconstrained) endoproteza.
- Za zamenjavo enega kondila stegnenice in tibije.
- Ligamentarno stabilno koleno z manj kot 10° varusa/valgusa.
- Običajno medialno.
- Pogačica in križne vezi ostanejo nedotaknjeni.

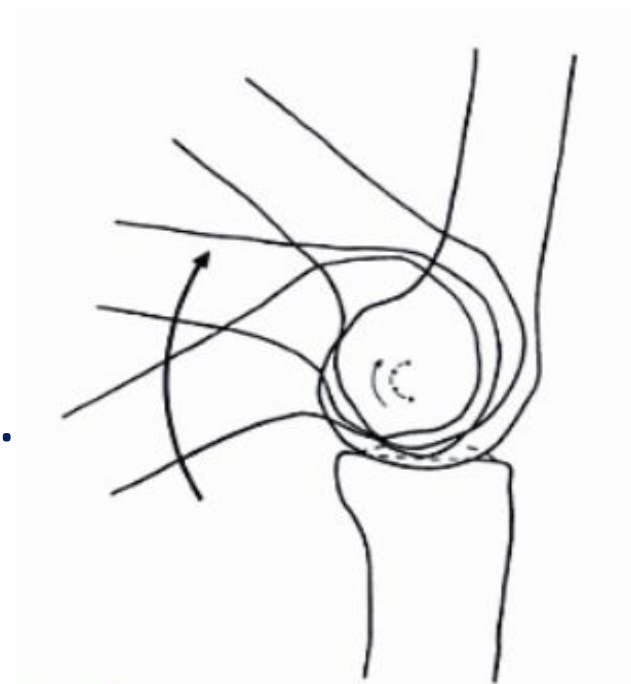


CR (cruciate retaining)

- Ohranja zadnjo križno vez, stabilnost ni vgrajena v protezo.
- Ligamentarno stabilno koleno.
- Stabilnost odvisna od ligamentov in mišic kolena.

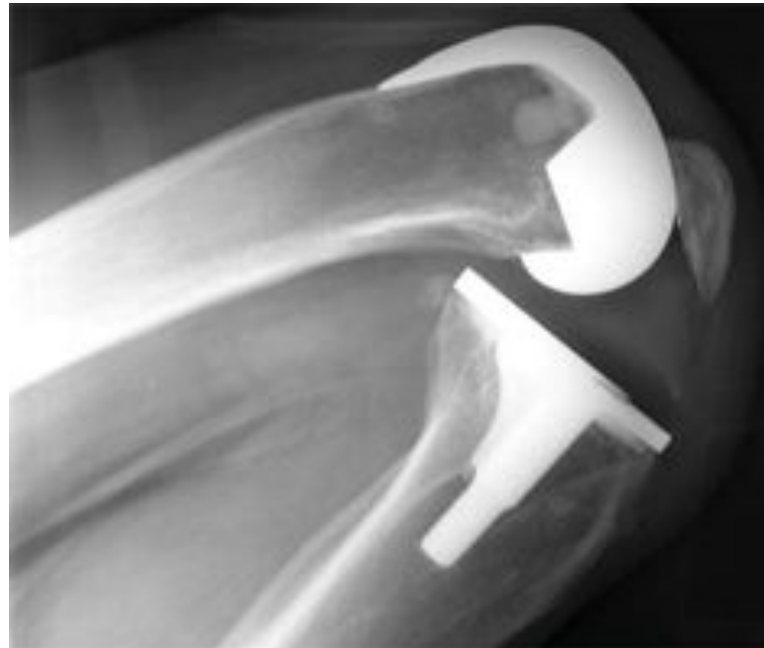
Delitev:

- o enoosna (single axis)
- o večosna (multiple axis).



PS (posterior stabilized)

- Odstranimo oba križna ligamenta.
- Stabilnost je vgrajena v protezo.
- Tibialna komponenta ima dvignjen del (centralni steber), ki se zatakne v femoralno komponento, kar prepreči pomik femurja navzpred pri pokrčenju kolena.



Constrained rotating knee - non hinged (nepovezana)

- Zasidrana intramedularno.
- Povišan centralni steber na tibialnem polietilenskem vložku, ki zadržuje femoralno komponento proteze in stabilizira protezo v smeri varus / valgus.
- Dopušča 10° rotacij pri flektiranem kolenu.
- Revizijska endoproteza, primarno pri veliki valgus deformaciji in ohlapnosti medialnega kolateralnega ligamenta.



Hinged

(povezana, vpeta šarnirska kolenska endoproteza)

- Zasidrana intramedularno.
- Tečaj, dopušča le fleksijo / ekstenzijo.

Primarna proteza pri:

- izraziti nestabilnosti kolateralnih ligamentov,
- hud varus / valgus - nad 30 stopinj,
- kostni defekt
- nevromuskularna obolenja (poliomiелitis), preprečitev hiperekstenzije (genu recurvatum)

Revizijska endoproteza (destrukcija kosti na mestu prejšnje endoproteze).



Možni zapleti in njihovo preprečevanje

- Zapleti pogostejši pri bolnikih s **SB, PAOB, BMI >30, predhodna operacija kolena, kadilcih.**
- **Okužba** - manj kot 1% .
- **Zgodnja intraoperativna okužba** (do 3 mesece po posegu), *staphylococcus aureus*.
- **Odložena intraoperativna okužba** (med 3 do 24 mesecev po operaciji) z nizko patogenimi bakterijami, najpogosteje *staphylococcus epidermidis*.
- **Hematogena okužba** (kadarkoli po operaciji).
- **Okvara živcev** (n.Peroneus, kožni živci).
- **Venska tromboza** - elastični povoji, nizko-molekularni heparin (35 dni
- **Pljučna embolija.**
- **Omajanje.**



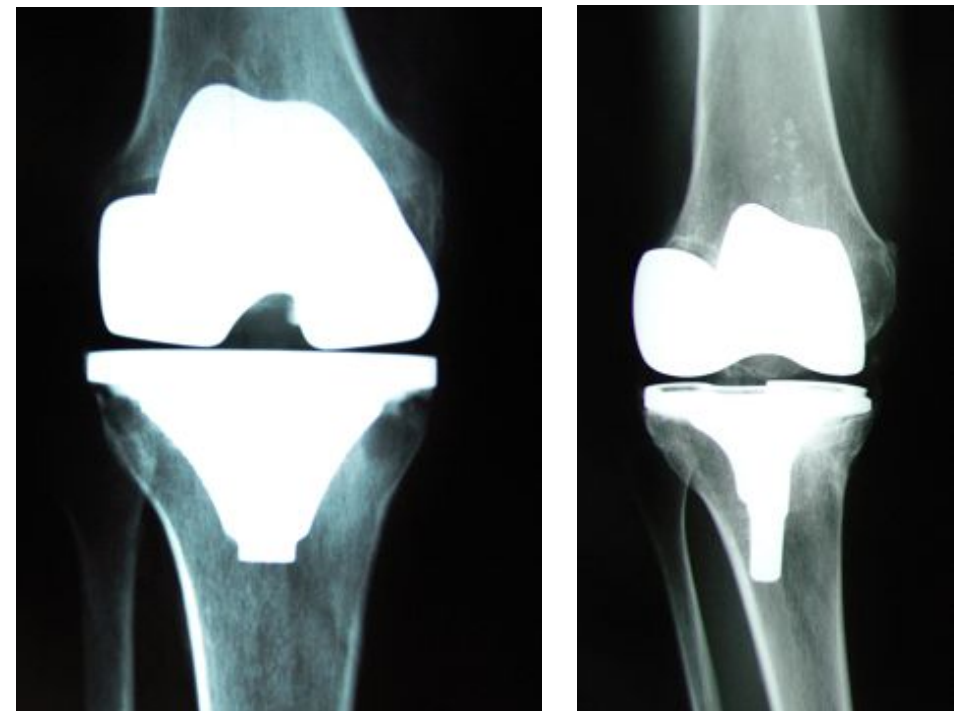
Rezultati

Potreba po revizijski operaciji:

- v roku 15 let - 4%.
- v roku 20 let - 22%.

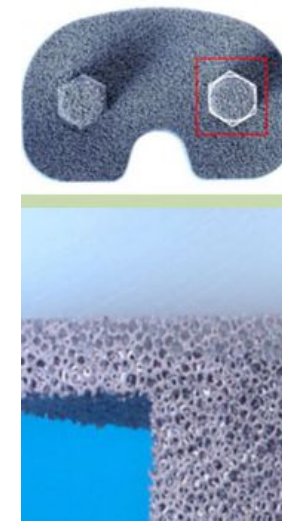
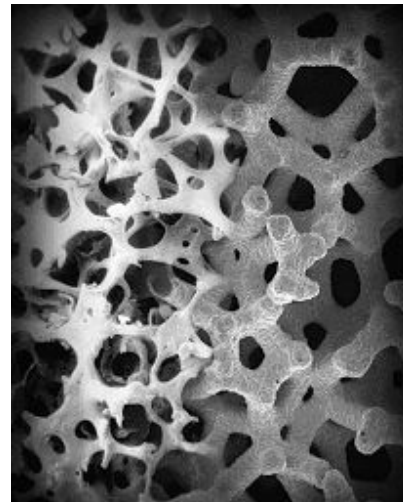
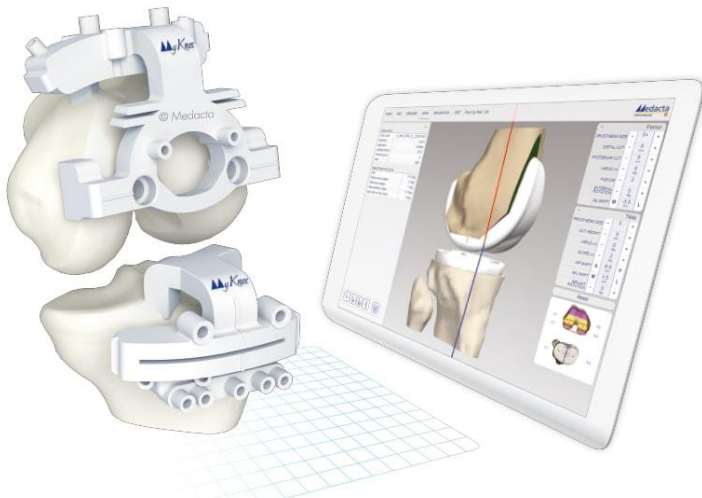
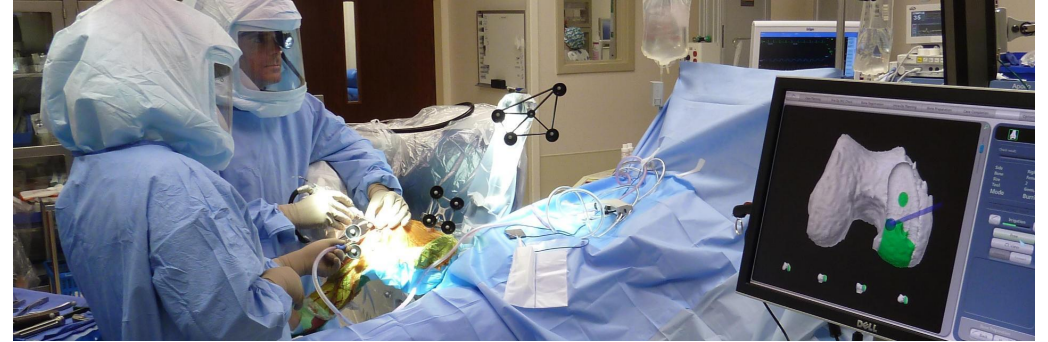
Vzroki:

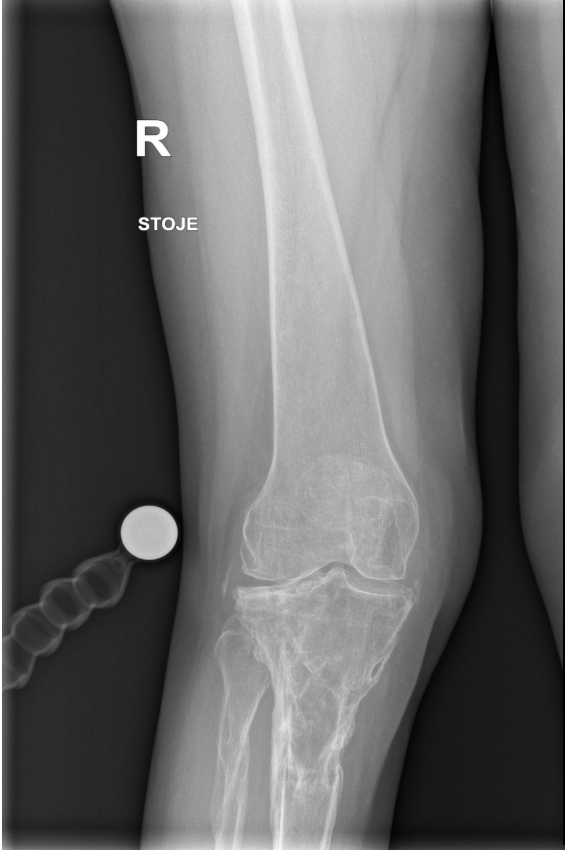
- Obraba polietilena,
- aseptično omajanje (tibija),
- osteoliza,
- nestabilnost, periprotetična fraktura,
- okužba, artrofibroza,
- slabost ekstenzornega mehanizma,
- utesnitveni sindromi.

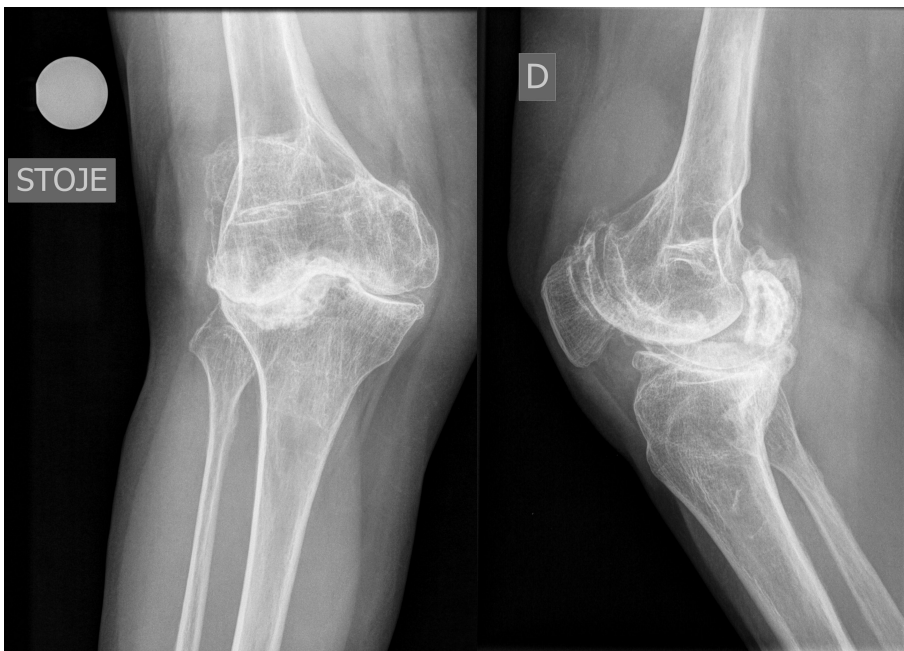


Prihodnost TKR

- Moderne oblike – po meri (moški/ženske).
- Kinematic alignment?
- Računalniška navigacija, robotika?
- Mini invazivnost.
- Parcialno sestavljene proteze (za vsak kompartment).
- Novi materiali (brezcementne endoproteze, mlajši pacienti).

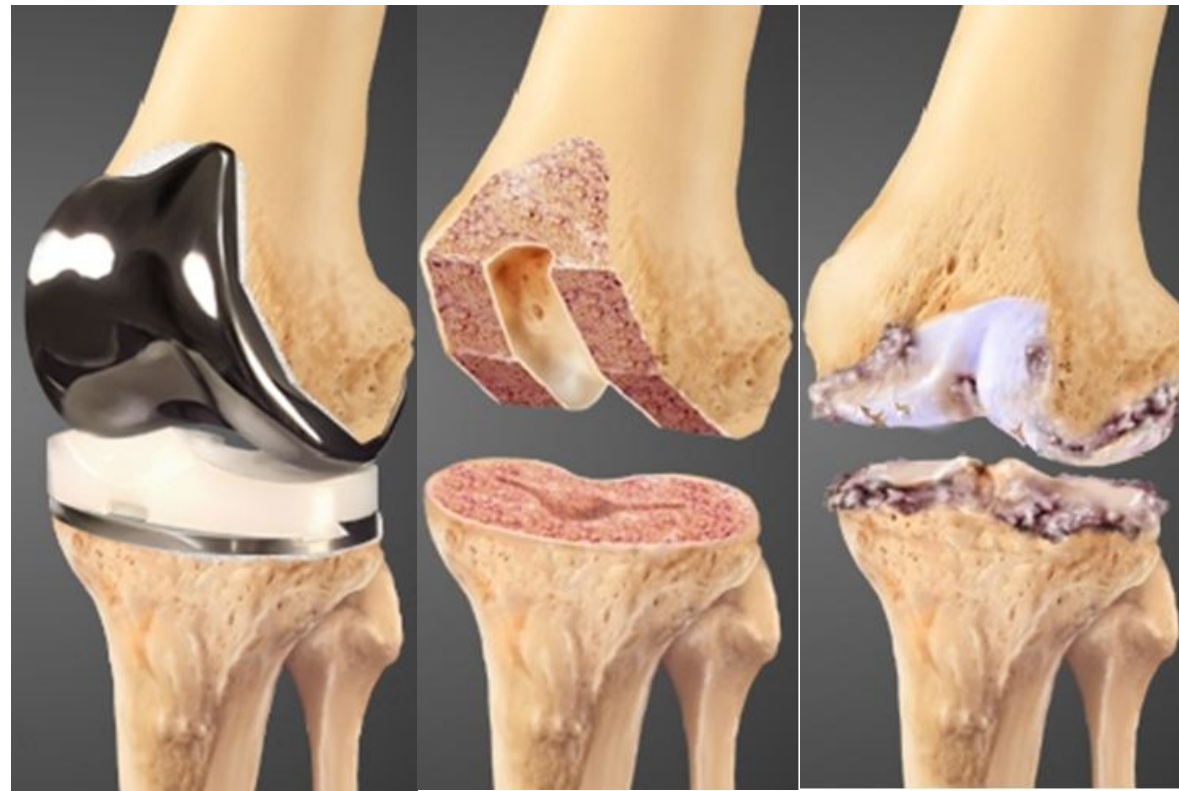






MOTIVACIJA IN CILJI KLINIČNIH RAZISKAV

- Zmanjšati število predčasno odpovedanih vsadkov.
- Najti vzroke aseptičnega rahljanja.
- Poiskati vzroke septičnih odpovedi.
- Doseči daljšo življensko dobo vsadkov.



DVA VODILNA VZROKA ZA ODPOVED VSADKOV

- Aseptično omajanje.
- Okužba.
- 😊 Proti obrabi odporne drsne površine.
- Močna osteointegracija in preprečevanje okužb.

Če gostiteljeve celice najprej dosežejo in zavzamejo površino vsadka, ne bo dosežena le močnejša integracija tkiva, temveč bo vzpostavljena tudi obrambna pregrada proti mikrobni pritrditvi in kolonizaciji (Gristina ag, science 1987).

Table 2.10 Patient characteristics for hip revision procedures in 2012, according to procedure type.

	Hip single-stage revision		Hip stage one of two-stage revision		Hip stage two of two-stage revision		Hip excision arthroplasty		Total revision procedures	
	No.	%	No.	%	No.	%	No.	%	No.	%
Total revision procedures	8,812	88%	560	6%	611	6%	57	<1%	10,040	
Number with patient data	8,475	96%	551	98%	599	98%	51	89%	9,676	96%
Indications for surgery										
Aseptic loosening	3,881	44%	62	11%	54	9%	11	19%	4,008	40%
Lysis	1,227	14%	44	8%	32	5%	8	14%	1,311	13%
Pain	2,219	25%	72	13%	51	8%	9	16%	2,351	23%
Dislocation/subluxation	1,207	14%	22	4%	19	3%	9	16%	1,257	13%
Periprosthetic fracture	797	9%	15	3%	27	4%	1	2%	840	8%
Infection	288	3%	455	81%	443	73%	36	63%	1,222	12%
Malalignment	450	5%	6	1%	4	<1%	0	0%	460	5%
Fractured acetabulum	97	1%	3	<1%	0	0%	1	2%	101	1%
Fractured stem	151	2%	4	<1%	3	<1%	0	0%	158	2%
Fractured femoral head	28	<1%	0	0%	0	0%	0	0%	28	<1%
Incorrect sizing head/socket	61	<1%	0	0%	0	0%	1	2%	62	<1%
Wear of acetabular component	1,177	13%	12	2%	10	2%	0	0%	1,199	12%
Dissociation of liner	133	2%	7	1%	16	3%	2	4%	158	2%
Adverse soft tissue reaction	1,286	15%	25	4%	19	3%	0	0%	1,330	13%
Other	819	9%	19	3%	57	9%	4	7%	899	9%



Izzivi in možne rešitve za osteointegracijo in bakterijske okužbe vsadkov

Causes of orthopaedic implant failure and potential solutions to mitigate each cause and improve implant efficacy and lifetime.

Causes of Implant Failure	Potential Solutions
Gaps at prosthesis-bone interface	<ul style="list-style-type: none">• Gap-bridging coatings
Poor bone in-growth on implants	<ul style="list-style-type: none">• Calcium phosphate coatings• Engineering surface topography• Bioactive glass coatings• 3D-printed coatings
Poor bone deposition on implant surfaces	<ul style="list-style-type: none">• Biomolecular coatings incorporating extracellular matrix proteins• Biomolecular coatings incorporating growth factors• Recruiting osteogenic cells to the implant surface
Initial microbial adhesion and infection	<ul style="list-style-type: none">• Engineering surfaces to inhibit bacterial adhesion• Engineering bactericidal surfaces
Late-stage infection	<ul style="list-style-type: none">• Long-term presentation of antibiotics• Slow-releasing antimicrobial coatings• Coatings containing antimicrobial peptides
Infection leading to osteolysis	<ul style="list-style-type: none">• Treatments to block inflammation and differentiation signaling cascades• Immunomodulatory treatments

[Biomaterials](#), 2016 Apr; 84: 301–314.

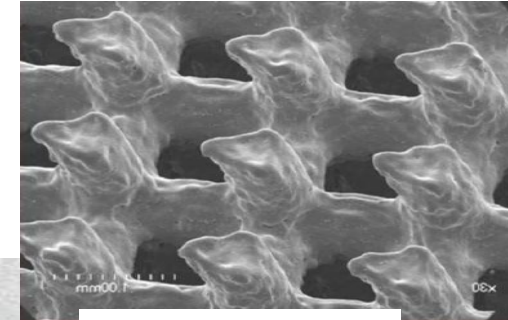
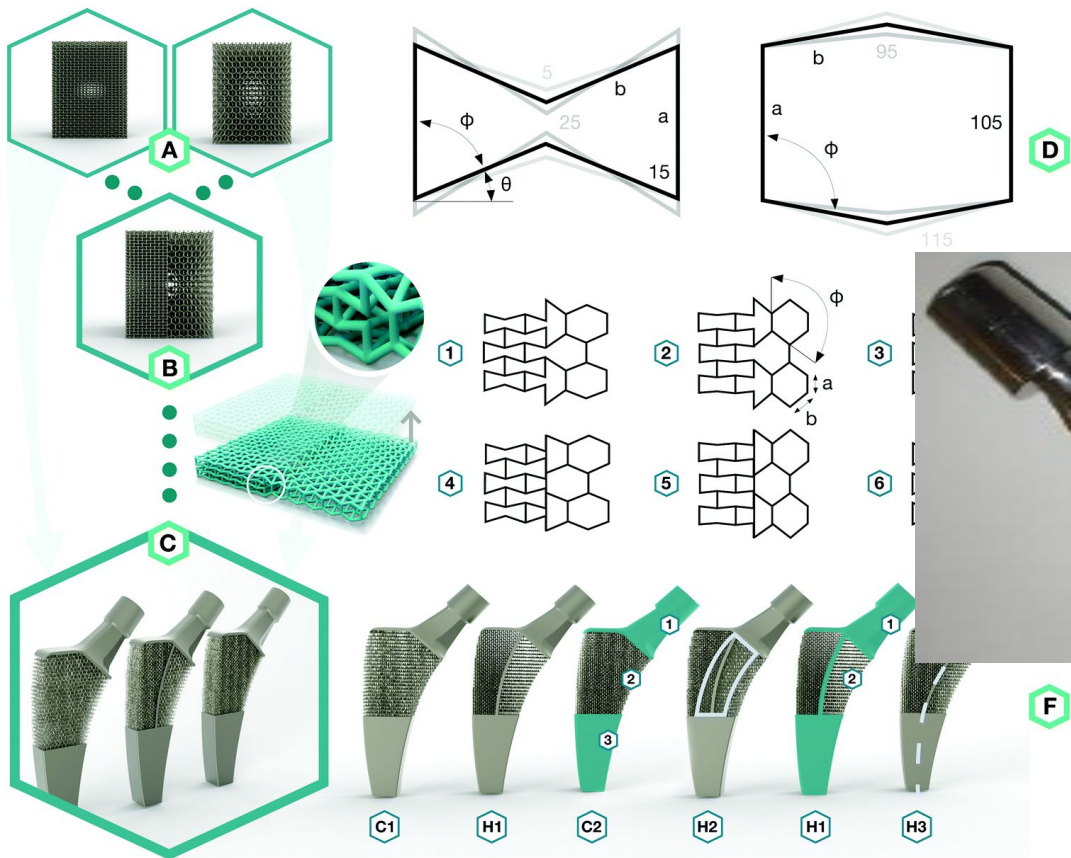
Published online 2016 Jan 18. doi: [10.1016/j.biomaterials.2016.01.016](#)

PMID: [2685139](#).

Multifunctional Coatings to Simultaneously Promote Osseointegration and Prevent Infection of Orthopaedic Implants

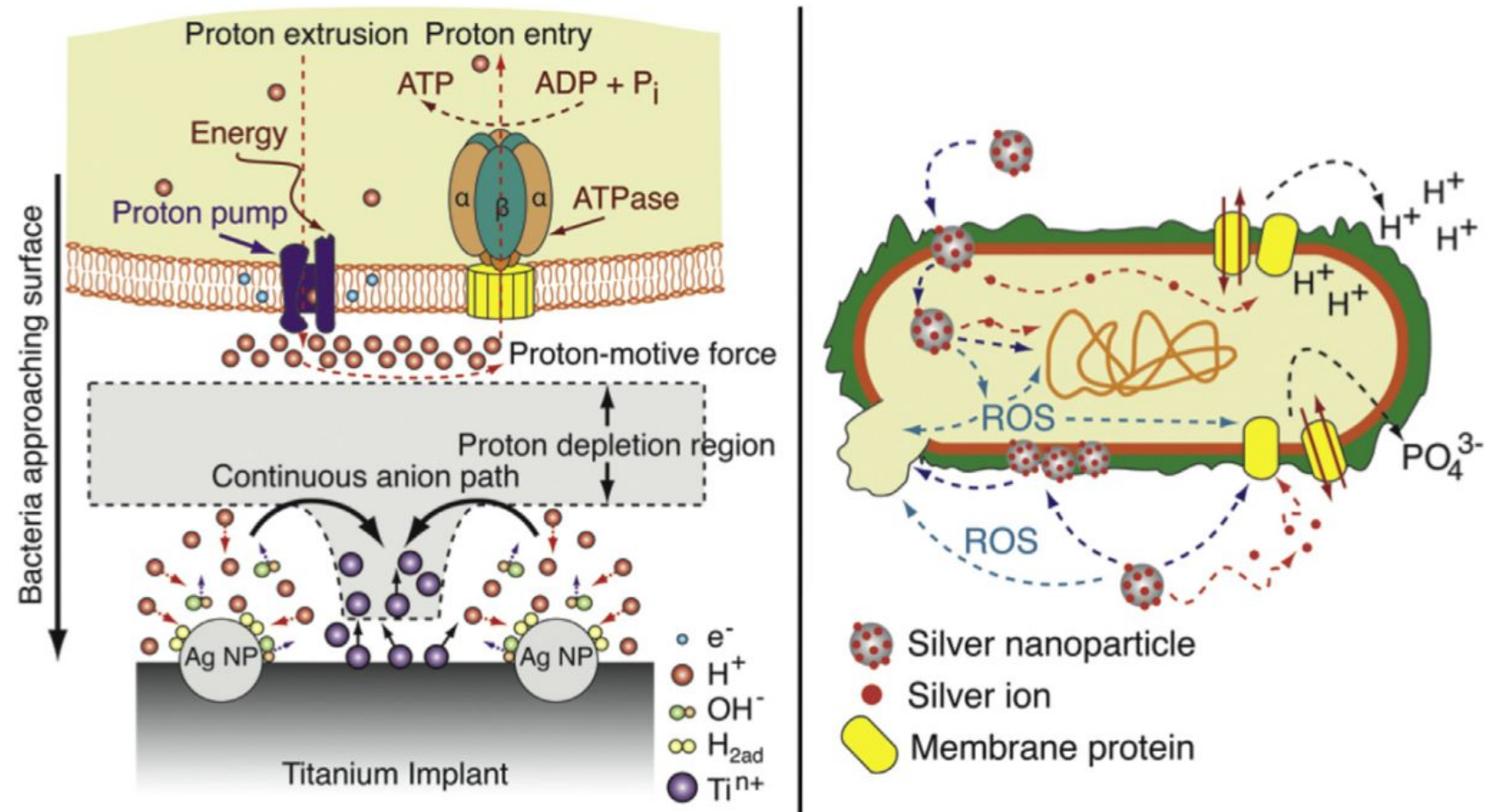
[Jordan Raphael](#),¹ [Mark Holodniy](#),² [Stuart B. Goodman](#),³ and [Sarah C. Heilshorn](#)^{1,*}

IZZIV: Slabo vraščanje vsadkov v kost



AM or 3D printed hip implant developed by TU Delft, using the new hybrid meta-biomaterial, a meta-implant combines a conventional metabiomaterial and auxetic meta-biomaterial.

IZZIV: Začetna mikrobna adhezija in okužba



Proposed bactericidal mechanisms of embedded and released silver. Microgalvanic interactions of embedded silver nanoparticles lead to the generation of protons for applications where ion generation is slow (left). Free silver ions and nanoparticles interact with membranes, transport proteins, and DNA to compromise bacteria (right).

Source:

Adapted and reproduced with permission from Elsevier, copyright 2011 (left) and Springer, copyright 2010 (right) [92,116]. J. Raphael et al. / Biomaterials 84 (2016) 301-314

PRIHODNJE PERSPEKTIVE

Jasna **smer za prihodnost** je **razvoj multifunkcionalnih premazov za vsadke**, ki lahko učinkovito uravnotežijo osteointegracijo in mikrobne izzive.

RAZISKOVALNA SKUPINA

(ORTOPEDI, STOMATOLOGI, EKSPERTI ZA MATERIALE, EKSPERTI ZA BIOFIZIKO MATERIALOV)

ORTOPEDSKA KLINIKA UKC LJ

Prof. dr. Drago Dolinar, dr. med.

Doc. dr. Boštjan Kocjančič, dr. med.

Dr. Klemen Avsec, dr. med.

STOMATOLOŠKA KLINIKA UKC LJ

Prof. dr. Maja Ovsenik, dr. dent. med

Prof. dr. Čedomir Oblak, dr. dent. med

ORTOPEDSKA BOLNIŠNICA VALDOLTRA

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Dr. Matevž Gorenšek, dr. med.

Bogomir Gorenšek, dr. med.

Dr. Urban Brulc, dr. med.

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prof. dr. Matjaž Godec, dr. Črtomir Donik, dr. Borut Žužek, dr.
Aleksandra Kocijan

Laboratorij za klinično biofiziko

Prof. dr. Veronika Kralj-Iglič

Prof. ddr. Aleš Iglič



Področja raziskav

surface phenomena

wettability, roughness, bone cell response

Interface Biomaterial-Biosystem physicochemical phenomena

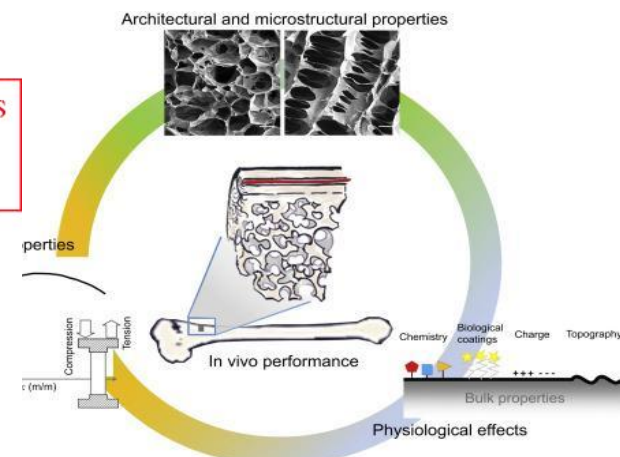
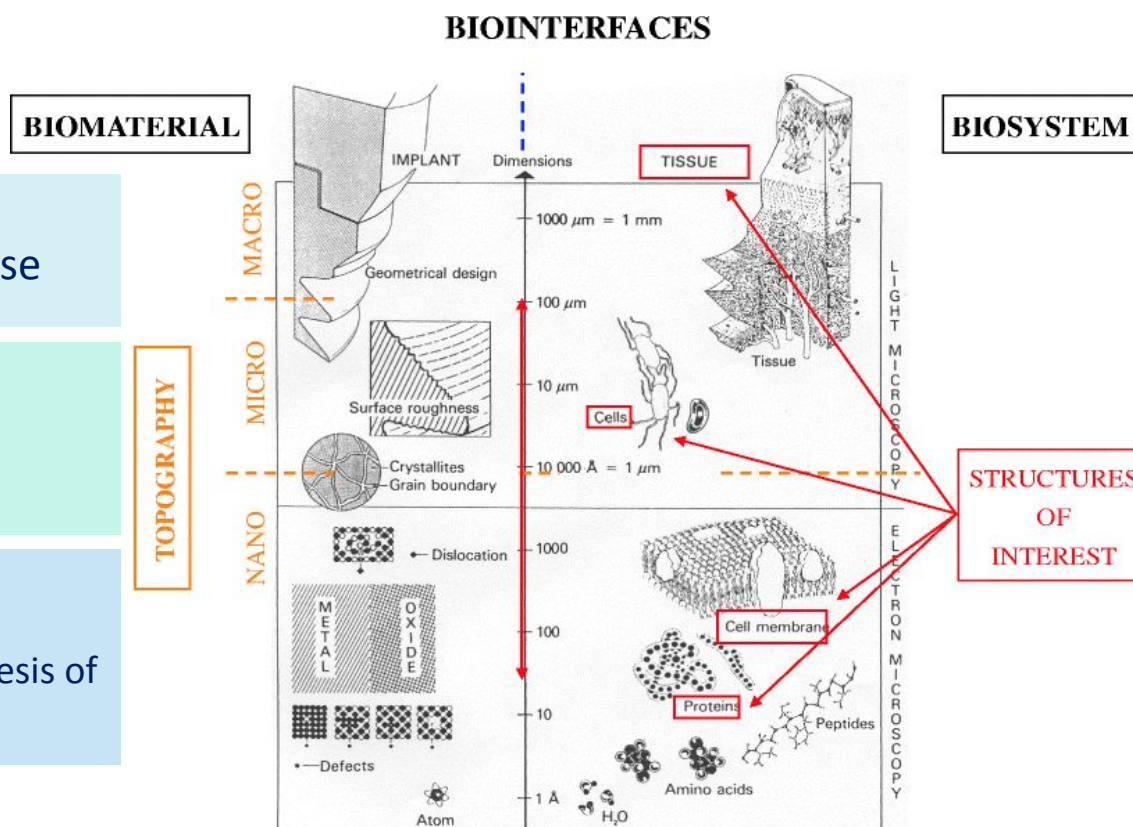
OSSEOINTEGRATION

surface chemistry and microstructure

of new and retrieved implants of metallic and polymer biomaterials, modification and synthesis of novel surfaces

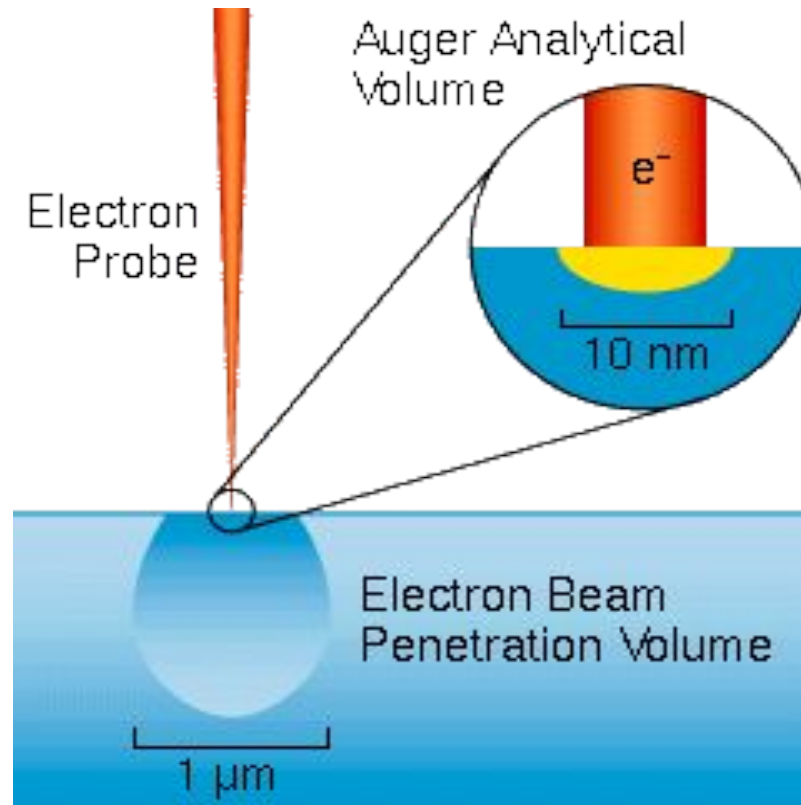
Cilji:

- Bolje razumeti fizikalno-kemijske procese na površinah vsadkov v povezavi s človeškim tkivom in tekočinami, saj je vse to ključnega pomena za uspešno osteointegracijo in dolgo življensko dobo vsadkov.
- Bolje razumevanje razlogov za predčasno odpoved – aseptično omajanje in okužba vsadkov.



AES, XPS površinska analiza

- Auger electron spectroscopy (aes) in X-ray photoelectron spectroscopy (xps).
- Uporabljene so bile metode za površinsko kemijska analizo in mikrostrukturo – globinsko profiliranje značilnih elementov vsadkov.



- **Zweymüller brezcementna kolčna endoproteza**

Clinical outcomes of titanium alloy SL-PLUS femoral stem (Zweymüller) [Elektronski vir] : 2,013 total hip arthroplasty cases with up to 25 years of follow-up
Mavčič, Blaž ; Roškar, Samo, štud. medicine ; Antolič, Vane

Vir: Program in knjiga povzetkov [Elektronski vir] = Program and book of abstracts (Str. 117)

Vrsta gradiva - prispevek na konferenci

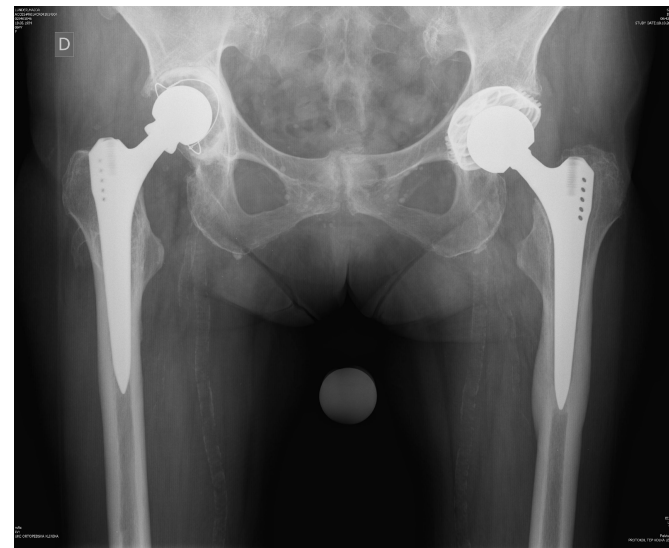
Leto - 2019

Jezik - angleški

COBISS.SI-ID - 6611372

Povezava(-e):

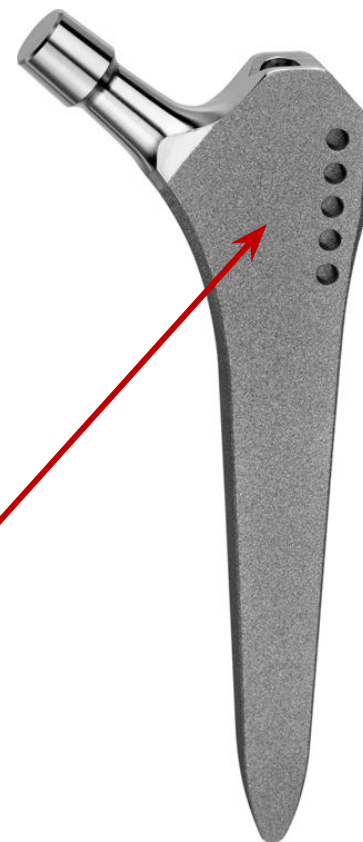
http://mit.imt.si/Revija/izvodi/mit194/BookOfAbstracts_27ICM&T.pdf



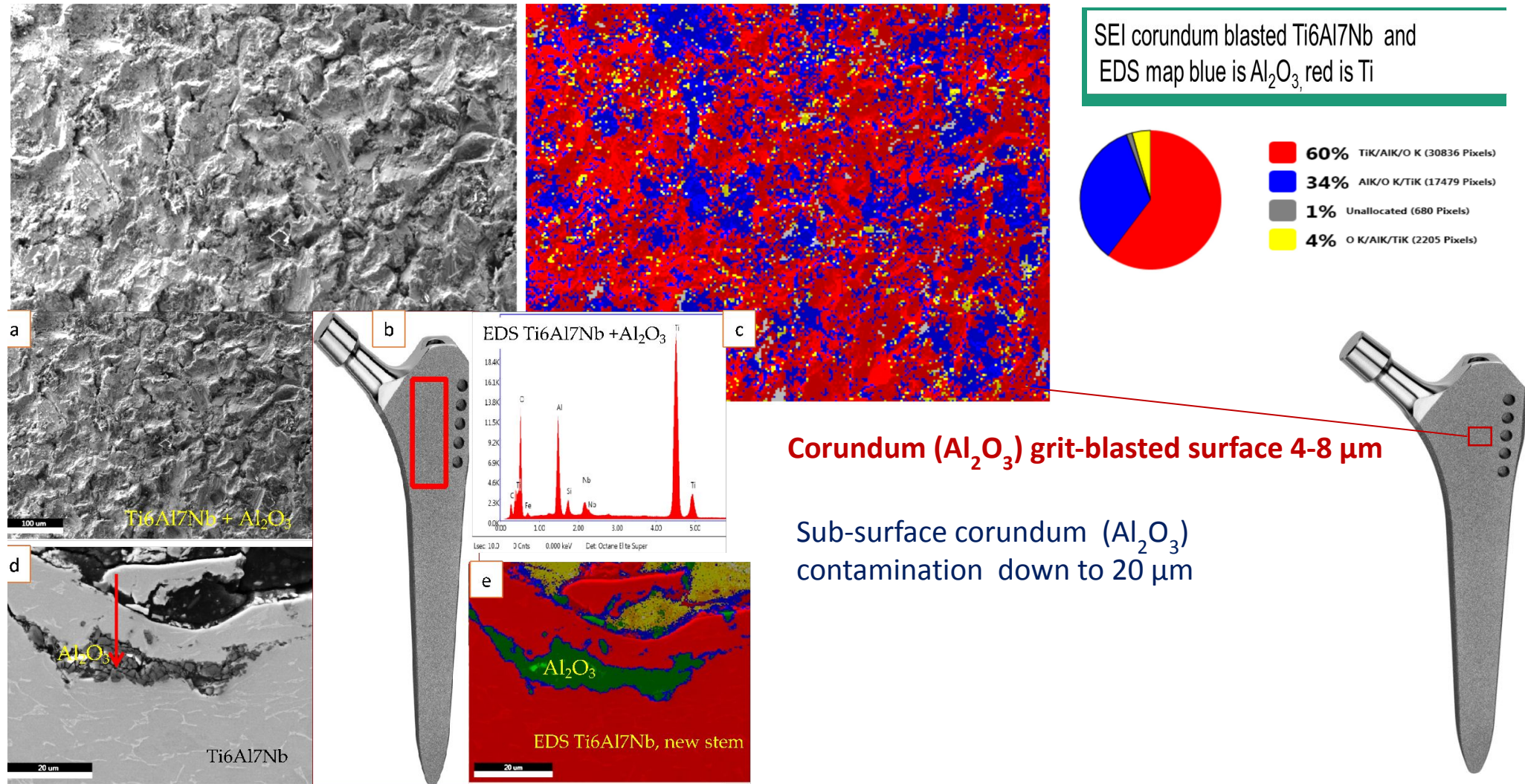
- SL-plus® stegnenična komponenta → kovana Ti-6Al-7Nb zlitina

- Dvojno stožčasto ravno deblo pravokotnega preseka

- **Površina (4-8 mikrom) peskana s korundom (Al_2O_3) za hitrejše vraščanje v kost**



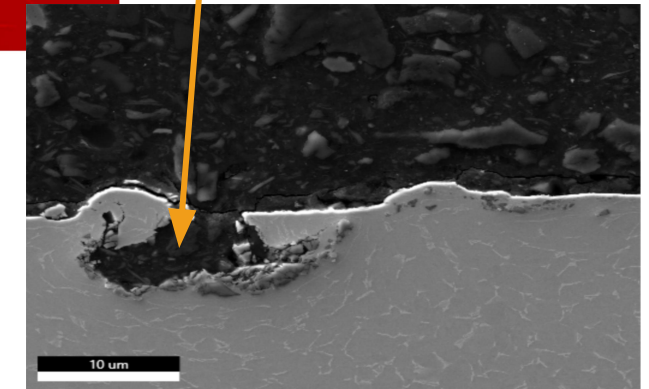
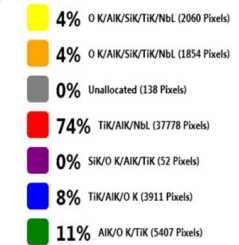
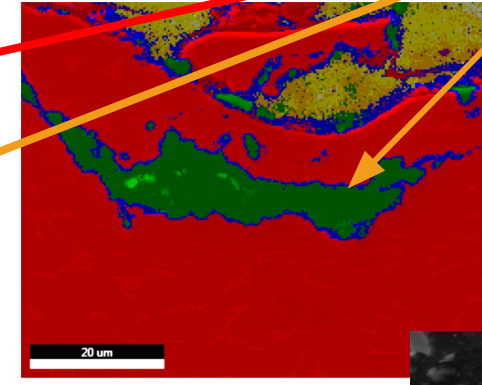
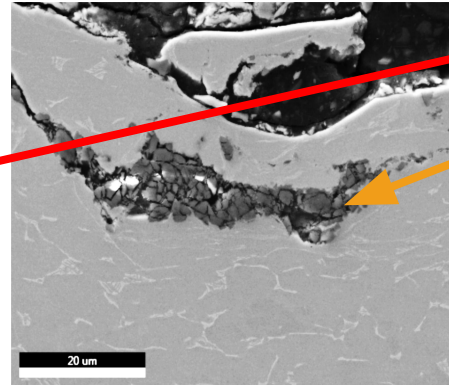
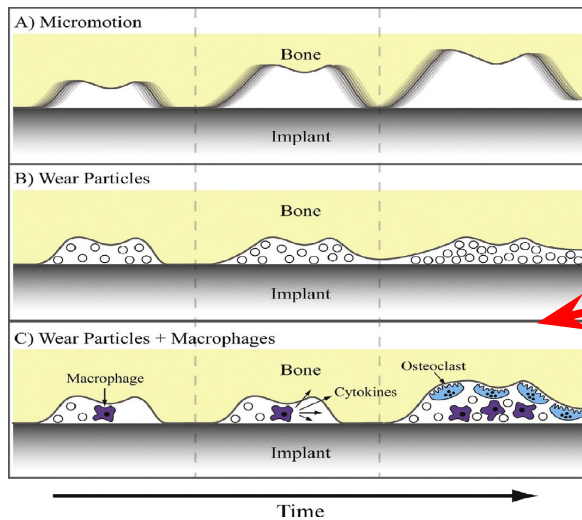
Kontaminacija površine ZM komponente z obrabnimi delci korunda



Corundum wear particles contamination - near the surface - cross section –

from grit blasted surface of ZM N1 uncemented implants

Indukcija osteolize



Aseptic loosening pathways associated with gaps at the bone-implant interface:

- A) Micromotion of the implant relative to the bone, leading to progressive worsening of micromotion.
- B) Wear particles interfering with direct contact between bone and implant.
- C) Wear particles activating macrophages, initiating a cytokine signaling cascade that leads to osteoclastogenesis and bone resorption.

J. Raphael et al. / Biomaterials 84 (2016) 301-314

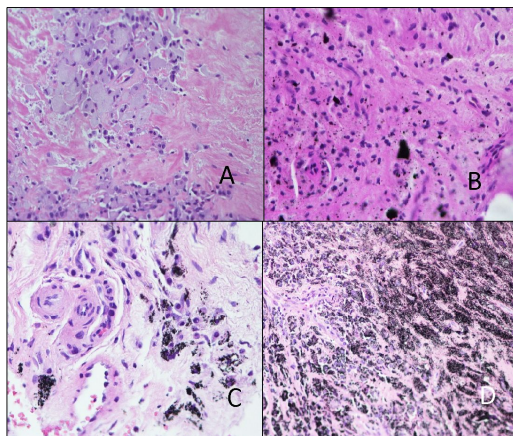


Figure. Photomicrographs of granulomatous tissue from periprosthetic membrane filled with macrophages containing metal wear particles. **A:** Gray-blue macrophage cytoplasm **B:** Black, needle-shaped to polygonal, sharp-edged, metal microparticles different in size. **C:** Cytoplasm filled with black particles; **D:** Severe metallosis with metal particles in macrophages and in extracellular compartments.

Manuscript ID: **materials-2661861**

Type of manuscript: Article

Title: The impact of Al₂O₃ particles from grit-blasted titanium implant surfaces on biocompatibility, aseptic loosening, and infection
Authors: Boštjan Kocjančič, Klemen Avsec, Barbara Šetina Batič, Darja Feizpour, Matjaž Godec, Veronika Kralj Iglič, Rok Podlipec, Andrej Cör, Mojca Debeljak, John T Grant, Monika Jenko *, Drago Dolinar
Received: 27 Sep 2023


AAOS
AMERICAN ACADEMY OF
ORTHOPAEDIC SURGEONS

2020 Annual Meeting
March 24 – 28, Orlando, Florida

ZLOM MODULARNEGA VRATU PO TOTALNI KOLČNI ARTROPLASTIKI

Primerjava dveh različnih zlitin vratnega stebra






 coatings

 MDPI

Article

Mechanisms of Premature Fracture in Modular Neck Stems Made of CoCrMo/Ti6Al4V and Ti6Al4V/Ti6Al4V Alloy

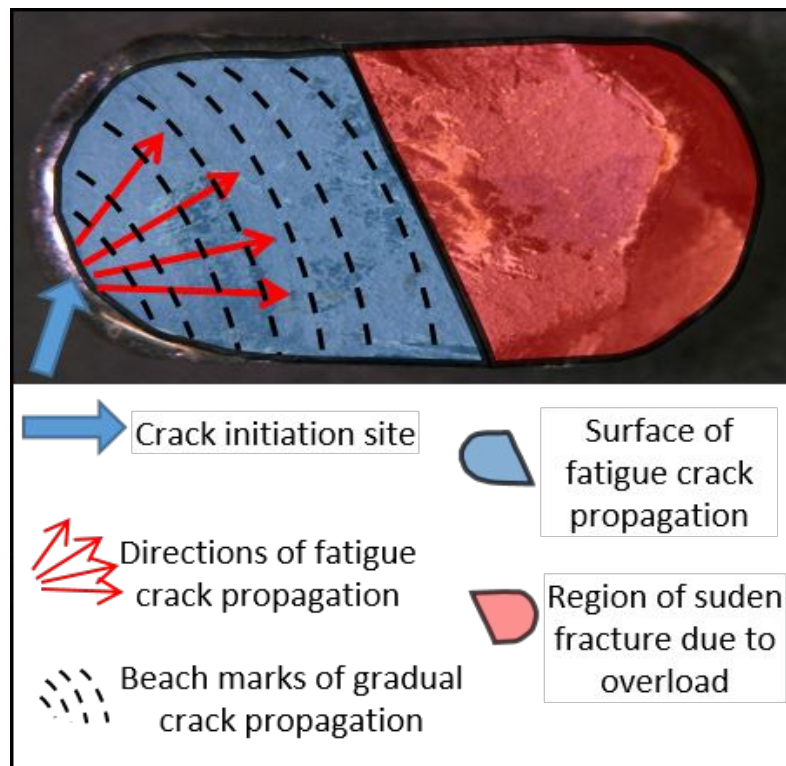
Drago Dolinar ^{1,2,3,4}, Miro Gorenšek ^{1,2}, Klemen Avsec ^{2,4}, Barbara Šetina Badic ⁵ , Majej Hračvar ⁵, Matjaž Godec ³, Borut Žužek ³, Mojca Debeljak ³, Muriška Jenko ^{1,3,5,*} , Juhn T. Grant ⁷  and Boštjan Kotjancič ^{2,4}



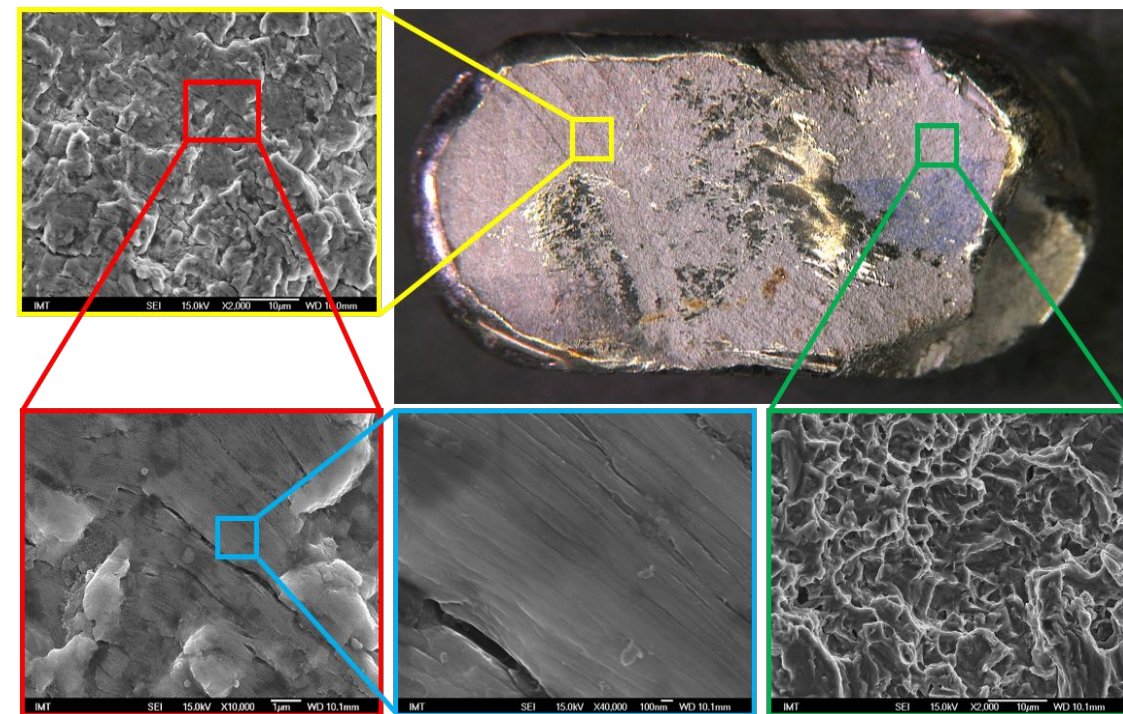
Ti6Al4V modularni vrat / Ti6Al4V stegnenično deblo



RTG zlomljenega modularnega vratu



Mehanizem zloma Ti6Al4V modularnega vratu

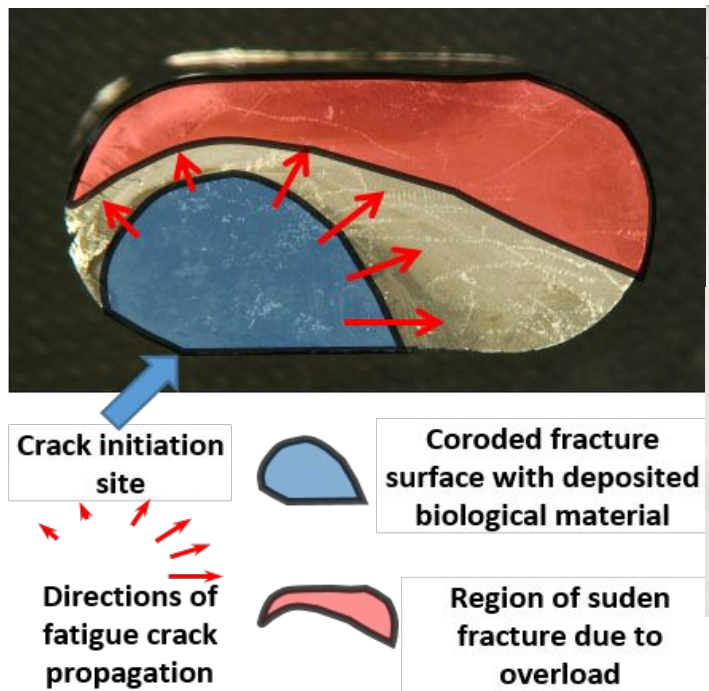


Površinska mikrostruktura zlomljenega modularnega vratu, ki kaže na različne mikrostrukture zlomljene površine, našli smo organske usedline na zlomljeni površini zaradi migracije nanodelcev UHWMPE

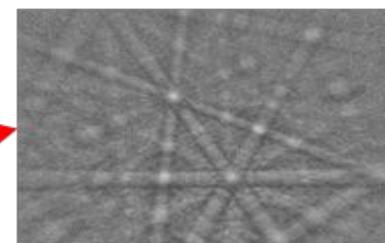
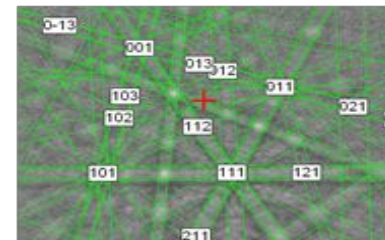
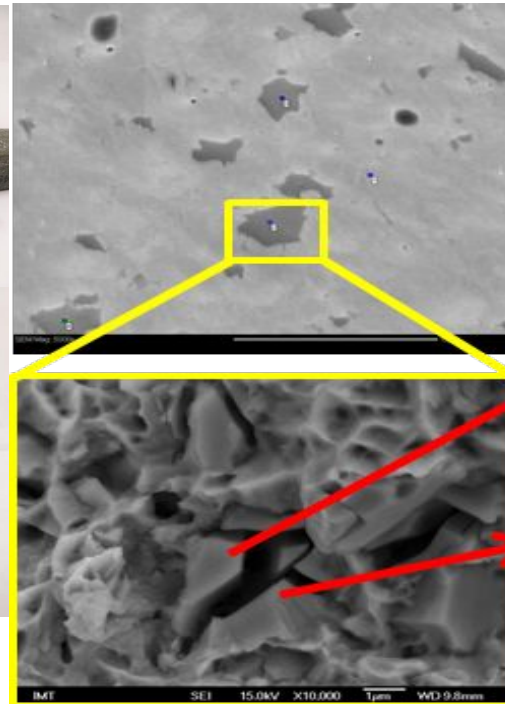
CoCrMo modularni vrat / Ti6Al4V stegnenično deblo



RTG zlomljenega modularnega vratu

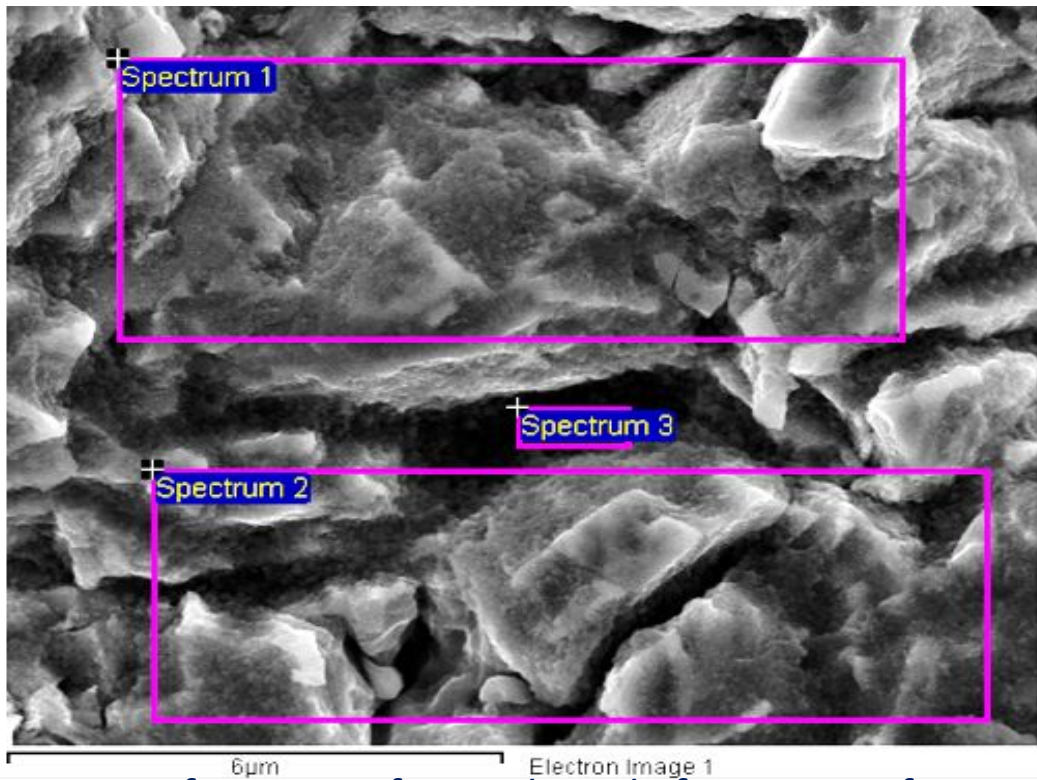


Mehanizem zloma CoCrMo modularnega vratu

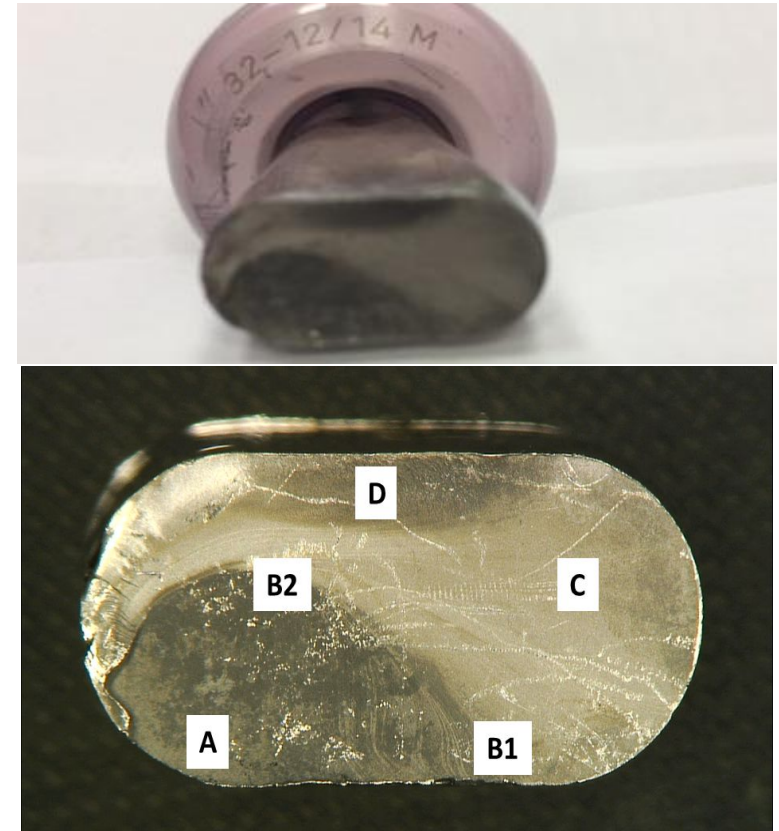


SE slika mikrostrukture CoCrMo, pod zlomljeno površino so krhki karbidi Cr23C6 vdelani v matrico CoCrMo. Zlomljena površina kaže razpokan karbid Cr23C6, ki je bil določen z metodo EBSD po Kikuchijevih linijah.

CoCrMo / Ti6Al4V modular neck stem



SE image of CoCrMo femoral neck fracture surface on region D with marked places of EDS elemental analysis



Macro image of fractured surface by digital microscope Tagarno FHD trend

Table 1 Results of EDS elemental chemical analysis

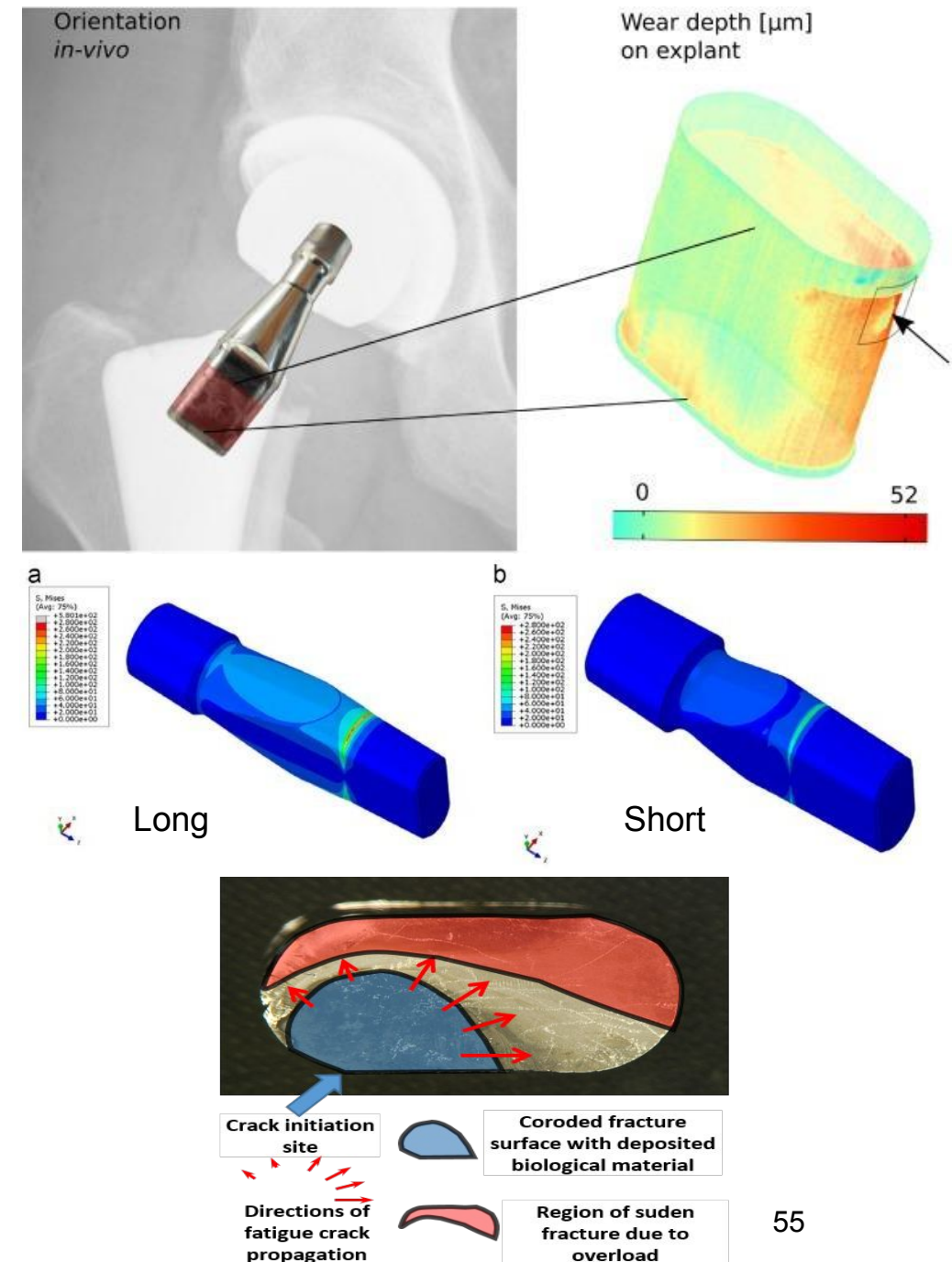
Spectrum/ element	C	O	Si	Ti	V	Cr	Mn	Fe	Co	Mo
Spectrum 1	3.91	5.48	0.80	4.71	0.00	26.71	0.00	0.85	50.93	6.61
Spectrum 2	4.46	7.36	0.53	6.30	0.00	26.73	0.00	0.00	48.40	6.21
Spectrum 3	1.34	6.72	0.00	28.02	1.92	27.27	0.00	0.00	34.72	

Razpoka se je začela na površini modularne endoproteze gibljivega vratu zaradi več različnih dejavnikov, vključno z drgnjenjem in režno korozijo, ki sta vplivala na modularni vrat.

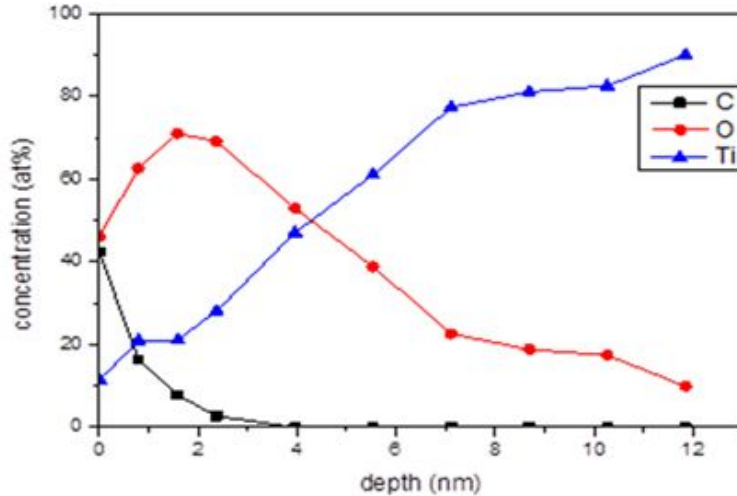
Poškodovani stegnenični **vrat cocrmo** je bil dinamično obremenjen, izpostavljen korozivnemu mediju in obdan z **zlitino Ti6al4v**, ki ima drugačen elektrokemijski potencial. Zaradi stalne dinamične obremenitve in kombinacije različnih materialov v korozivnem mediju je prišlo do galvanske korozije na površini modularnega vratu.

Med obremenjevanjem se je razpoka na mestu največjih napetosti počasi in postopoma širila zaradi korozije. Območje razpoke se je napolnilo z biološkim materialom (modra barva). Obremenitev na preostalem delu poškodovanega vratu se je povečala in pojavili so se sledovi postopnega širjenja razpoke (svetel neobarvan del, označen z rdečimi puščicami).

Ko je preostalo nepoškodovano območje postalo premajhno, je prišlo do nenadne preostale frakture materiala (rdeče obarvana površina).



AES globinski profili pasivnega filma (oksidnega filma) na površini odvzetega vsadka



AES depth profile of thin oxide film (passive film) on the surface of the Ti6Al7Nb alloy



Applied Surface Science
Volume 427, Part A, 1 January 2018, Pages 584-593



Full Length Article

Surface chemistry and microstructure of metallic biomaterials for hip and knee endoprostheses

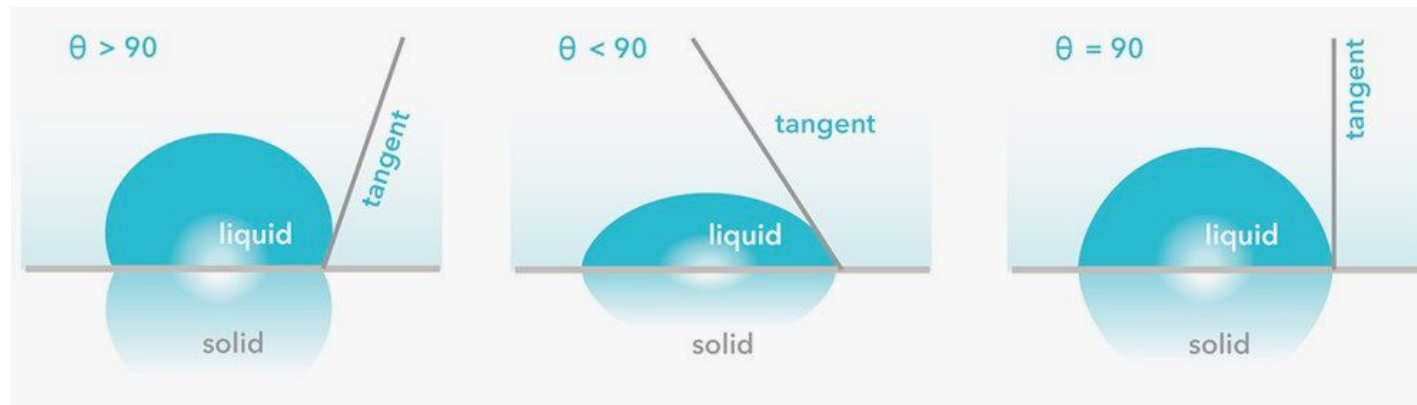
Monika Jenko^a, Matevž Gorenšek^b, Matjaž Godec^a, Maxinne Hodnik^c,
Barbara Šetina Batič^a, Črtomir Donik^a, John T. Grant^d, Drago Dolinar^e

- The thicknesses of the thin oxide films on the surface of the Ti6Al7Nb alloy (primarily of TiO_2) were estimated using AES and XPS depth profiling. The Ti, O and C Auger peaks were detected in the AES analysis. The estimated oxide thickness was about 7 nm, consisting primarily of TiO_2 .
- The surface-chemistry results showed that thin oxide films on the Ti alloys prevent further corrosion, improve the biocompatibility, and affect the osseointegration.

Figure shows the AES depth profiles of the thin oxide film on the surfaces of the Ti6Al7Nb alloy. The TiO_2 and traces of Al_2O_3 and Nb_2O_3 are below the detection limit.

Meritve površinske omočljivosti kolčnih vsadkov

- Kontaktni kot je ena najpogostejše uporabljenih metod merjenja površinskih lastnosti.
- Je enostavna in hitra metoda, s katero je mogoče oceniti homogenost, čistočo in oprijem površine.



- the contact angle is less than 90° - the liquid wets the surface,
- zero contact angle representing complete wetting
- the contact angle is greater than 90° , the surface is non-wetting with that liquid

<https://www.biolinscientific.com/measurements/contact-angle>

Meritve kontaktnega kota



UDK 614.48:620.191:544.722.3:669.017.3
Original scientific article/Izvirni znanstveni članek

ISSN 1580-2949
MTAEC9, 55(1)59(2021)

EFFECT OF STERILIZATION ON THE SURFACE PROPERTIES OF Ti6Al7Nb ALLOY FEMORAL STEMS

VPLIV STERILIZACIJE NA POVRŠINSKE LASTNOSTI
FEMORALNIH KOLČNIH KOMPONENT ENDOPROTEZ IZ
Ti6Al7Nb ZLITINE

Klemen Avsec^{1,2}, Marjetka Conradi³, Monika Jenko^{3,4}, Boštjan Kocjančič^{1,2},
Mojca Debeljak⁵, Matevž Gorenšek⁶, Drago Dolinar^{1,2,3*}

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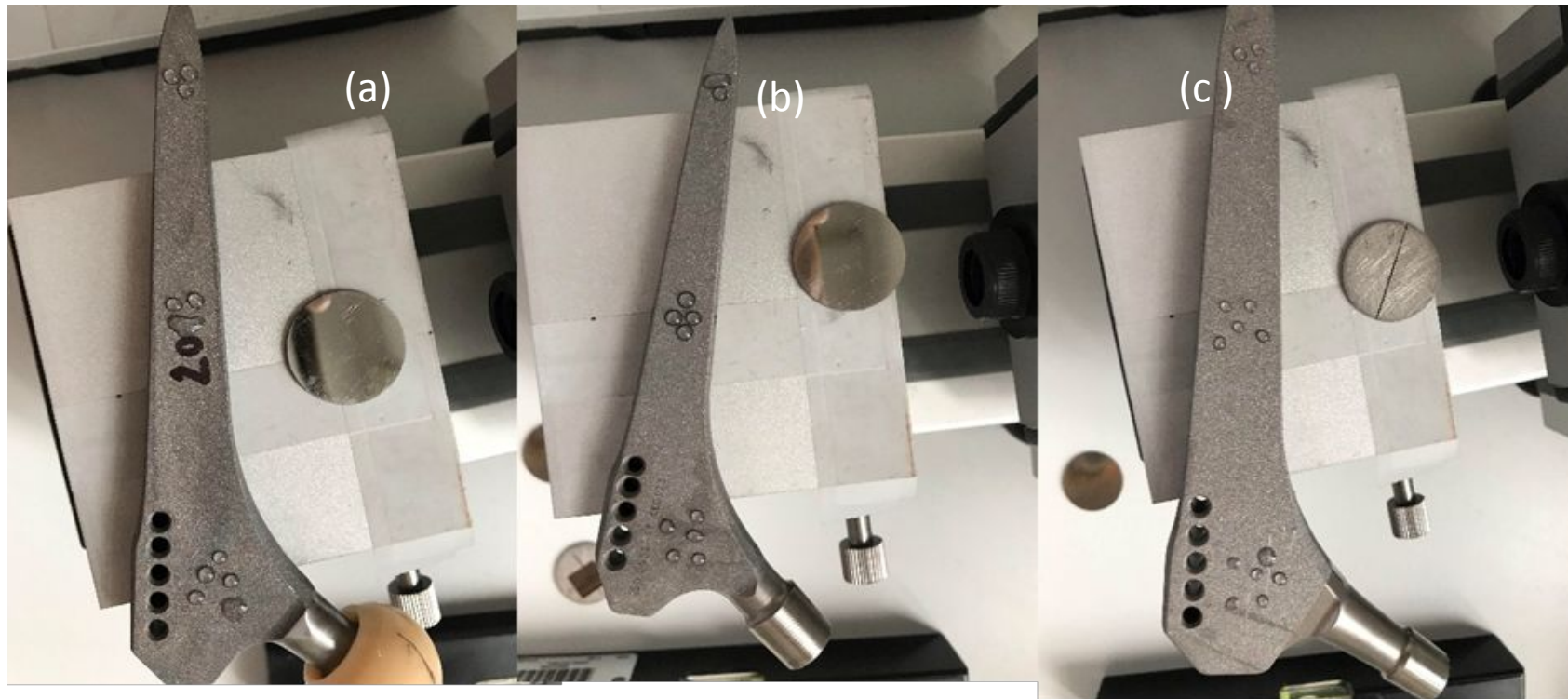
		23-01-2019	11-2-2019 after sterilization		
Implant 1	Sa [μm]	θ [deg]	θ [deg]		
site1	5,209	116,3	66,5 (dispersed from 49 to 85)		
site2	5,884	114,8	73,7		
site3	5,5702	115,9	36,8		

Meritve kontaktnega kota novega stebra
pred in po sterilizaciji

(1) Jenko, M., Gorenšek, M., Godec, M., Hodnik, M., Šetina, B., Donik, Č., Grant, J. T., Dolinar, D.. Surface chemistry and microstructure of metallic biomaterials for hip and knee endoprotheses. Applied Surface Science, ISSN 0169-4332. [Print ed.], 2017, 427, 584-593,. (2) Jung Hwa Park , Rene Olivares-Navarrete, Robert E. Baier, Anne E. Meyer, Rina Tannenbaum, Barbara D. Boyan, Zvi Schwartz, Effect of cleaning and sterilization on titanium implant surface properties and cellular response, Acta Biomaterialia 8 (2012) 1966–1975 (3) Noh El-Wassefy, Abeer El-Fallal, Mahasen Tahac, Effect of different sterilization modes on the surface morphology, ion release, and bone reaction of retrieved micro-implants, Angle Orthodontist, Vol 85, No 1, 2015.

Meritve kontaktnega kota pri predčasno odpovedanih kolčnih endoprotezah zaradi: v (a) aseptičnega rahljanja, (b) okužbe in (c) prikrite okužbe.

Ni velike razlike glede na vzrok predčasne odpovedi.



A20	Sa [μm]	θ [deg]
site1	4,284	82,5
site2	4,219	80,4
site3	4,316	81,3

I28	Sa [μm]	θ [deg]
site1	4,588	82,1
site2	4,585	86,9
site3	4,705	91,6

I5	Sa [μm]	θ [deg]
site1	4,531	80,4
site2	4,553	70,6
site3	4,376	75,7



Article

Surface Properties of Retrieved Cementless Femoral Hip Endoprostheses Produced from a Ti6Al7Nb Alloy

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Biokompatibilnost – ocena citotoksičnosti

z uporabo mezenhimskih stromalnih celic človeškega kostnega mozga v sistemu neposrednega stika

Biocompatibility – cytotoxicity assesment

using human bone marrow derived mesenchymal stromal cells (BMSCs) in direct contact system (ISO 10993-5)

Materials and Methods

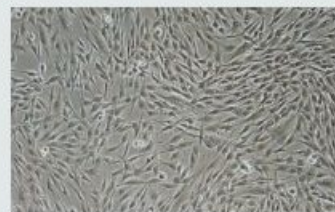
Samples

Corundum ceramic (Al_2O_3) –White Fused Alumina discsc

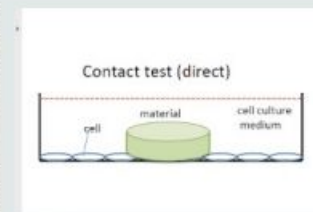
Corundum fine particles (corundum sand granulation 300-425 microns)

Titanium block “sample 1” rough surface blasted covered with corundum

Titanium block “sample 1” polished



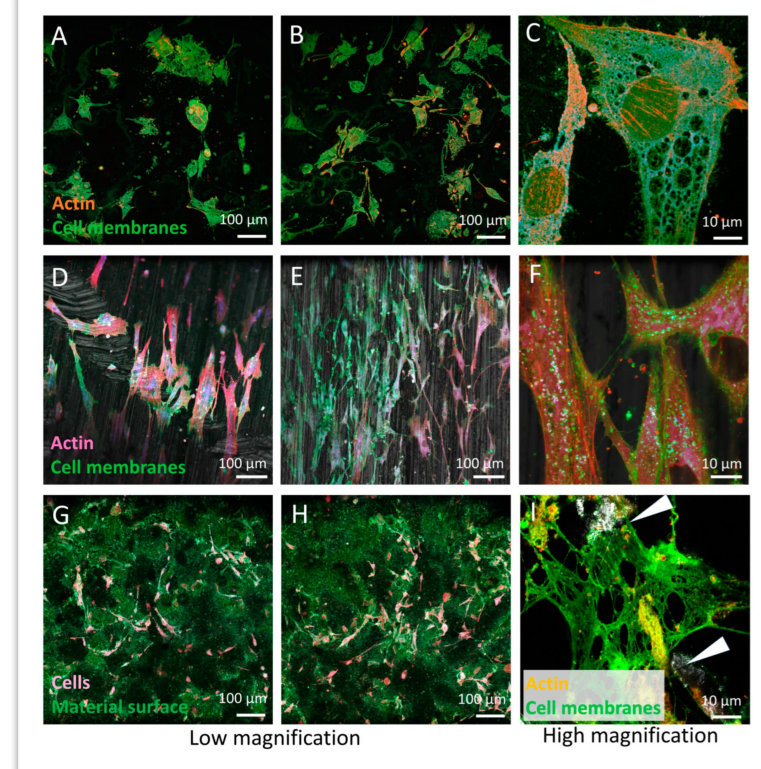
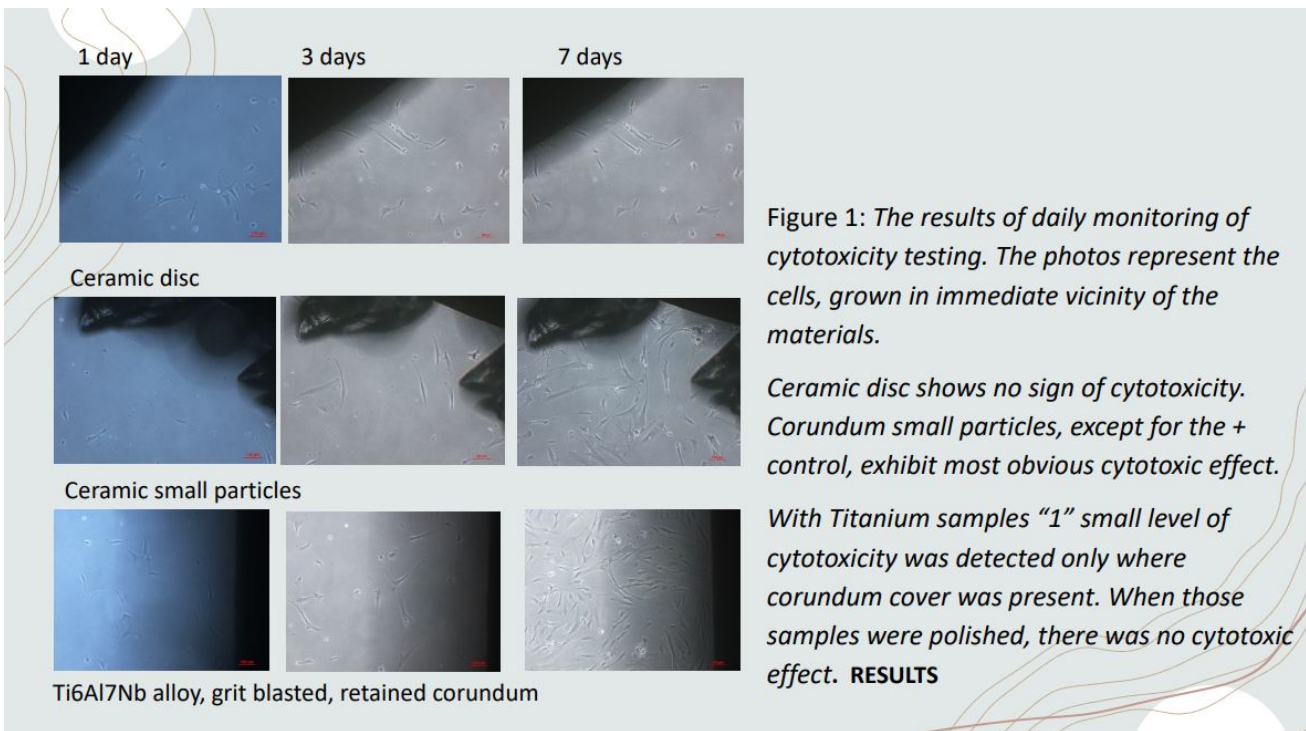
Primary BMSCs



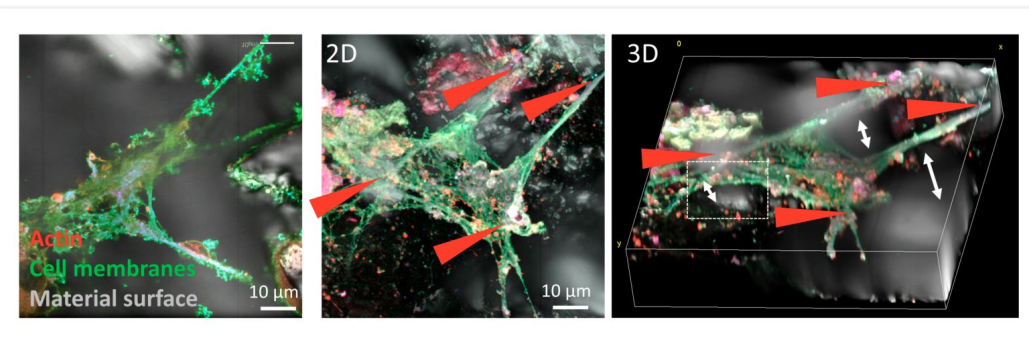
Experimental

All materials were sterile, packaged separately. The materials were tested with human primary mesenchymal stromal (stem) cell culture derived from bone marrow (BMSCs) in a direct contact system, where the biomaterial is in direct contact with cells.

The biomaterials were fixed on the bottom of the cell culture vessel and primary human BMSCs were seeded evenly throughout the cell culture vessel (including biomaterial surface) in cell culture media. The biomaterials with cells were incubated on 37 °C, 5 % CO_2 for 7 days. The cells in the vicinity of the biomaterial were monitored for their morphology and after 7 days the biomaterials were stained and inspected for the presence of live cells (violet crystals). The controls (negative showing no cytotoxic effect, + showing cytotoxicity) were included.



Konfokalne fluorescenčne slike živih BSMC, gojenih na zlitinah Ti6Al7Nb z različno površinsko obdelavo. (A–C) BSMC na polirani (zrcalni) površini z neusmerjeno rastjo; (D–F) BSMC na površini z usmerjeno rastjo; (G–I) BSMC na hrapavi z Al₂O₃ kontaminirani površini z neusmerjeno slabo rastjo, večinoma le delno pritrjeno na površino s sidrnimi točkami (glej puščice).



Konfokalna 2D/3D fluorescenčna mikroskopija lokalno pritrjenih živih BSMC na hrapavi površini Ti6Al7Nb z vgrajenimi preostalimi delci korunda Al₂O₃. Površino materiala (siva barva) opazujemo z detekcijo povratno sipanega laserskega vira.

V tem primeru so celice pritrjene na površino skozi štiri sidrišča (rdeče puščice), kjer so vrzeli med površino in celico označene z belo puščico in črtkanim pravokotnikom. Vrzeli bi lahko bile možni kraj za oprijem bakterij in posledično prezgodnjo odpoved endoproteze kolka zaradi infekcije