



ČVUT

ČESKÉ VYSOKÉ
UČENÍ TECHNICKÉ
V PRAZE

Klinická biomechanika kyčelního kloubu a jeho náhrad

Matej DANIEL

Odbor biomechaniky

Ústav mechaniky, biomechaniky a mechatroniky

Fakulta strojní ČVUT v Praze

15.4.2018, NTM



SOLVAY CONFERENCE 1927

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Absents : Sr W.H. BRAGG, H. DESLANDRES et E. VAN AUBEL

osteoartróza



Život bez obtíží

Onemocnění

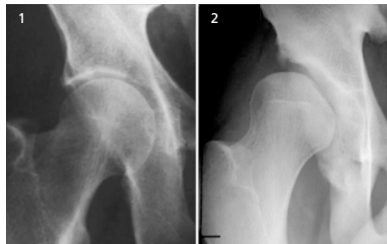
osteoartróza - léčba



Život bez obtíží

Náhrada kloubu

mechanická příčina osteoartrózy



mm

Posunutí

N

Síla

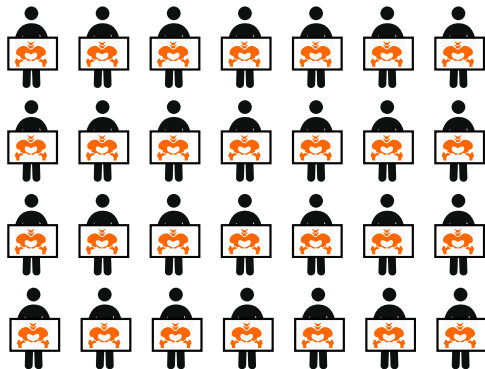
MPa

Napětí

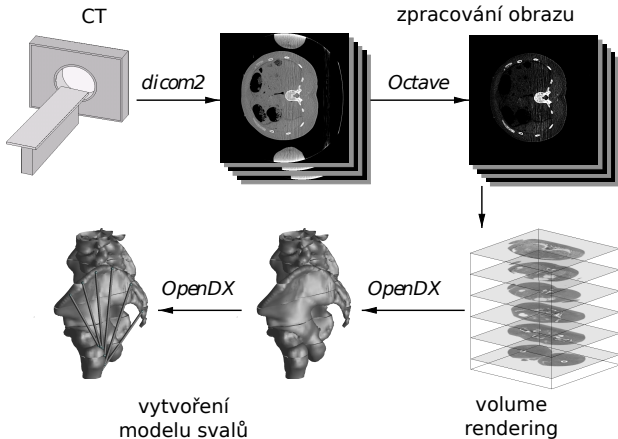
výzva biomechaniky kloubů



klinická biomechanika

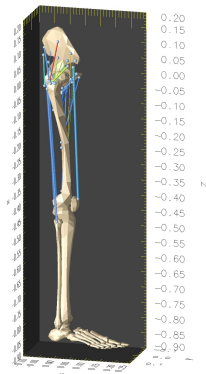


kvantitativní geometrie



Daniel, M., Iglič, A., Kralj-Iglič, V., and Konvičková, S. (2005). Computer system for definition of the quantitative geometry of musculature from CT images. *Comput Methods Biomech Biomed Eng*, 8(1):25–29.

zatížení kloubu R



Rovnice rovnováhy

$$m\mathbf{a} = \mathbf{W} + \sum_{i=1}^n \mathbf{F}_{Ii}$$

$$\mathbf{I}_S \boldsymbol{\alpha} + \boldsymbol{\omega} \times \mathbf{I}_S \boldsymbol{\omega} = \sum_{i=1}^n \mathbf{M}_{Ii}$$

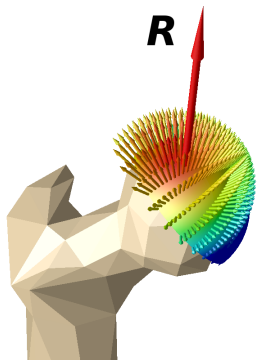
Metoda optimalizace 27 svalů

minimalizuj $G(\mathbf{F}) = \sum_i \left(\frac{F_i}{PCSA_i} \right)^3$

za podmínek $\mathbf{g}(\mathbf{F}) = \mathbf{0}; \mathbf{l}_F \leq \mathbf{F} \leq \mathbf{u}_F$

Daniel M., Iglic A., Kralj-Iglic V. (2008) Hip contact stress during normal and staircase walking - influence of acetabular anteversion angle and lateral coverage of acetabulum, J App Biomech. 24(1):88-93.

výpočet kontaktního tlaku



DEA - discrete element analysis

$$U = \frac{1}{2} \iint_A (\delta^T \mathbf{D} \delta) dA$$

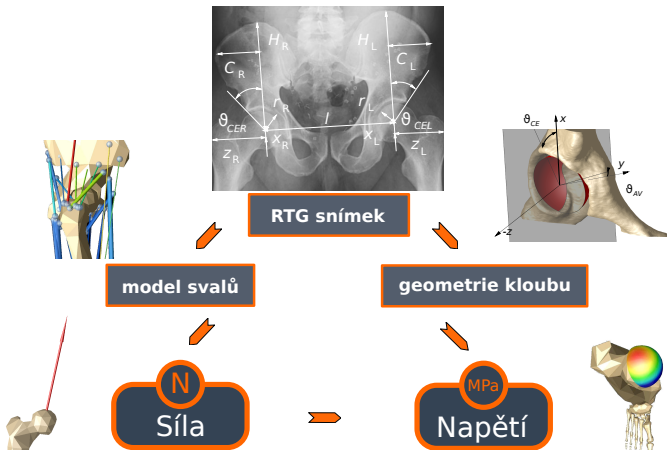
$$U = \frac{1}{2} u^T \mathbf{K} u$$

$$\mathbf{K} = \iint_A \mathbf{B}^T \mathbf{D} \mathbf{B} dA$$

$$\mathbf{R} = \frac{\partial U}{\partial u} = [\mathbf{K}] u$$

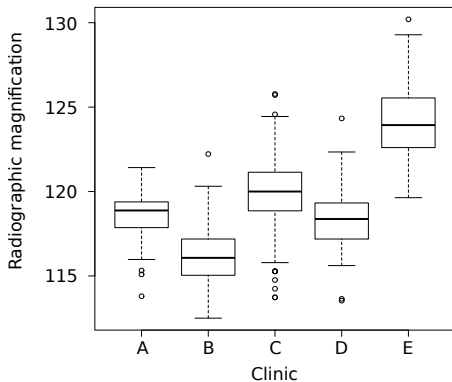
- Kralj-Iglič, V., Dolinar, D., Ivanovski, M., Daniel, I., and Daniel, M. (2012). Role of biomechanical parameters in hip osteoarthritis and avascular necrosis of the femoral head. In Ganesh, R. N., editor, *Applied Biological Engineering – Principles and Practice*, pages 347–364. InTech.

metoda HIPSTRESS



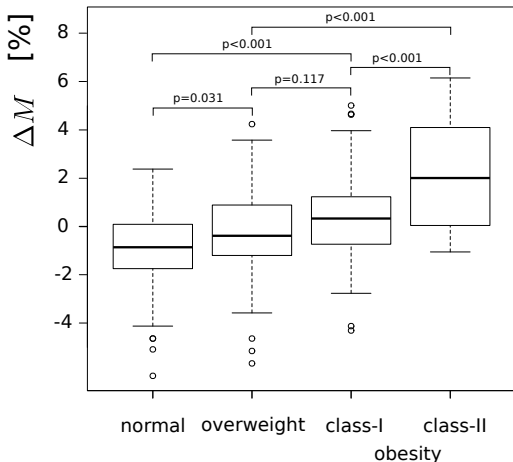
- Košak R, Kralj-Iglič V, Iglič A, Daniel M (2011). Polyethylene Wear is Related to Patient-specific Contact Stress in THA. *Clinical Orthopaedics and Related Research*, 469(12), 3415–3422.

zvětšení RTG snímku

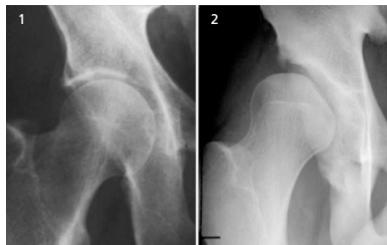


- Hornová J, Růžička P, Hrubina M, Šťastný E, Košková A, Fulín P, Gallo J, Daniel M. Magnification of digital hip radiographs differs between clinical workplaces. PLoS One. 2017 Nov 30;12(11):e0188743. doi: 10.1371/journal.pone.0188743

obezita a zvětšení RTG



mechanická příčina osteoartrózy



mm

Posunutí

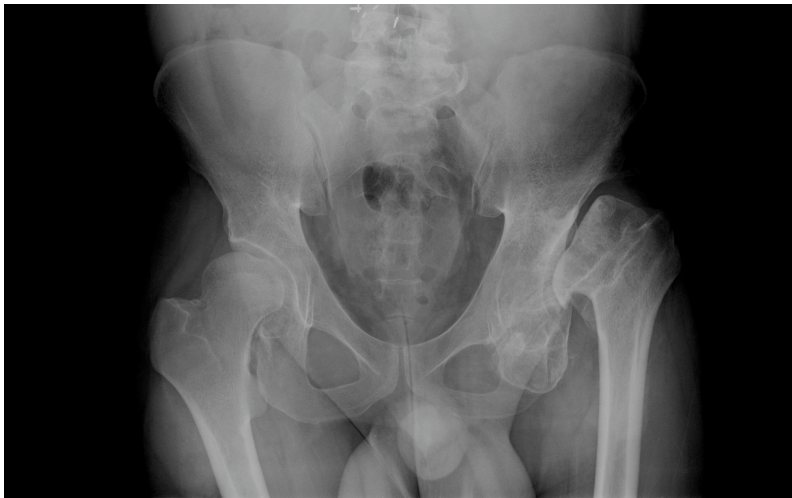
N

Síla

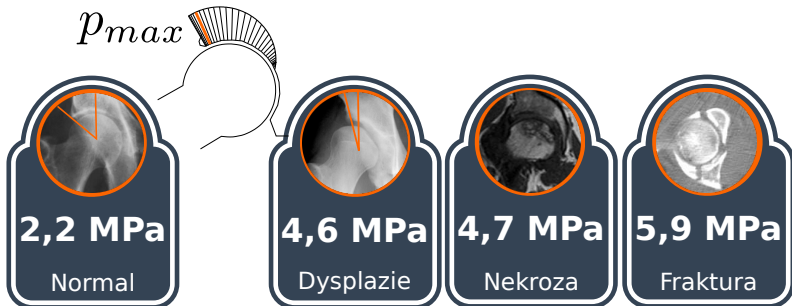
MPa

Napětí

vrozené deformity



tvar kloubu

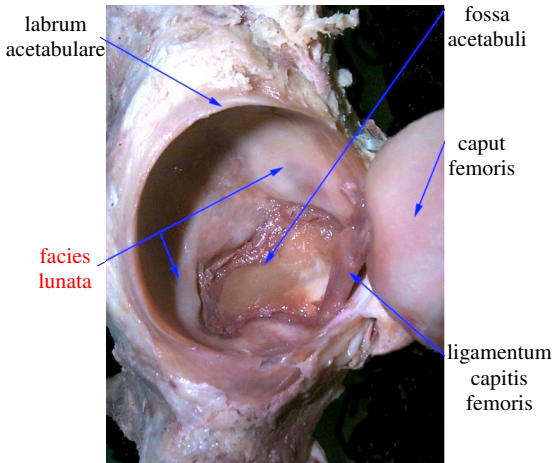


Mavcic B., Pompe B., Antolic V., Daniel, M., Iglic A., Kralj-Iglic V. (2002) Mathematical estimation of stress distribution in normal and dysplastic human hips, *J. Orthop. Res.* 20(5):1025-30.

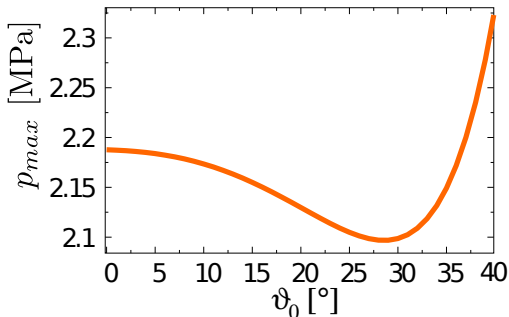
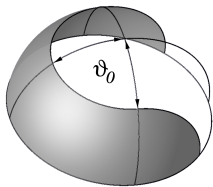
Daniel, M, Herman S, Dolinar D, Iglic A, Sochor M, Kralj-Iglic V (2006). Contact stress in hips with osteonecrosis of the femoral head. *Clin Orthop Relat Res.*, 447:92-9.

Pompe, B., Daniel, M., Sochor, M., Vengust, R., Kralj-Iglic, V., and Iglic, A. (2003). Gradient of contact stress in normal and dysplastic human hip. *Medical Engineering & Physics*, 25:379–385.

chrupavka kyčelního kloubu

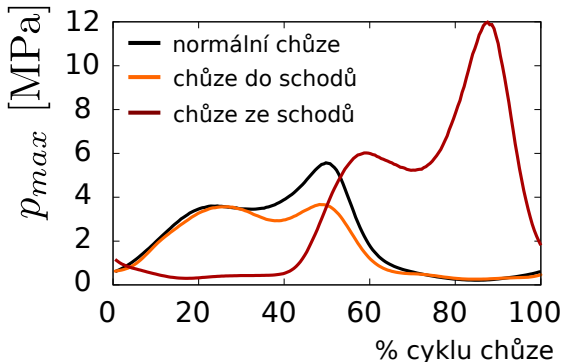


chrupavka kyčelního kloubu



- Daniel M, Iglic A, Kralj-Iglic V. (2005) The shape of acetabular cartilage optimizes hip contact stress distribution. *J Anat.* 207(1):85-91.
- Konvičková, S., Sýkora, J., Daniel, M. Hlavice totální náhrady kyčelního kloubu optimalizující rozložení kontaktního tlaku Užitečný vzor Úřad průmyslového vlastnictví, č. 2006-18258/17312

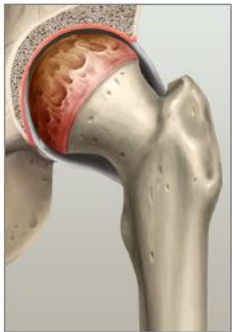
nadměrné zatížení



- Elkins JM, Daniel M, Pedersen DR, Singh B, Yack HJ, Callaghan JJ, Brown TD. Morbid obesity may increase dislocation in total hip patients: a biomechanical analysis. Clin Orthop Relat Res. 2013;471(3):971-80.
- Debevec H, Pedersen DR, Iglic A, Daniel M. One-legged stance as a representative static body position for calculation of hip contact stress distribution in clinical studies. J Appl Biomech. 2010 Nov;26(4):522-5.

nemoc za nemoc

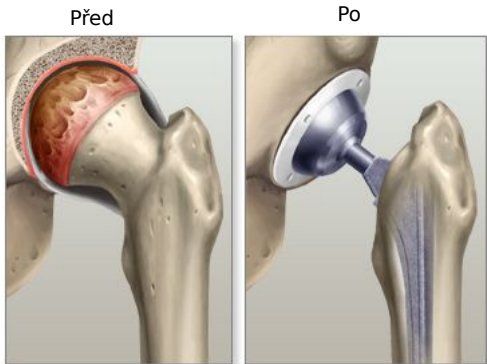
Před



Po



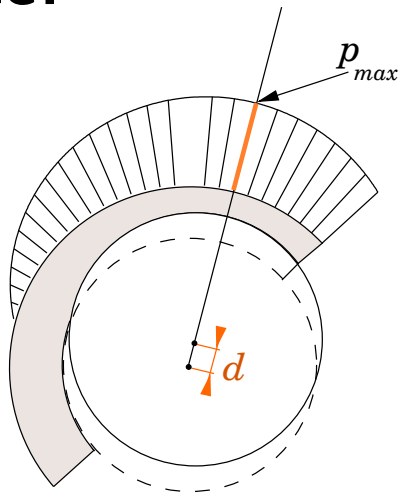
nemoc za nemoc



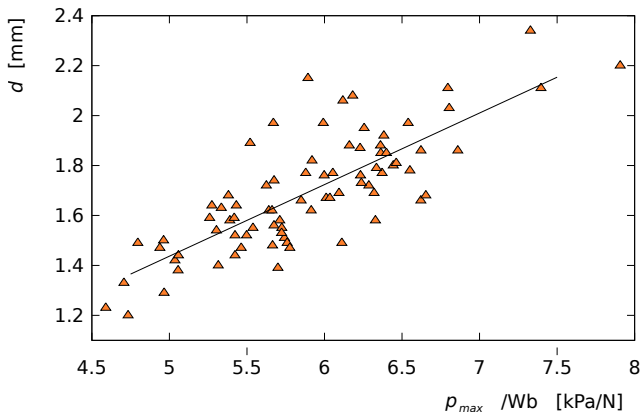
Archardův zákon adhezivní otěř

$$w = \int kp(t)v(t)dt$$

- p - kontaktní tlak
- v - rychlost pohybu třecích ploch
- k - koeficient otěru



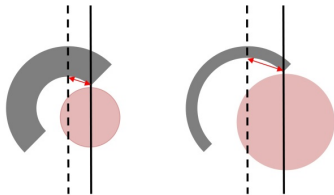
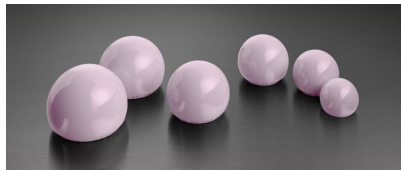
opotřebení náhrady kloubu



- Košak R, Kralj-Iglič V, Iglič A, Daniel M (2011). Polyethylene Wear is Related to Patient-specific Contact Stress in THA. *Clinical Orthopaedics and Related Research*, 469(12), 3415–3422.

velikost hlavičky

$$w = \int kp(t)v(t)dt$$



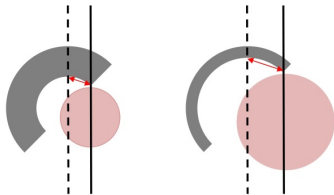
velikost hlavičky

$$w = \int kp(t)v(t)dt$$

$$v \propto r$$

$$p \propto \frac{1}{A} = \frac{1}{r^2}$$

$$w \propto r \frac{1}{r^2} = \frac{1}{r}$$



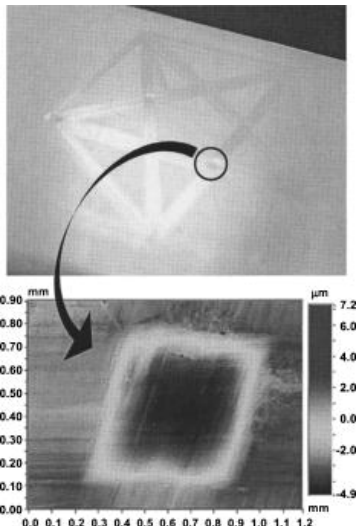
velikost hlavičky

$$w = \int kp(t)v(t)dt$$

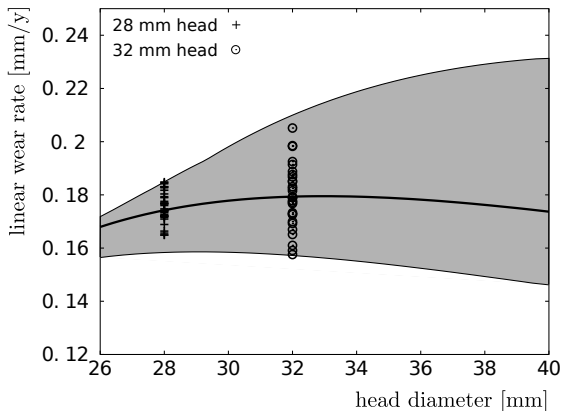
$$w \propto r \frac{1}{r^2} = \frac{1}{r}$$

UHMWPE

$$k = e^a e^{b \ln Co} e^{c P_{AVE}}$$

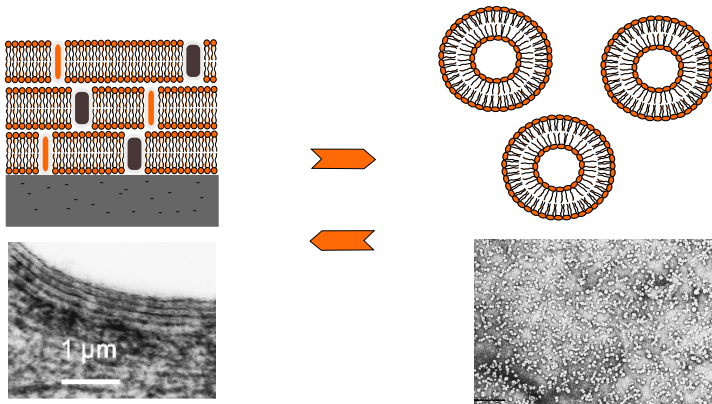


klinická studie



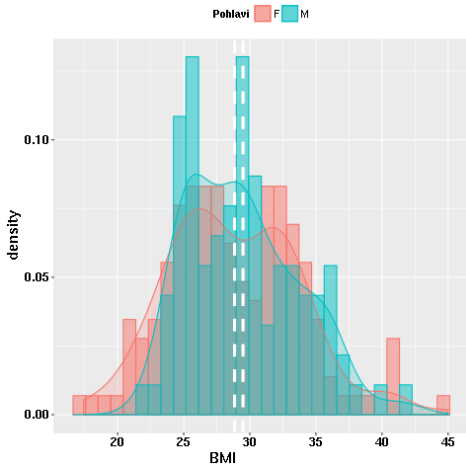
- Daniel M, Rijavec B, Dolinar D, Pokorný D, Iglíč A, Kralj-Iglíč V. Patient-specific hip geometry has greater effect on THA wear than femoral head size. J Biomech. 2016 Dec 8;49(16):3996-4001.

mezní lubrikace



- Daniel, M. (2012). Role of Surface-Active Lipids in Cartilage Lubrication. In Iglič, A., editor, *Advances in planar lipid bilayer and liposomes*, pages 226–244. Academic Press.

BMI u totálních náhrad kyče



Spolupráce

- ▶ I. ortopedická klinika 1. LF UK a FN Motol - FN Motol
- ▶ Klinika dětské a dospělé ortopedie a traumatologie 2. LF UK a FN Motol
- ▶ Ortopedická klinika Fakultní nemocnice Olomouc
- ▶ Ljubljana University Medical Centre
- ▶ Ortopedická klinika, Jesseniova lekárska fakulta v Martine
- ▶ Clinic of Masticatory Disorders, Removable Prosthodontics, Geriatric and Special Care Dentistry, University of Zurich
- ▶ Orthopedic Clinic, University of Iowa Hospitals and Clinics

Děkuji za pozornost

`www.biomechanika.cz`