



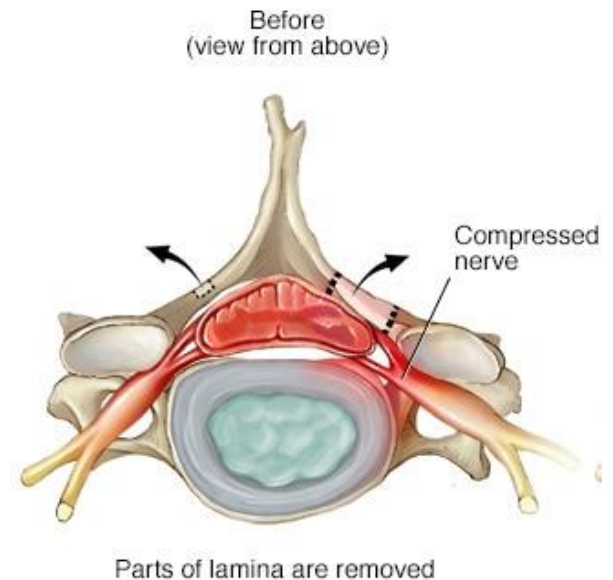
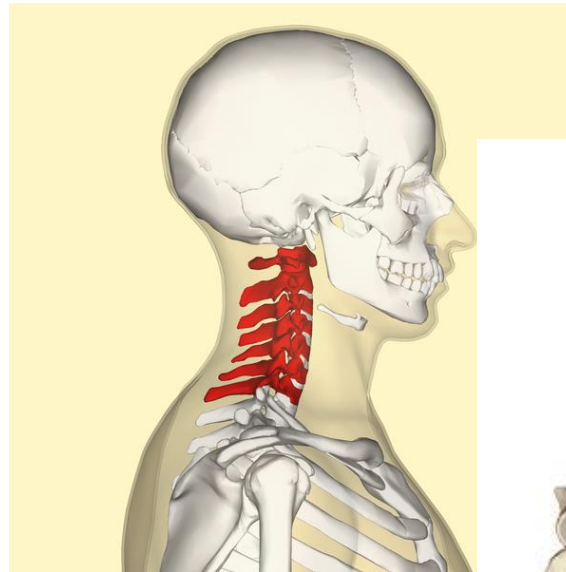
Optimalizace invazivní krční elastické laminoplastiky

Ing. Aleš Hrouda
Doc. Ing. Lukáš Čapek, PhD.
MUDr. Jan Hradil



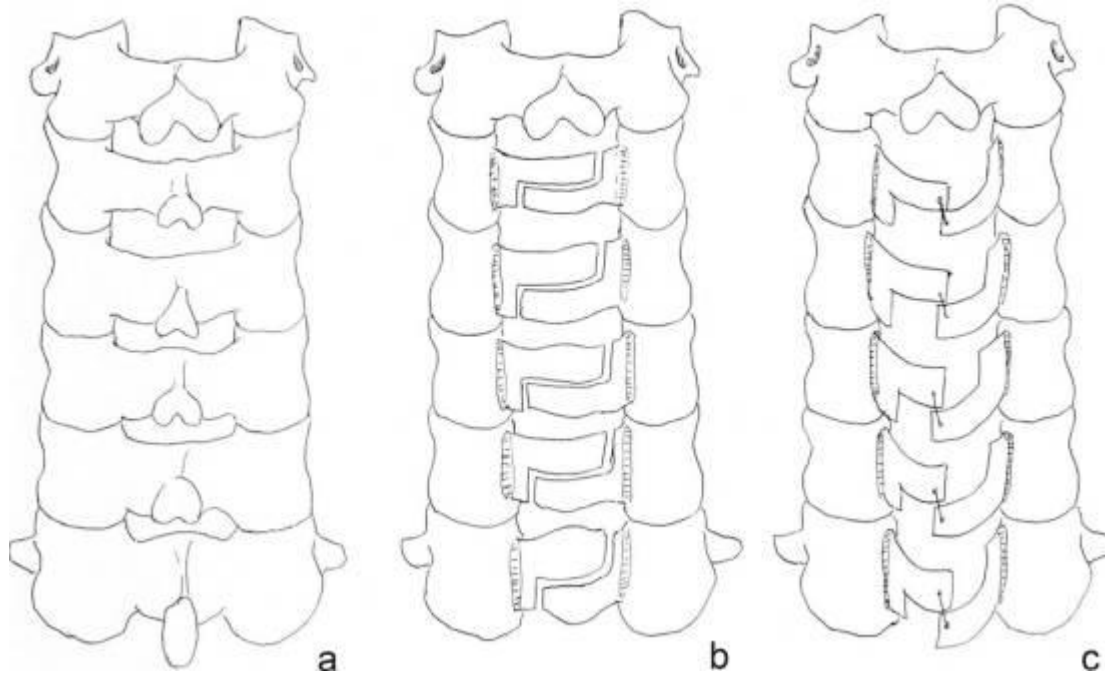
Úvod do problematiky

Spondylogenní cervikální
myelopatie (SCM) = míšní
komprese degenerativně
změněnými strukturami páteře
na místě úzkého spinálního
kanálu



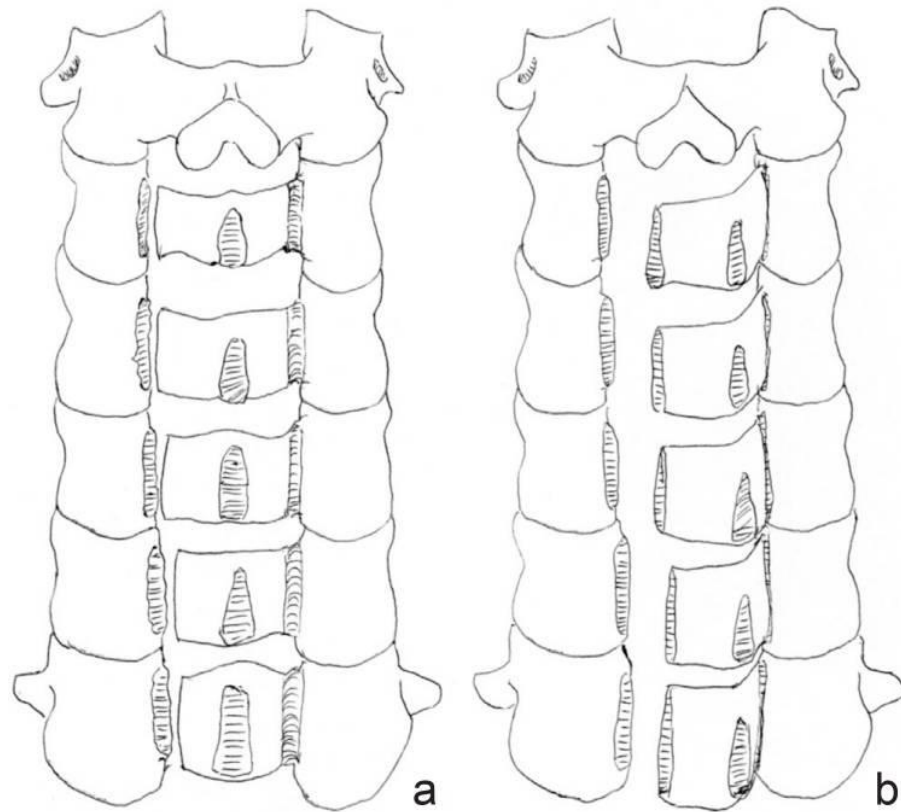
Úvod do problematiky

Oyama – Z plastika (1973)



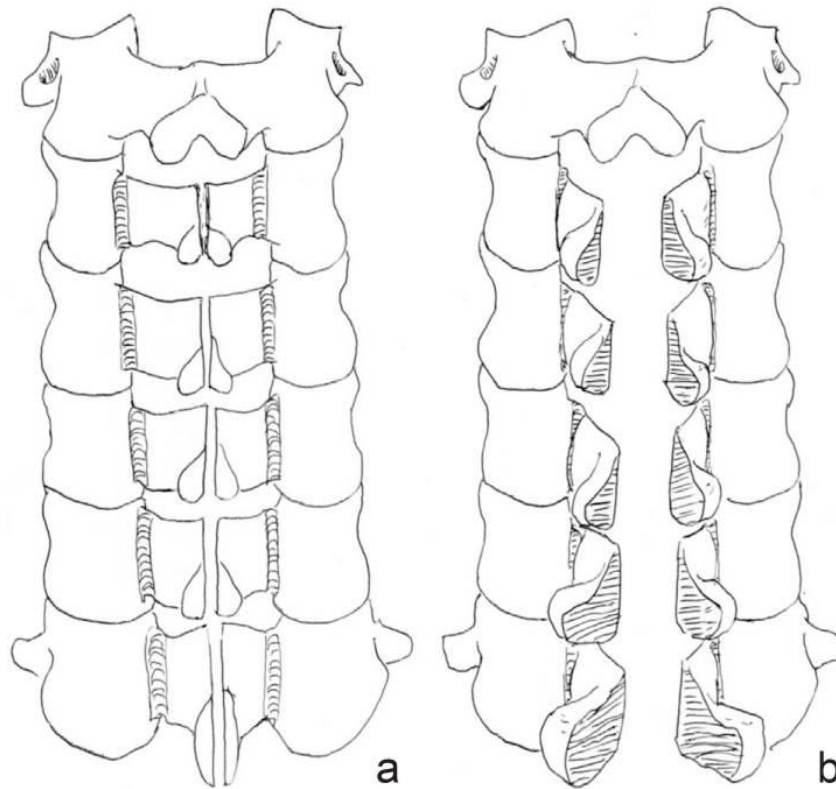
Úvod do problematiky

Hirabayashi – open door (1983)



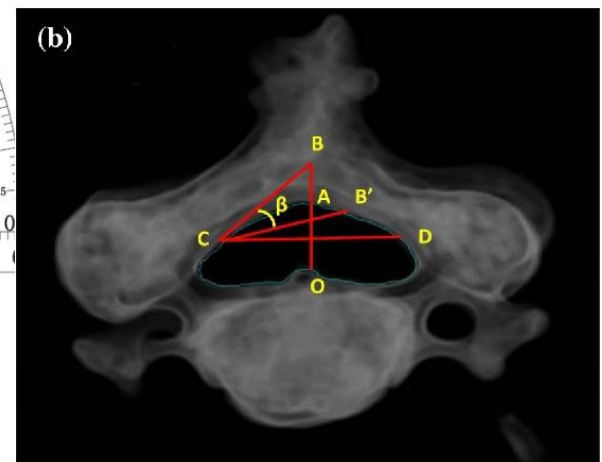
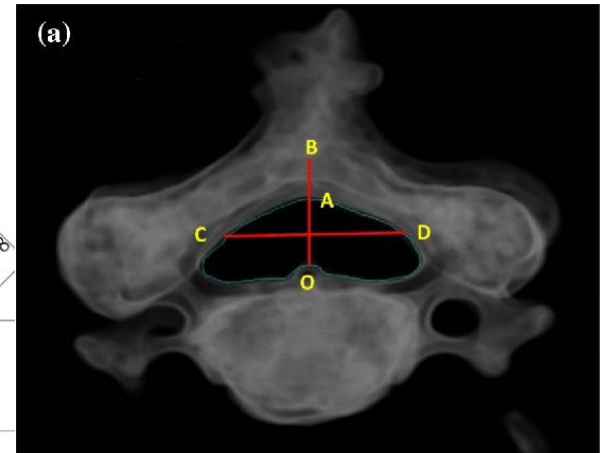
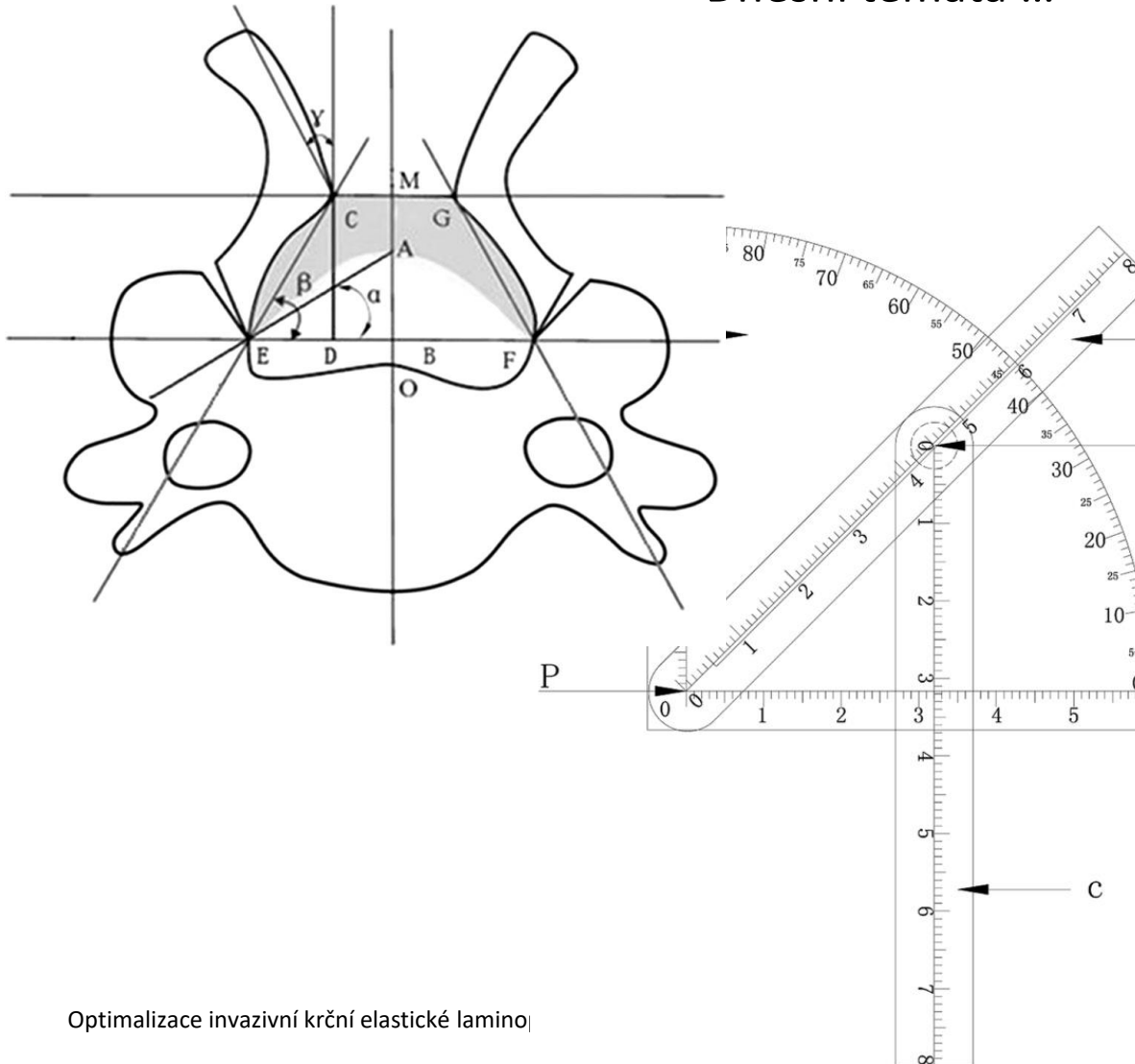
Úvod do problematiky

Kurokawa – double door (1982)



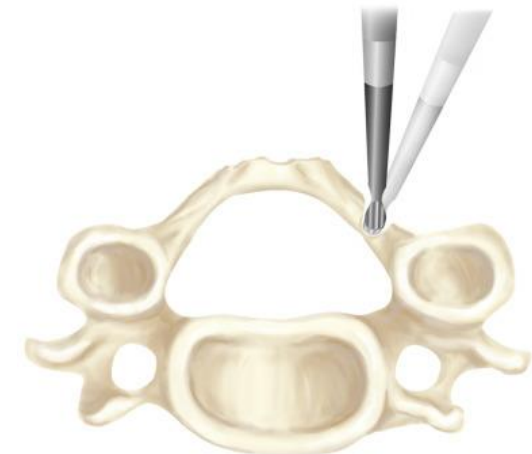
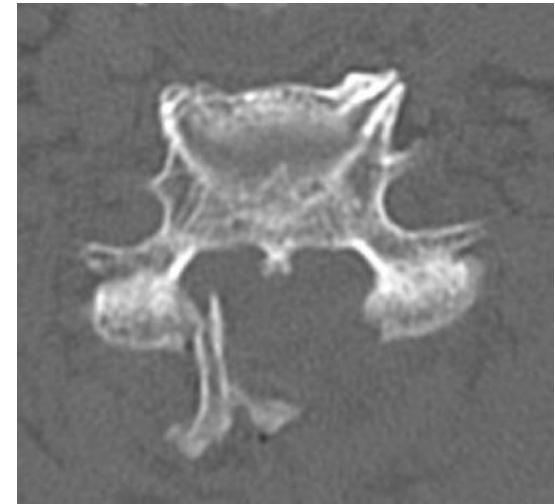
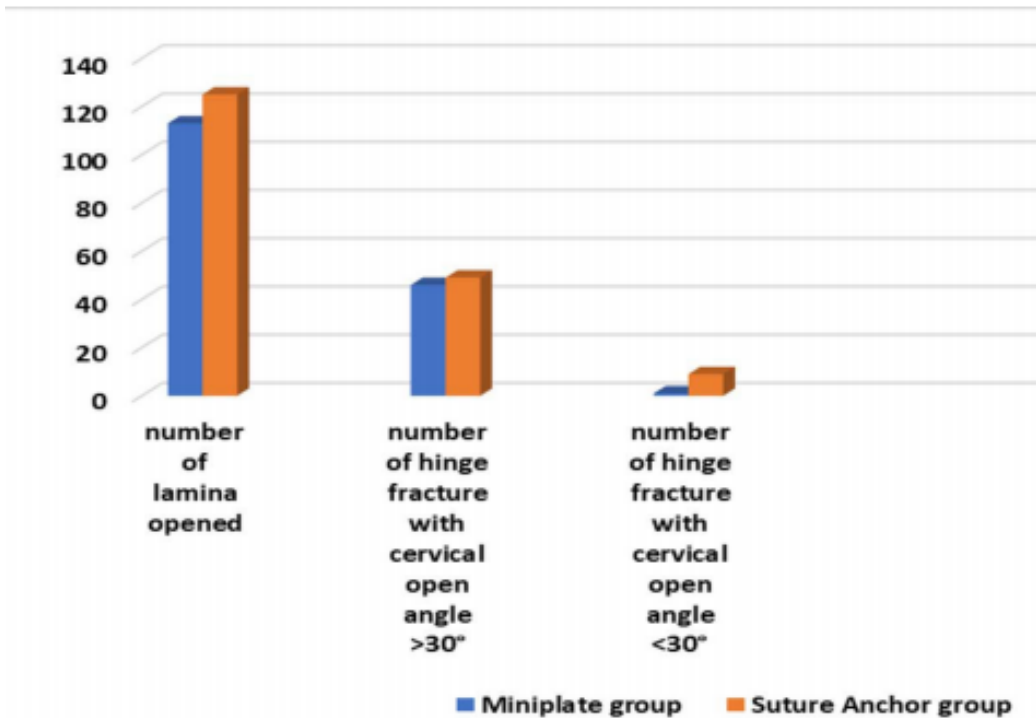
Úvod do problematiky

Dnešní témata ...



Úvod do problematiky

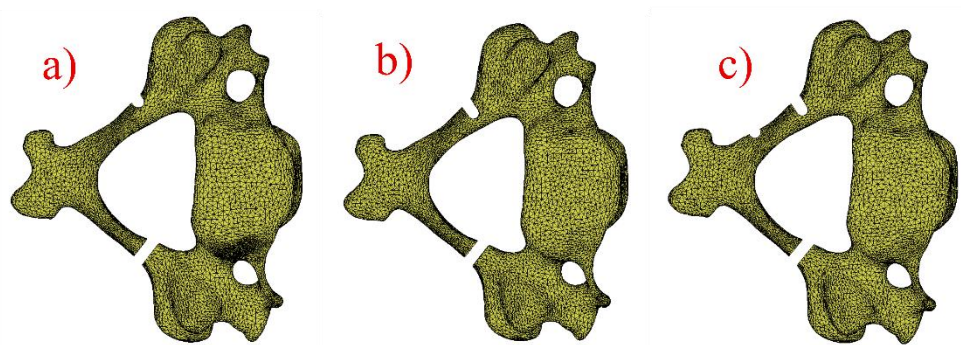
Zakopaný pes ...



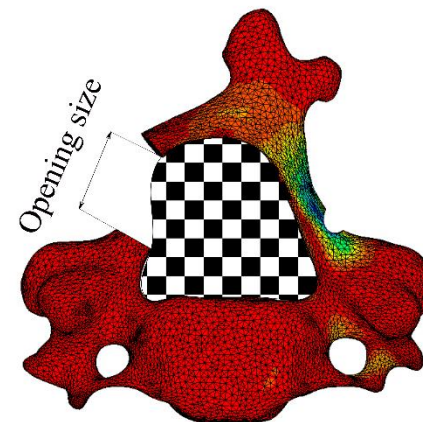
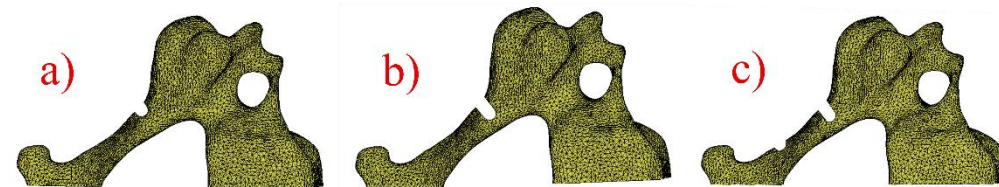
Úvod do problematiky

Předcházející studie ...

Open door laminoplasty computational models

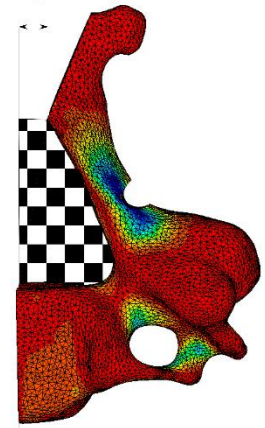


Double door laminoplasty computational models



Open door laminoplasty

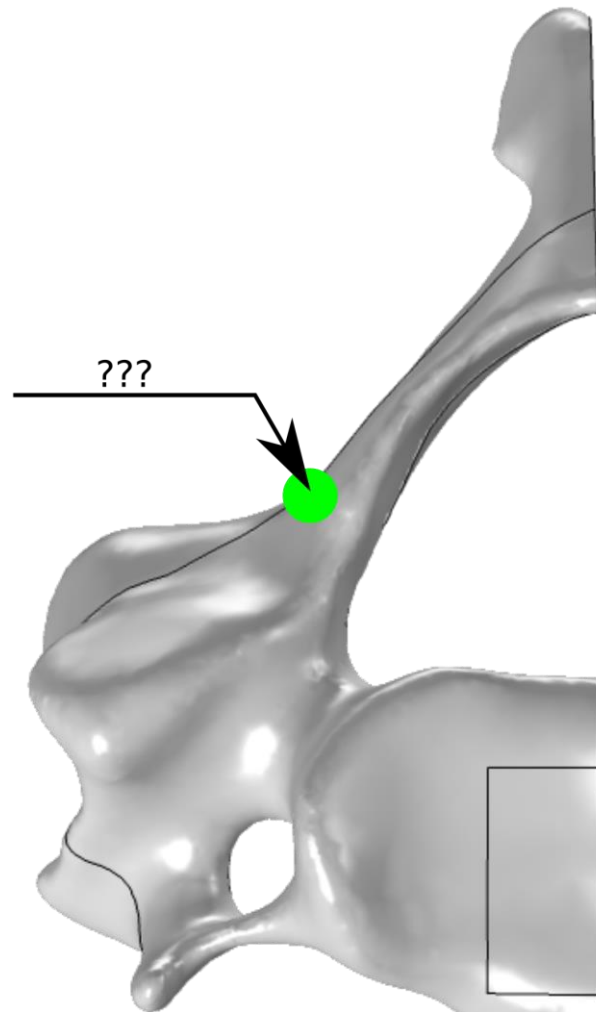
Half of opening size



Double door laminoplasty

Úvod do problematiky

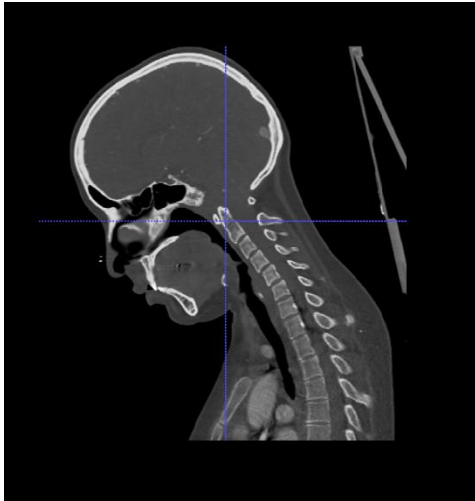
Cíl studie ...



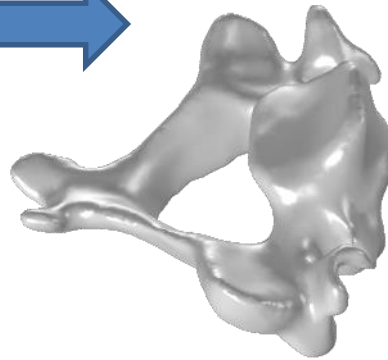
Vývoj výpočtového modelu

Geometrie

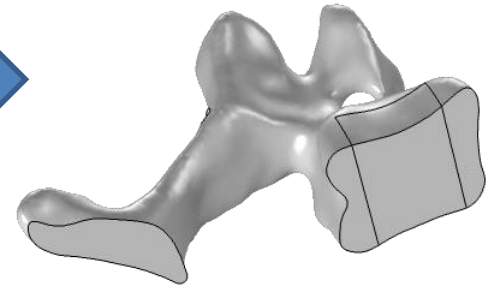
Reálná geometrie z CT scanu



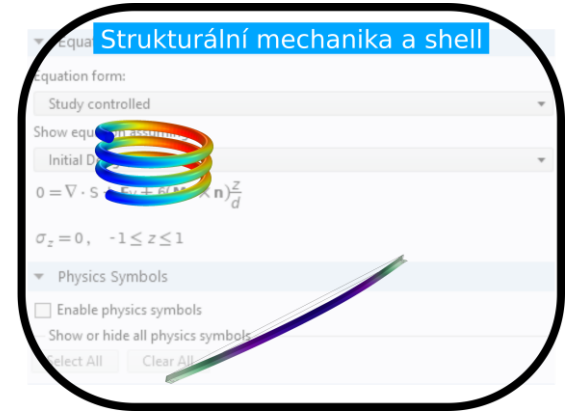
Nativní CT data

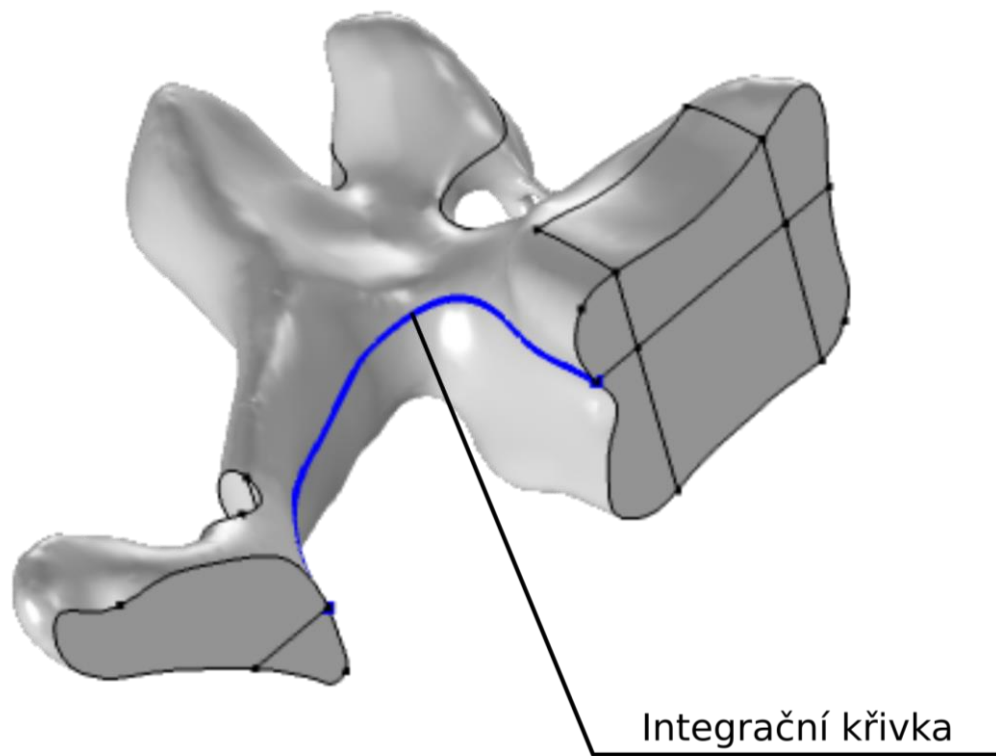
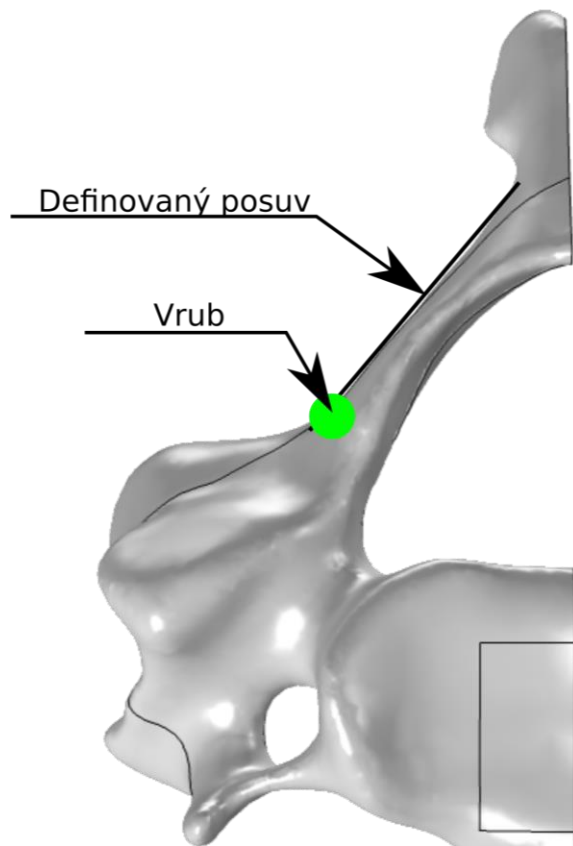


Originální model
(STL soubor)



½ modelu





Finální geometrie

COMSOL Multiphysics 5.6.0.280

File Home Definitions Geometry Materials Physics Mesh Study Results Developer

Application Builder Component Add Component Parameters Import Add Material Shell Add Physics Build Mesh Compute Study Add Study Stress (shell) Add Plot Windows Reset Desktop Layout

Model Builder

- Vertebrae_56_surface_calc.mph (root)
 - Global Definitions
 - Parameters 1
 - Variables 1
 - Mech Parts
 - Materials
 - Component 1 (comp 0)
 - Definitions
 - Analytic 1 (an 1)
 - Selections
 - Edge Probe 1 (edge 1)
 - Edge Probe 2 (edge 2)
 - Integration 1 (intop 1)
 - Integration 2 (intop 2)
 - Boundary System 1 (bsys 1)
 - Shell Local System (shell) (shell 1)
 - View 1
 - Geometry 1
 - Materials
 - Solid Mechanics (solid)
 - Linear Elastic Material 1
 - Free 1
 - Initial Values 1
 - Symmetry 1
 - Symmetry 2
 - Prescribed Displacement 1
 - Shell (shell)
 - Linear Elastic Material 1
 - Shell Local System 1
 - Thickness and Offset 1
 - Free 1
 - Initial Values 1
 - Fixed Constraint 1
 - Symmetry 1
 - Symmetry 2
 - Prescribed Displacement/Rotation 1
 - Multiphysics
 - Mesh 1
 - Study 1
 - Parametric Sweep
 - Step 1: Stationary
 - Solver Configurations
 - Job Configurations
 - Study 2
 - Results

Settings

Edge Probe

Update Results

Label: Edge Probe 1

Variable name: edge1

Probe Type

Type: Average

Source Selection

Selection: Explicit 4

16

Expression

Expression: $\text{abs}(\text{intop}1(x+u))$

Table and plot unit: mm²

Description: $\text{abs}(\text{intop}1(x+u))$

Integration Settings

Method: Integration

Integration order: 4

Frame: Material

Table and Window Settings

Graphics

Messages Progress Log Objective Table 4

COMSOL Multiphysics 5.6.0.280
 License will expire in 36 days.
 Warning: The preference setting Number of cores is ignored because the environment variable 'OMP_NUM_THREADS' is set to '16'.
 [May 25, 2021 12:34 PM] Opened file: D:\Comsol\Comsol\vertebrae\Vertebrae_56_surface_calc.mph

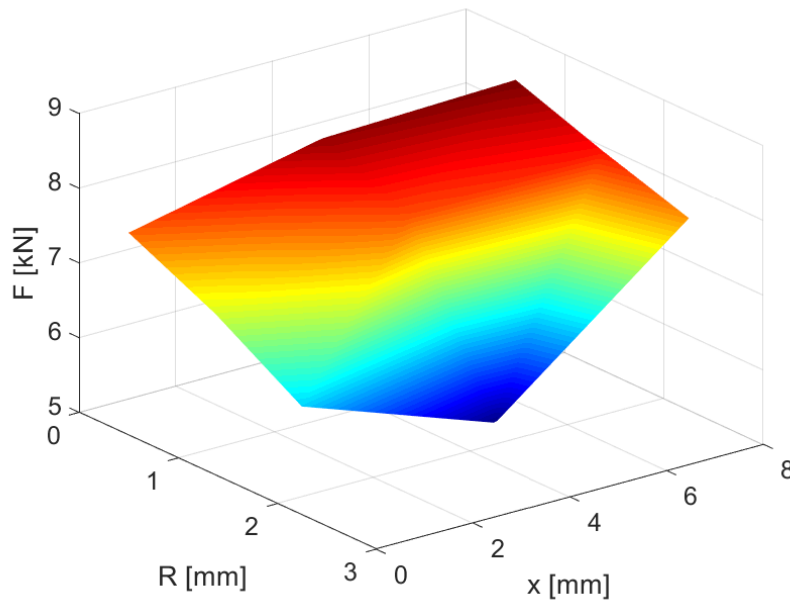
2.72 GB | 3.07 GB

Optimalizace

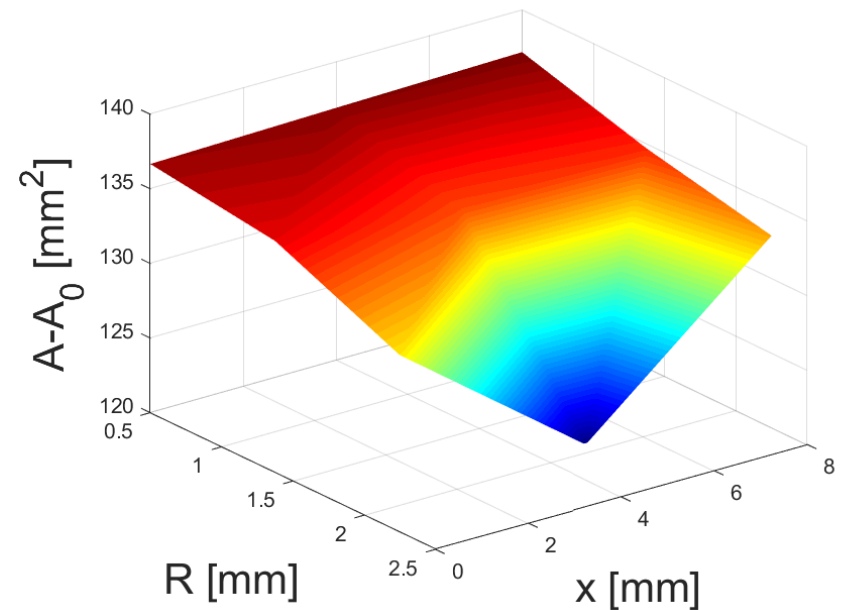
- Parametric sweep
 - Posuv 0 - 8 mm
 - Průměr vrubu 1 - 2,5 mm
- Optimalizace
 - Posuv 0 - 8 mm
 - Průměr vrubu 1 - 2,25 mm

Parametric sweep

- $X=0 - 8$ mm
- $R=0,5 - 2,5$ mm
- Kontrolované veličiny – reakční síla a rozšířená plocha



Obr.: Reakční síla

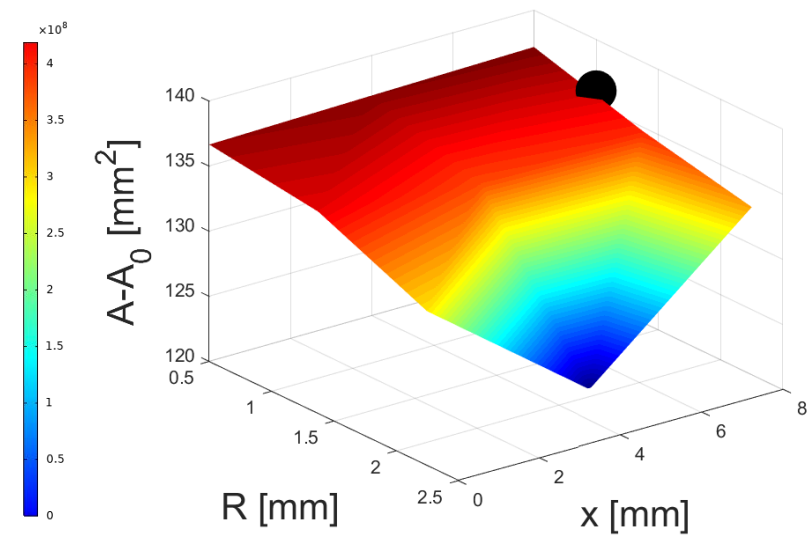
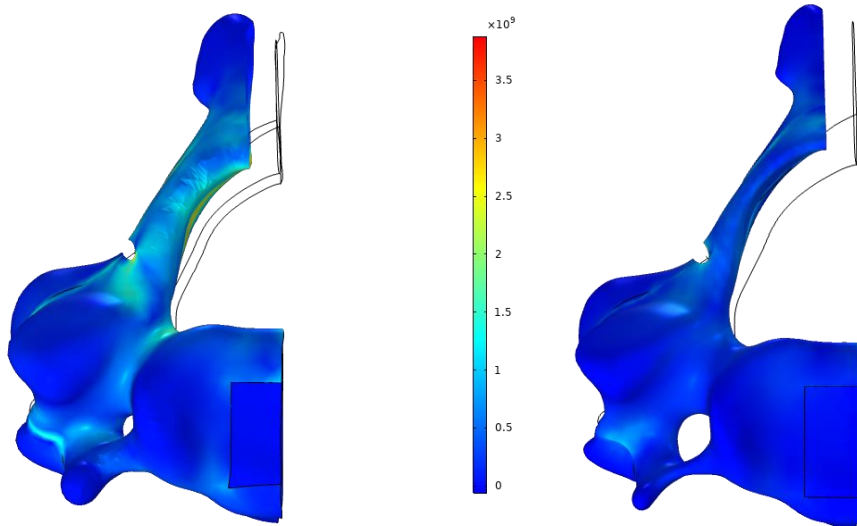


Obr: Vytvořená plocha

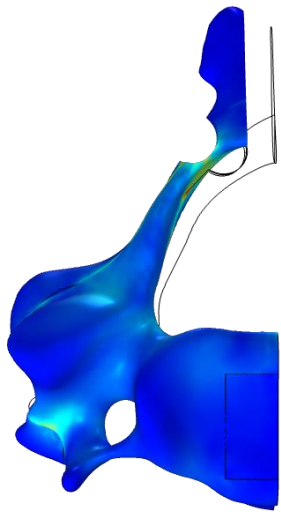
Optimalizace

- Algoritmus Nelder-Mead
- 3 definice optimalizace
 - 1) Minimalizace reakční síly
 - 2) Maximalizace plochy
 - 3) Minimalizace poměru F/A

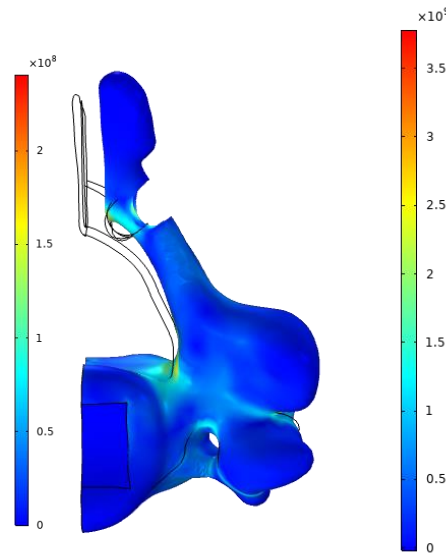
Maximalizace plochy



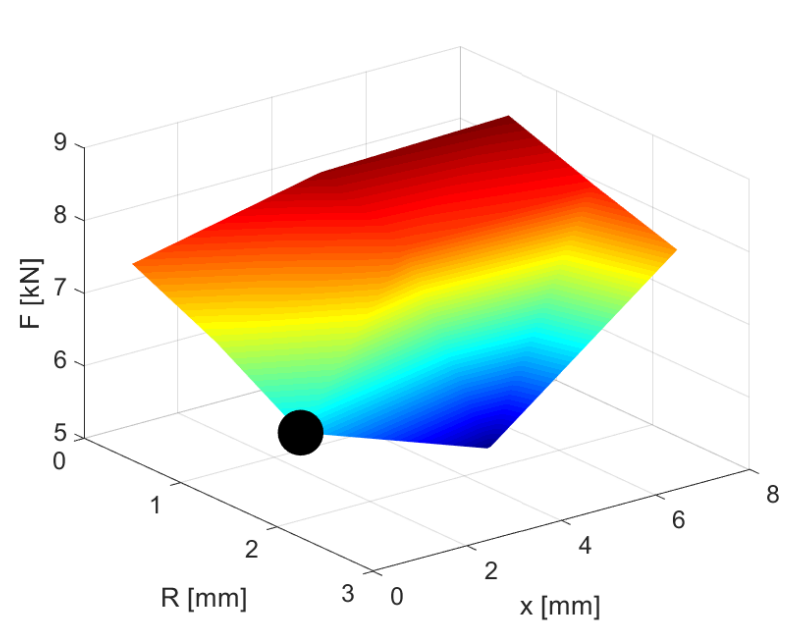
Minimalizace reakční síly



Spongióza - von Mises

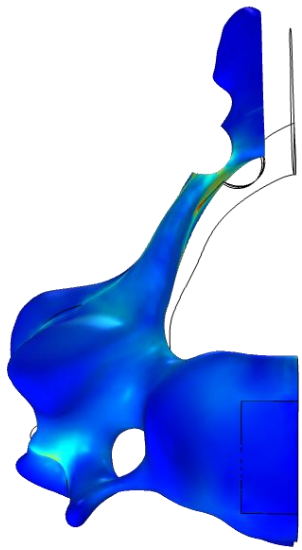


Kortikální k.t.- von Mises

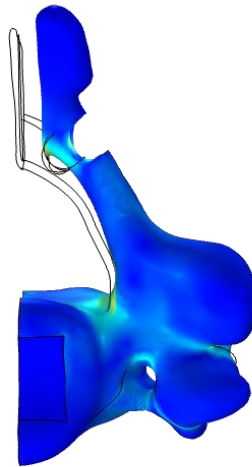
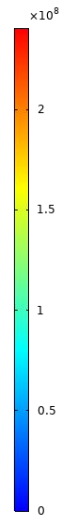


Výsledná plocha

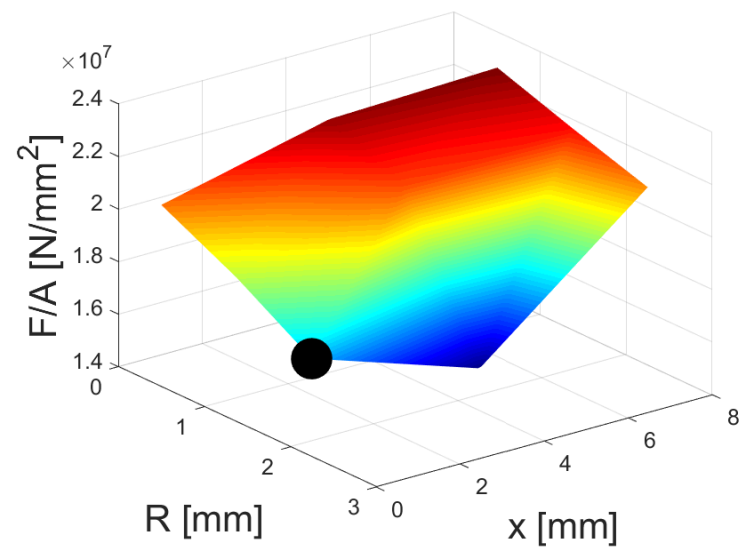
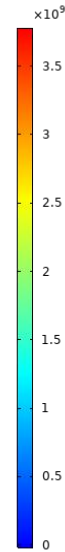
Minimalizace F/A



Spongióza - von Mises



Kortikální k.t. - von Mises



Výsledná plocha

Děkuji za pozornost

Použitá literatura

1. Lee DH, Kim H, Lee CS, Hwang CJ, Cho JH, Cho SK. Clinical and radiographic outcomes following hinge fracture during open-door cervical laminoplasty. *J Clin Neurosci*. 2017 Sep;43:72-76.
2. Kurokawa R, Kim P. Cervical Laminoplasty: The History and the Future. *Neurol Med Chir (Tokyo)*. 2015;55(7):529-539. doi:10.2176/nmc.ra.2014-0387
3. Yang, Xiao-jiang et al. "A new method for calculating the desired laminoplasty opening size based on the target sagittal canal diameter before single-door cervical laminoplasty." *European Spine Journal* (2019): 1-9.
4. Lang, Xj., Sang, Hx., Liu, Cx. *et al.* A new method for calculating the desired laminoplasty opening size based on the target sagittal canal diameter before single-door cervical laminoplasty. *Eur Spine J* **28**, 2302–2310 (2019).
5. <https://musculoskeletalkey.com/cervical-laminoplasty-3/>
6. <https://www.mayoclinic.org/diseases-conditions/spinal-stenosis/multimedia/laminoplasty/img-20149228>