

# Testovací a kalibrační obrazová data pro mikro-CT vyšetřování vláknitých a porézních materiálů

**Zbyněk Tonar, Miroslav Jiřík, Martin Bartoš, Tereza Kubíková, Jana Horáková,  
David Lukáš, Tomáš Suchý, Pavla Sauerová, Marie Hubálek Kalbáčová**

Ústav histologie a embryologie a Laboratoř kvantitativní histologie Biomedicínského centra  
Lékařská fakulta Univerzity Karlovy v Plzni

# Odkud pocházíme a kde pracujeme

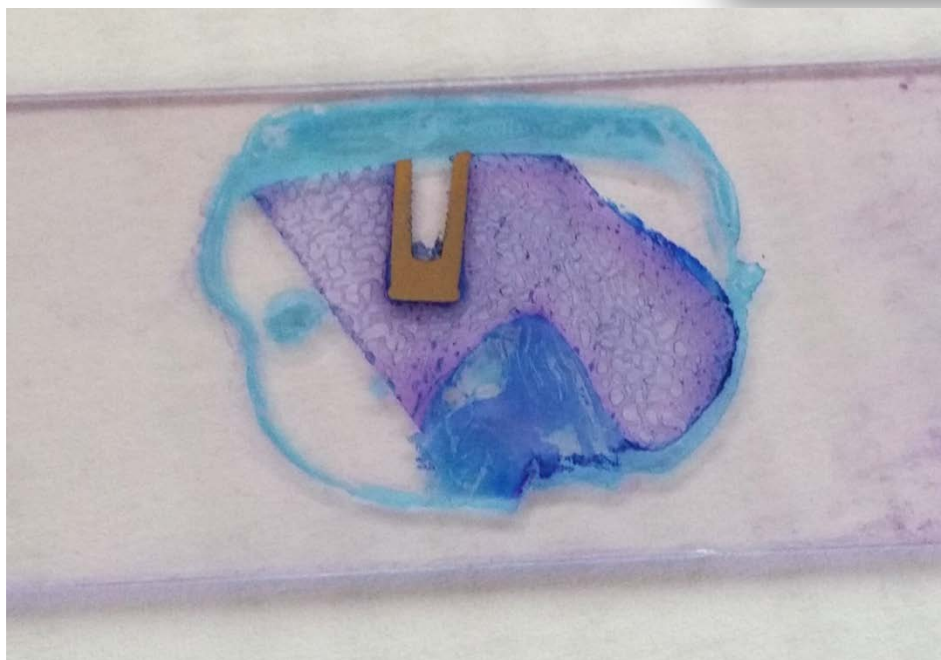
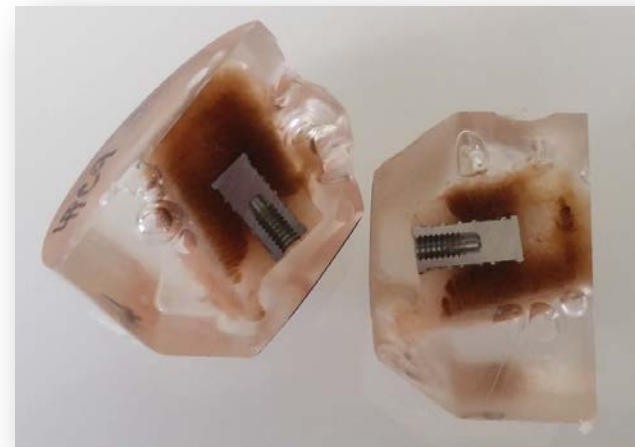
Ústav histologie a embryologie a Biomedicínské centrum LF UK v  
Plzni

Laboratoř kvantitativní histologie

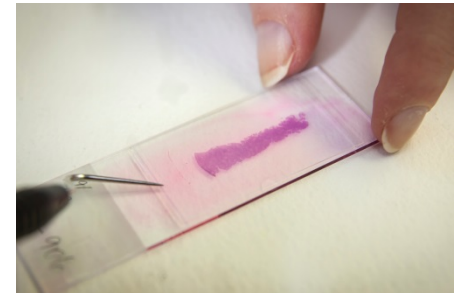
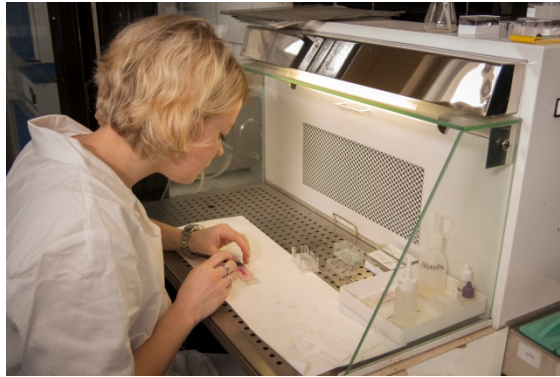
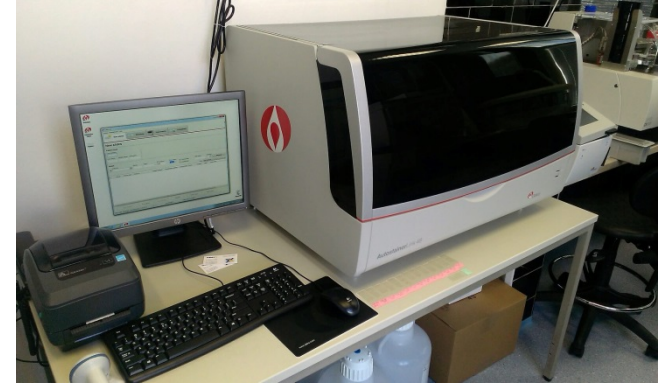




# Zpracování tvrdých tkání



# Měkké tkáně - parafinové řezy, imunohistochemie

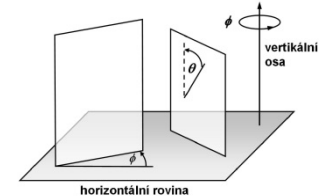
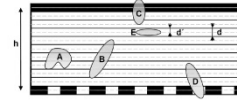
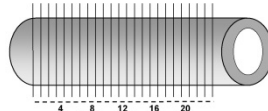




# Základní strategie: Unbiased stereology

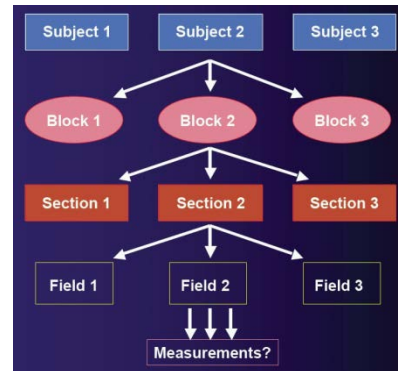
Randomizace **orientace** a **víceúrovňové systematické** a **nestranné vzorkování** při

- **odběru** orgánů a bločků
- **výběru** histologických řezů a mikroskopických zorných polí



**Složení vzorků** je vizualizováno

- přehlednými metodami
- imunohistochemicky



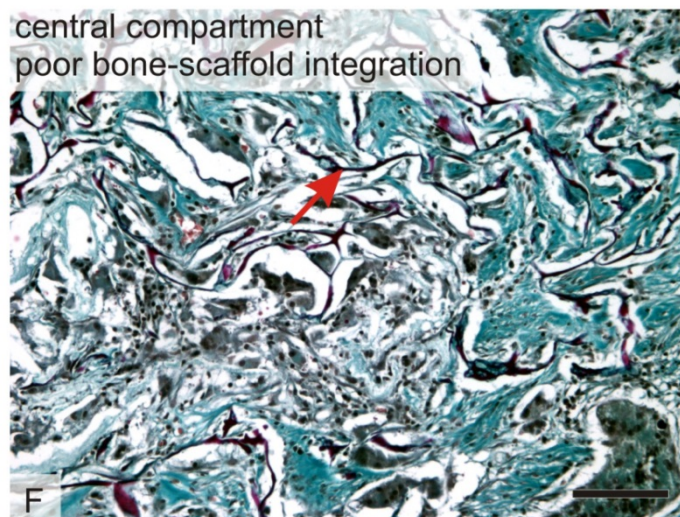
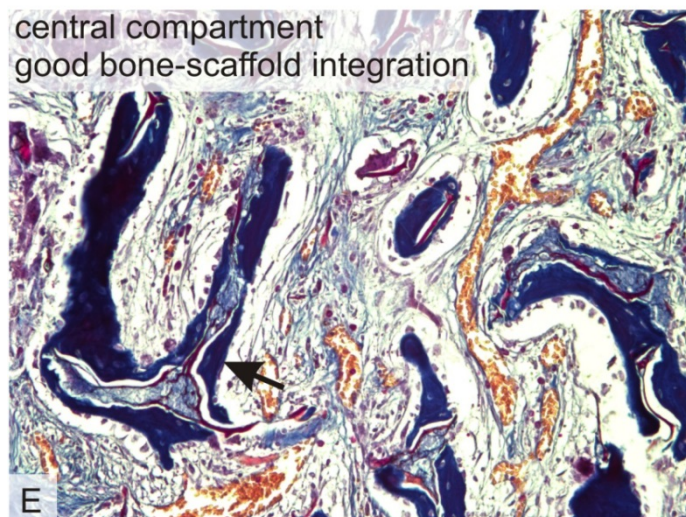
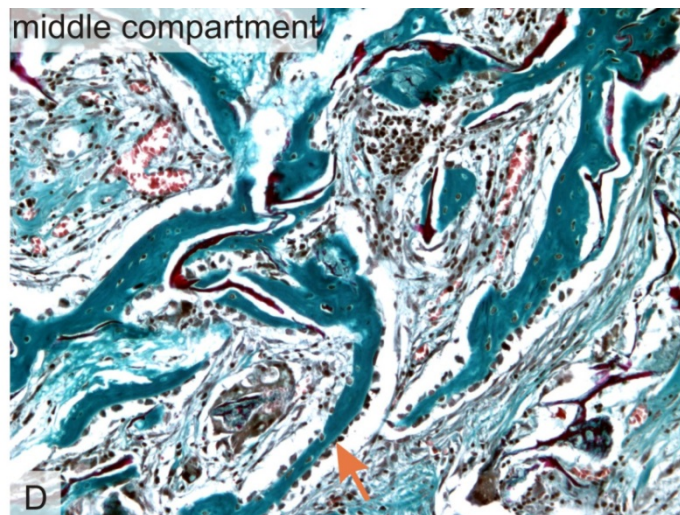
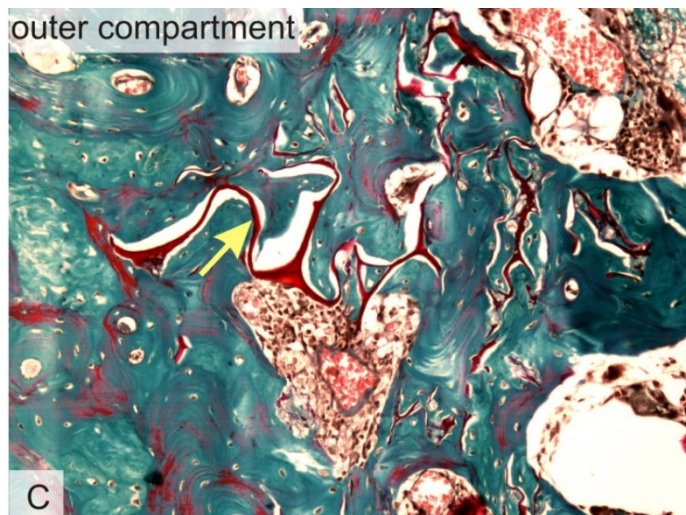
→ Popis složení  
vzorků pomocí  
**spojitých**  
**kvantitativních**  
**proměnných**

**Stereologie:** Popis 3D objektů na základě studia 2D řezů

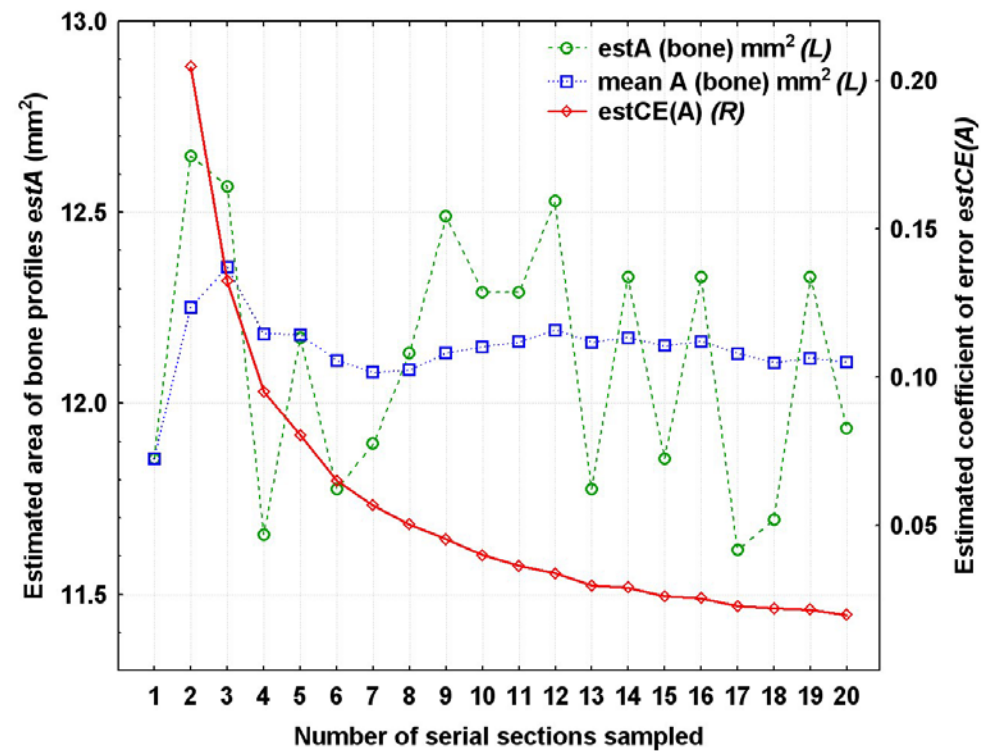
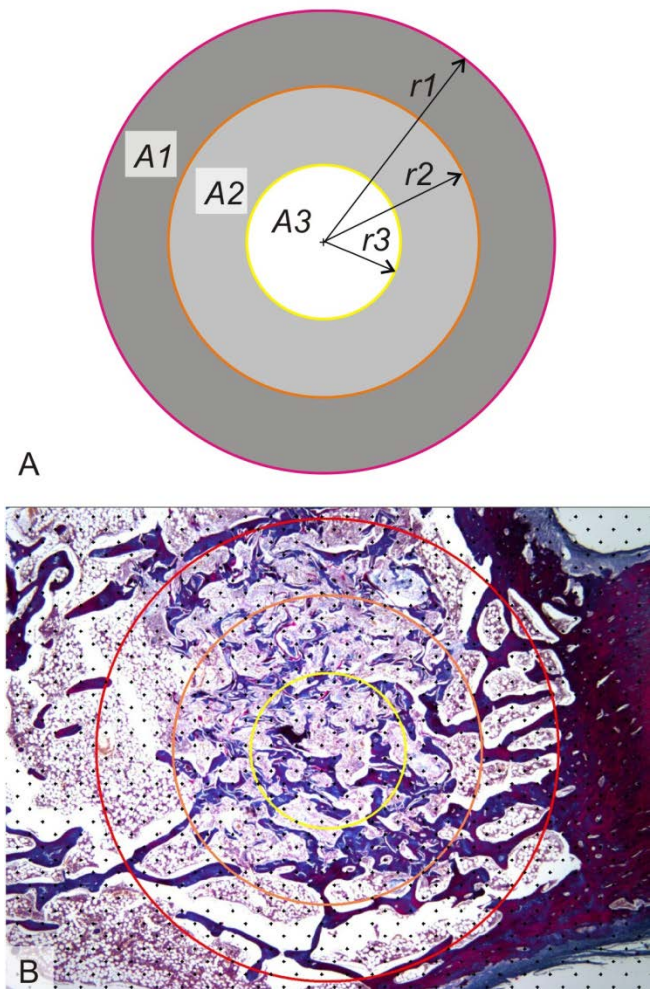
- počítání mikroskopických objektů (disektor, frakcionátor)
- odhady a měření délek, ploch, objemů
- hodnocení hustoty mikrocév
- plošné a objemové podíly vícefázových struktur
- tortuozita vláknitých struktur
- shlukování objektů

# Příklady řešených výzkumných otázek

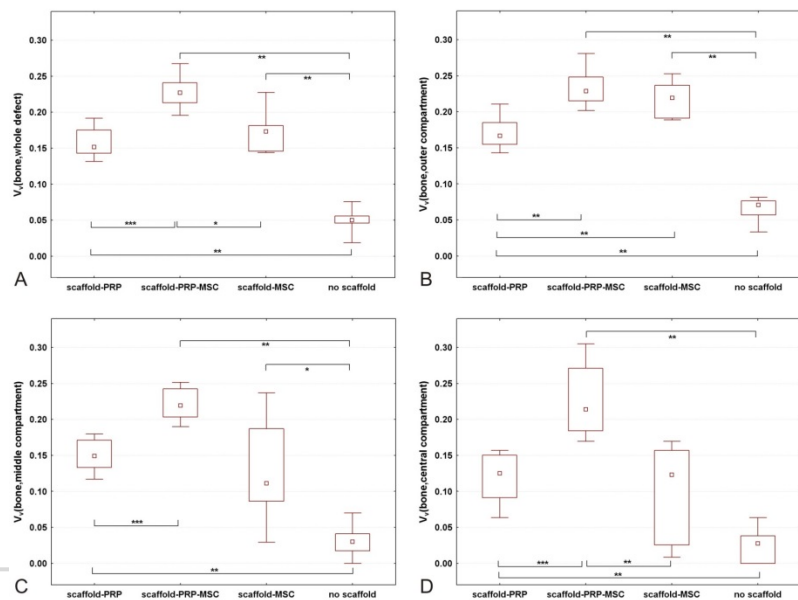
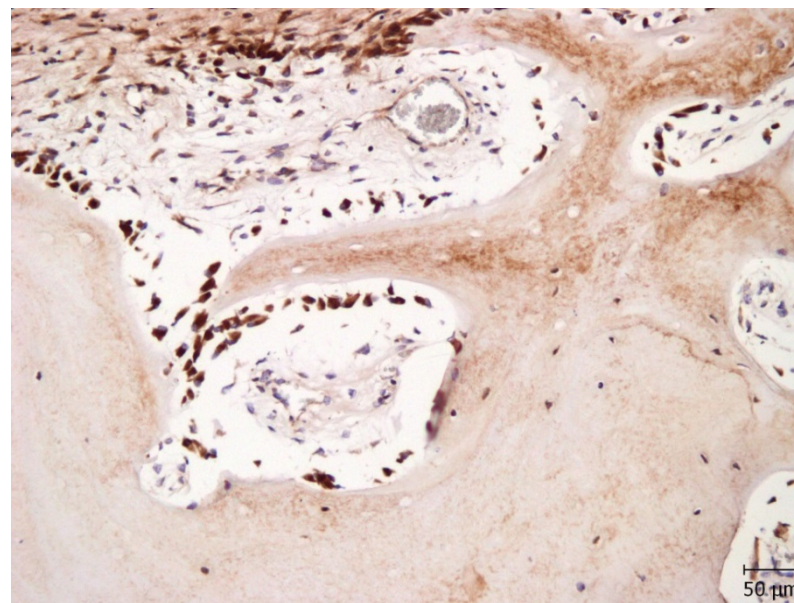
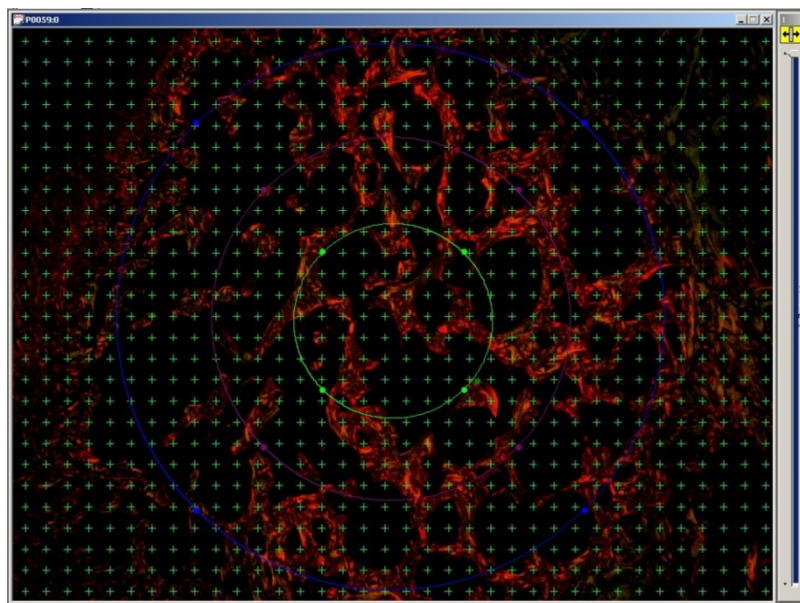
## Objem a rovnoměrnost distribuce novotvořené kosti v experimentálním defektu







Parameter	Compartment		
	Outer	Middle	Central
Circle diameter (mm)	6	4	2
Area per section (mm <sup>2</sup> )	15.71	9.42	3.14
Area label	A1	A2	A3
Volume in 4 s (mm <sup>3</sup> )	3.142	1.884	0.628
Volume fraction	0.552	0.331	0.114



## Collagen/hydroxyapatite scaffold enriched with polycaprolactone nanofibers, thrombocyte-rich solution and mesenchymal stem cells promotes regeneration in large bone defect in vivo

E. Prosecká,<sup>1,2,3</sup> M. Rampichová,<sup>2,4</sup> A. Litvinec,<sup>2</sup> Z. Tonar,<sup>5</sup> M. Králíčková,<sup>5</sup> L. Vojtová,<sup>6</sup> P. Kochová,<sup>7</sup> M. Plencner,<sup>1,2</sup> M. Buzgo,<sup>1,2,4</sup> A. Mičková,<sup>1,2,4</sup> J. Jančár,<sup>6,8</sup> E. Amler,<sup>1,2,9</sup>

<sup>1</sup>Institute of Biophysics, 2nd Faculty of Medicine, Charles University in Prague, V Úvalu 84, 150 06, Prague, Czech Republic

<sup>2</sup>Department of Tissue Engineering, Institute of Experimental Medicine ASCR v.v.i., Viděnská 1083, 14240, Prague, Czech Republic

<sup>3</sup>Student Science s.r.o., Horní Podluží 237, Horní Podluží, 407 57, Czech Republic

<sup>4</sup>University Centre for Energy Efficient Buildings, Quality of Indoor Environment, Czech Technical University in Prague, Nám. Sítná 3105, 272 01, Kladno, Czech Republic

<sup>5</sup>Biomedical Centre, Faculty of Medicine in Pilsen, Charles University in Prague, Husova 3, 306 05 Pilsen, Czech Republic

<sup>6</sup>Central European Institute of Technology, Brno University of Technology, Technická 3058/10, 616 00 Brno, Czech Republic

<sup>7</sup>European Centre of Excellence-New Technologies for Information Society, Faculty of Applied Sciences, University of West Bohemia, Univerzitní 22, 306 14 Pilsen, Czech Republic

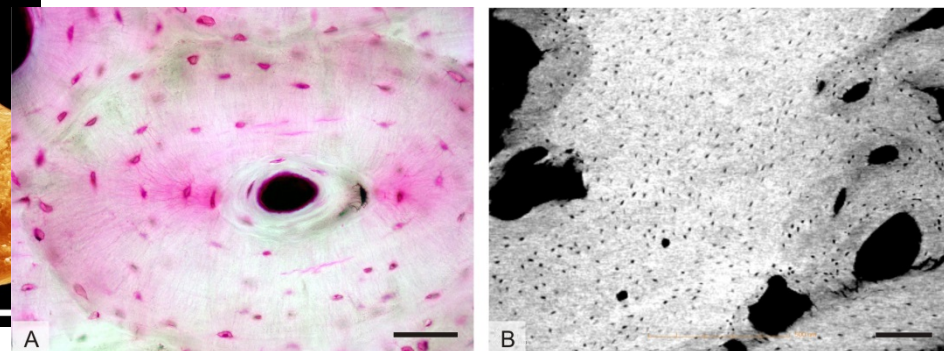
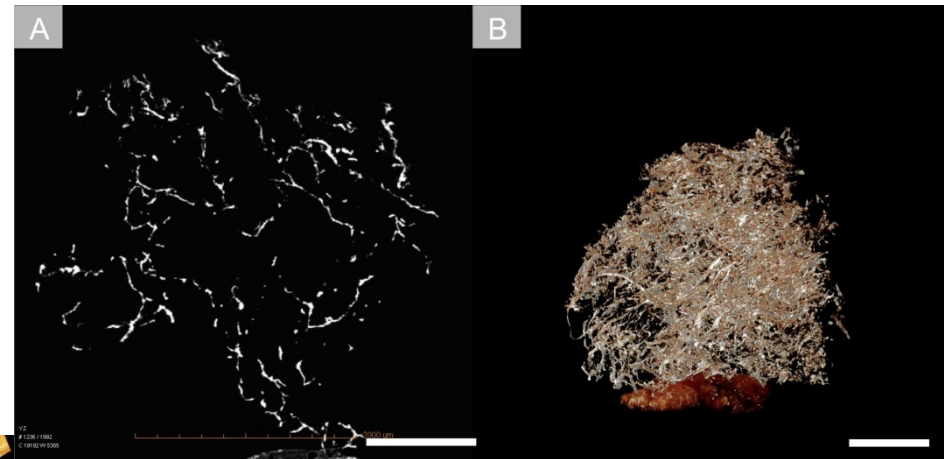
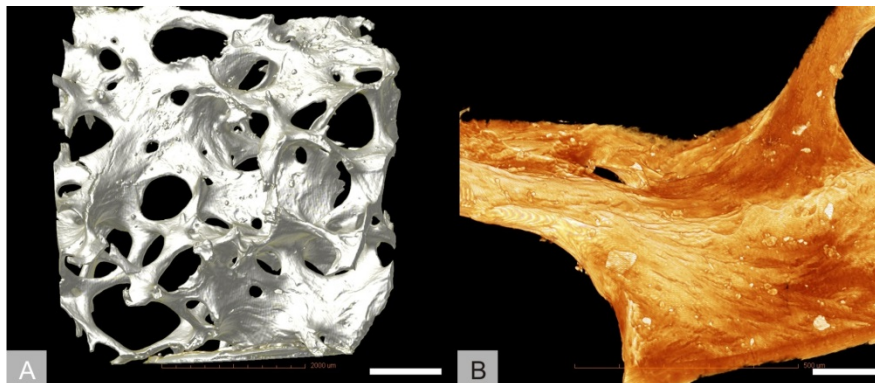
<sup>8</sup>Faculty of Chemistry, Institute of Materials Chemistry, Brno University of Technology, Purkyňova 118, 612 00 Brno, Czech Republic

<sup>9</sup>Faculty of Biomedical Engineering, Czech Technical University in Prague, Nám. Sítná 3105, 272 01 Kladno, Czech Republic

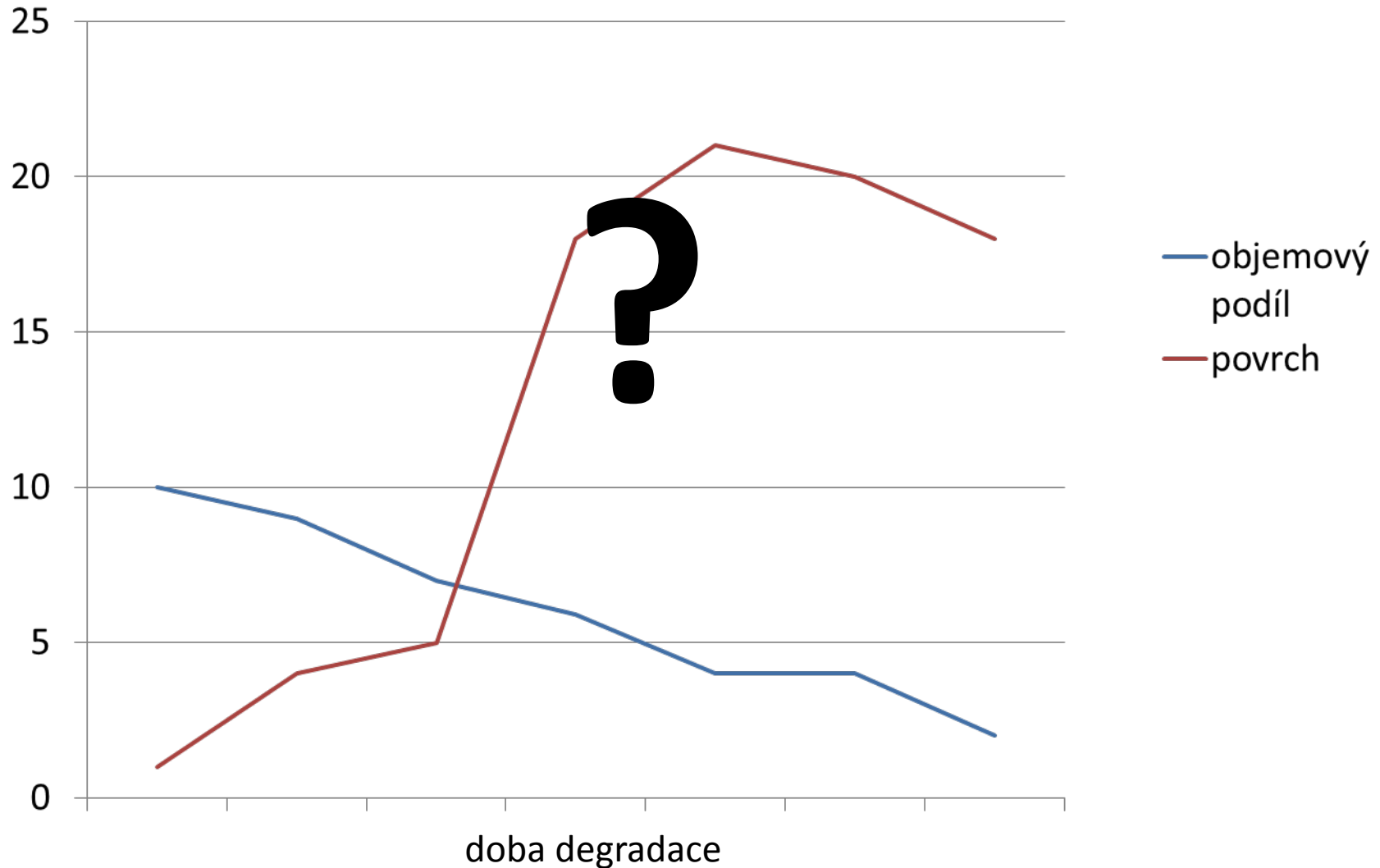


# Výhody $\mu$ -CT

- nativně 3D → minimální vzorkovací chyba
- obejde histologické artefakty
  - teplota
  - rozpouštědla
  - smrštění
  - demineralizace
  - ztráta materiálu řezáním a krájením...)



# mikro-CT jako slibná metoda pro posouzení *in vivo* degradace biomateriálu?





# Mikro-CT: kritické shrnutí možností kvantifikace

**status: September 2016**

**location: Herbertov**

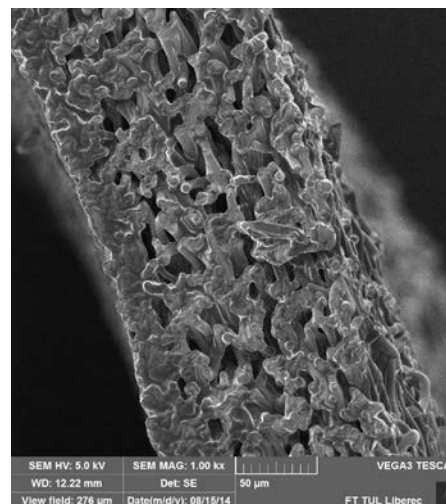
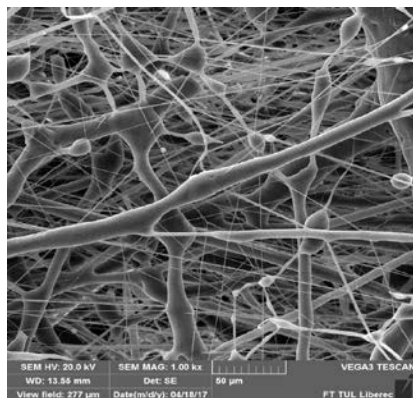


- objemové podíly vláken i porozit jsou bezesporné
- CAVE: měření **povrchů** a **délek** silně **závisí** na **způsobu segmentace**
- Návrh: provést **analýzu citlivosti** a **doporučit nejvhodnější postup**

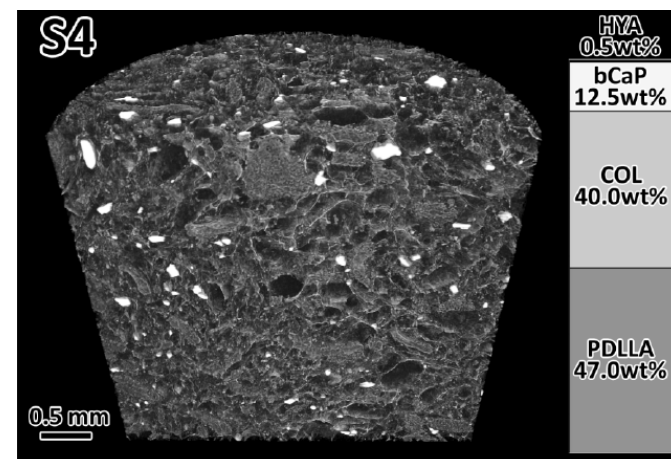
**Ponaučení:** U některých charakteristik nemáme „**zlatý standard**“ ani **kalibrační nástroje**!

# Reálné materiály předlohou testovacích dat

1. nanovláknenné textilie z polykaprolaktonových vláken

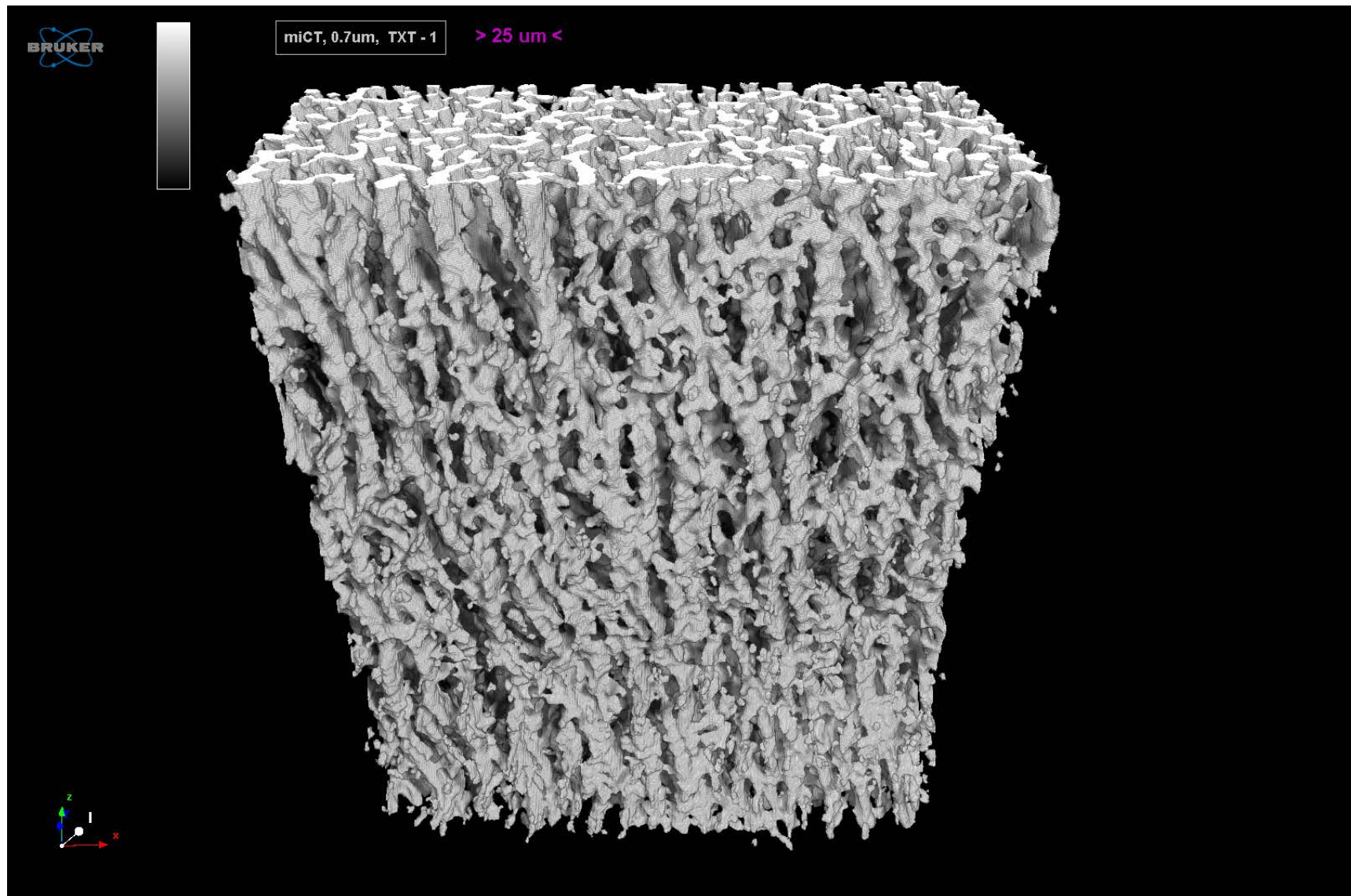


2. kompozitní nosiče složené z kolagenu, polylaktidových vláken a fosforečnanu vápenatého

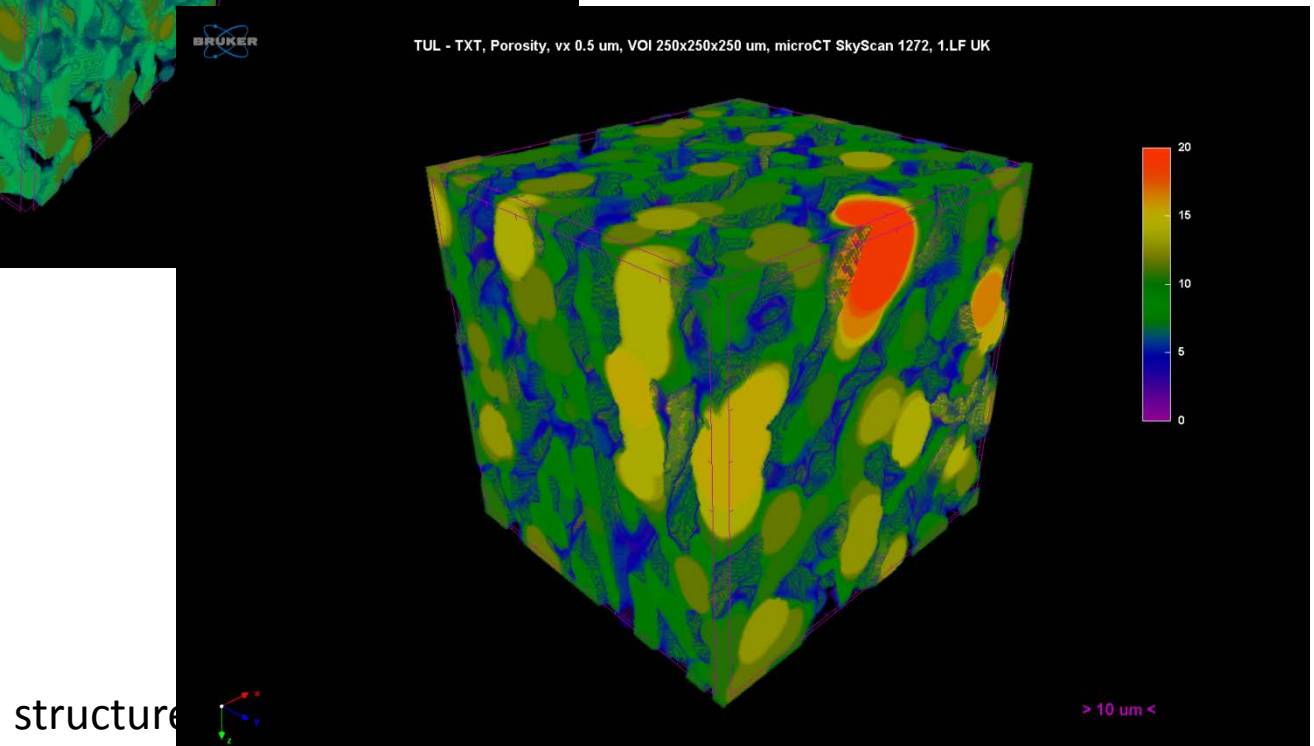
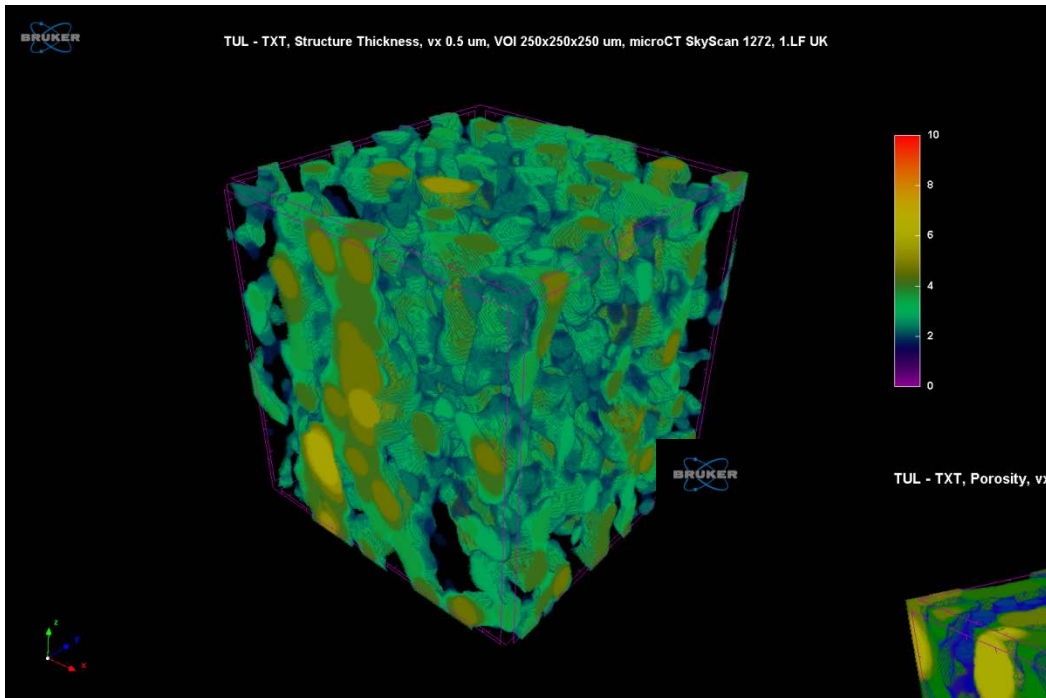




# Mikro-CT, rozlišení 0,5 $\mu\text{m}$



# Mikro-CT – vizualizace textilie i porozity



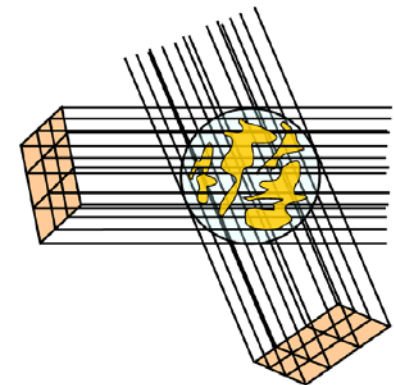


# Mikro-CT

- vyžaduje **binarizaci**
- běžná **morfometrie** ve **2D i 3D**
- charakteristiky **celku i jednotlivých objektů** v něm
- **an/izotropie** (míra 3D symetrie, analýza preferenčních orientací)
- **konektivita** (redundance spojek bránících rozpadu na samostatné objekty) pomocí Euler-Poincarého čísla

$$\chi = \Sigma (\text{connected components}) - \Sigma (\text{bridges, „handles“, loops}) + \Sigma (\text{holes, voids})$$

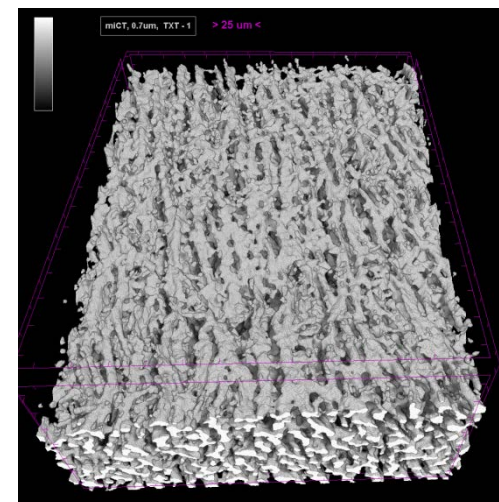
- analýza **porozit**
- uplatnění **stereologie** v analýze  $\mu$ -CT obrazů



**Figure 2.** For the MIL analysis, a grid of lines is sent through the volume over a large number of 3D angles (just two are illustrated here). The MIL for each angle is calculated as the average for all the lines of the grid.

# Problémy s délkou – interaktivní měření

- binární obraz je **silně ovlivněn kontaktem vláken**
- záporná 3D Eulerova charakteristika se projeví **podceněním odhadu délky**, který se počítá z 2D Eulerových charakteristik ve 3 kolmých rovinách
- **x**přístup založený na skeletonizaci naopak nadhodnocuje délku **o nadbytečné spojky**
- různými druhy filtrace lze před binarizací získat výrazně větší a kladnou Eulerovu charakteristiku a **odhad délky ze zvýší**
- **x**skeletonizací a vyhlazením dostáváme pak o něco **kratší délku**





# Software Teigen

<https://mjirik.github.io/teigen/>

## Teigen

Test Image Generator

[View the Project on GitHub](#)

[mjirik/teigen](#)

Download  
**ZIP File**

Download  
**TAR Ball**

View On  
**GitHub**

This project is maintained by [mjirik](#)

Hosted on GitHub Pages — Theme by [orderedlist](#)

## teigen

Test Image Generator

## Installation

```
conda install -c mjirik -c simpleitk teigen
```

## Windows

[Windows installer](#)



# Flowchart – generátor neprotínajících se válců a koulí

## vstupní parametry

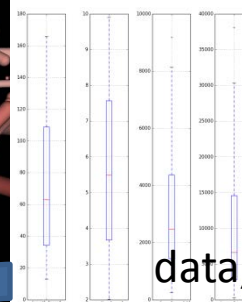
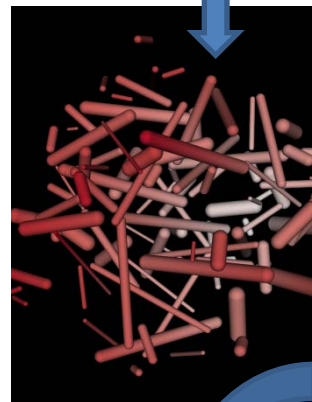
- počet objektů
- objemový podíl
- distribuce průměrů válců/koulí
- distribuce délek válců
- profily intenzit uvnitř/na okraji objektů
- izotropie/anizotropie
- rozlišení
- gaussovské rozostření
- parametrický generátor náhodného šumu
- počty iterací
- seed
- ...

load

save

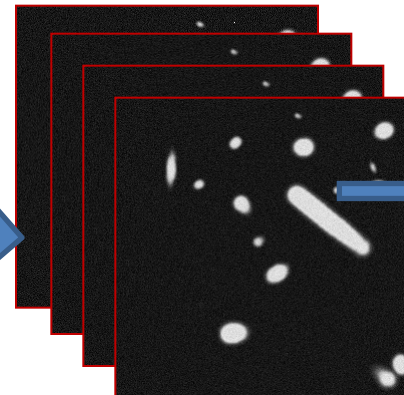
YAML  
konfigurační  
soubor

generate skeleton



data, graphs, tables, histograms

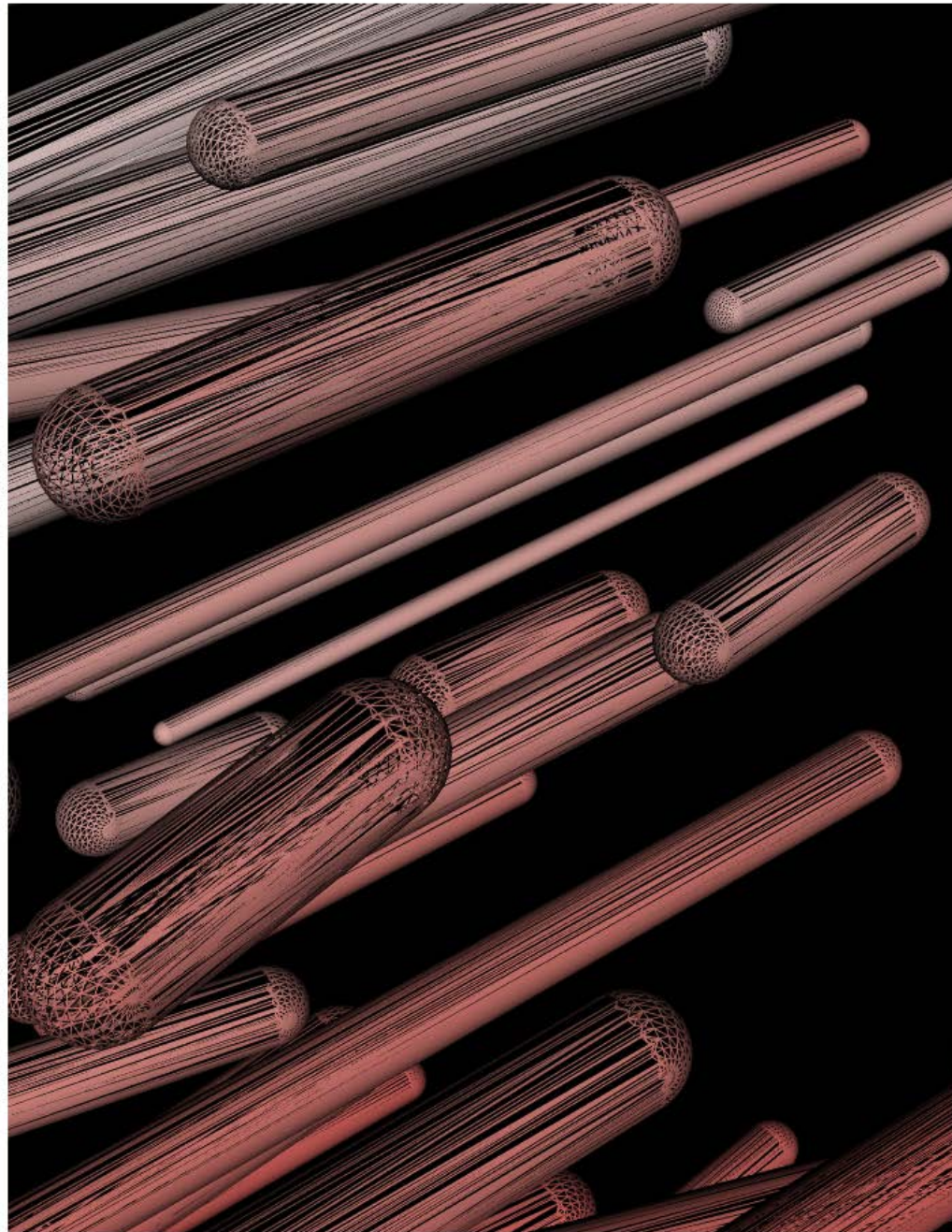
generate  
and save  
volumetric  
data



- micro-CT SW
- ImageJ
- interaktivní stereologie
- ...

```
YamlEditor - [C:\source\issue_engineering\stereologie_cenich_nahrad_TU\software_generator... 88 %
Soubor Upravit Množství Kódování Název souboru
appearance: {show_surface: true}
aresampling:
  areasize_mm: [300.0, 300.0, 300.0]
  areasize_px: [300, 300, 300]
  voxelsize_mm: [1.0, 1.0, 1.0]
  filepathpattern: C:\Users\stumar\trigen_data\{seriesName}\slice\{sliceID}.jpg
  filepathpattern_series_number: 27
  generator_id: 3
generators:
  - cylinder_generator
    - !python/object/apply:collections.OrderedDict
      - [element_number, 30]
      - !python/object/apply:collections.OrderedDict
        - [uniform_radius_distribution, true]
        - [normal_radius_distribution, false]
        - [fixed_radius_distribution, false]
        - [radius_distribution_minimum, 2.0]
        - [radius_distribution_maximum, 10.0]
        - [radius_distribution_mean, 5.0]
        - [radius_distribution_standard_deviation, 5.0]
        - [intensity_profile_radius,
            - <id0001 [0.5, 0.7, 1.0, 1.3]
            - [intensity_profile_intensity,
                - <id0002 [195, 190, 200, 20]
            - [random_generator_seed, 0]
        - [random_generator_seed, 0]
        - !python/object/apply:collections.OrderedDict
          - [n_objects, 10]
          - cylinder_continues
          - !python/object/apply:collections.OrderedDict
            - [element_number, 30]
            - [uniform_radius_distribution, true]
            - [normal_radius_distribution, false]
            - [fixed_radius_distribution, false]
            - [radius_distribution_minimum, 2.0]
            - [radius_distribution_maximum, 10.0]
            - [radius_distribution_mean, 5.0]
            - [radius_distribution_standard_deviation, 5.0]
            - [intensity_profile_radius,
                - <id0001
                - [intensity_profile_intensity,
                    - <id0002
            - [random_generator_seed, 0]
            - !python/object/apply:collections.OrderedDict
              - [element_number, 50]
              - [uniform_radius_distribution, true]
              - [normal_radius_distribution, false]
              - [fixed_radius_distribution, false]
              - [radius_distribution_minimum, 10.0]
              - [radius_distribution_maximum, 50.0]
              - [radius_distribution_mean, 25.0]
              - [radius_distribution_standard_deviation, 5.0]
              - [length_distribution_mean, 100.0]
              - [length_distribution_standard_deviation, 30.0]
              - [intensity_profile_radius,
                  - [0.5, 0.7, 1.0, 1.3]
              - [intensity_profile_intensity,
                  - [195, 190, 200, 20]
              - [orientation_anisotropic, false]
              - [orientation_axis,
                  - [1.0, 1.0, 0.0]
              - [orientation_variance_rad, 0.1]
              - [volume_fraction, 0.15]
              - [maximum_iteration_number, 10]
              - [random_generator_seed, 0]
              - !python/object/apply:collections.OrderedDict
                - [gaussian_blur, true]
```





Teigen 0.2.17

Parameter

Value

Batch processing

Run batch

Add

Area Sampling

voxelsize\_mm

01mm

11mm

21mm

areaseize\_mm

0300mm

1300mm

2300mm

areaseize\_px

0300px

1300px

2300px

Appearance

show\_surface

Postprocessing

gaussian\_blur

gaussian\_filter\_sigma\_mm

1

add\_noise

noise\_preview

limit\_negative\_intensities

noise\_random\_generator\_seed

0

exponent

0.0001

lambda\_start

0.1

lambda\_stop

3

noise\_amplitude

40

noise\_mean

30

surface\_measurement

measurement\_multiplier

-1

measurement\_resolution

20

output\_dtype

uint8

negative

Cylinder generator

Gensei generator

Cylinder continues

Unconnected cylinders

element\_number

100

uniform\_radius\_distribution

normal\_radius\_distribution

fixed\_radius\_distribution

radius\_distribution\_minimum

2.000000

radius\_distribution\_maximum

10.000000

radius\_distribution\_mean

2.000000

radius\_distribution\_standard\_deviation

5.000000

length\_distribution\_mean

150.000000

length\_distribution\_standard\_deviation

10.000000

intensity\_profile\_radius

0.400000

0.700000

1.000000

1.300000

intensity\_profile\_intensity

195

190

200

30

orientation\_anisotropic

orientation\_main

1.000000

1.000000

0.000000

orientation\_variance\_rad

0.100000

volume\_fraction

0.150000

maximum\_1000\_iteration\_number

10

random\_generator\_seed

1000

last\_element\_can\_be\_smaller

output\_directory

C:\Users\tonar\teigen\_data\{seriesn:03d}\data\{:05d}.jpg

Set dir

C:\Users\tonar\teigen\_data\005\data\_parameters.yaml

Save parameters

Save parameters and add to batch

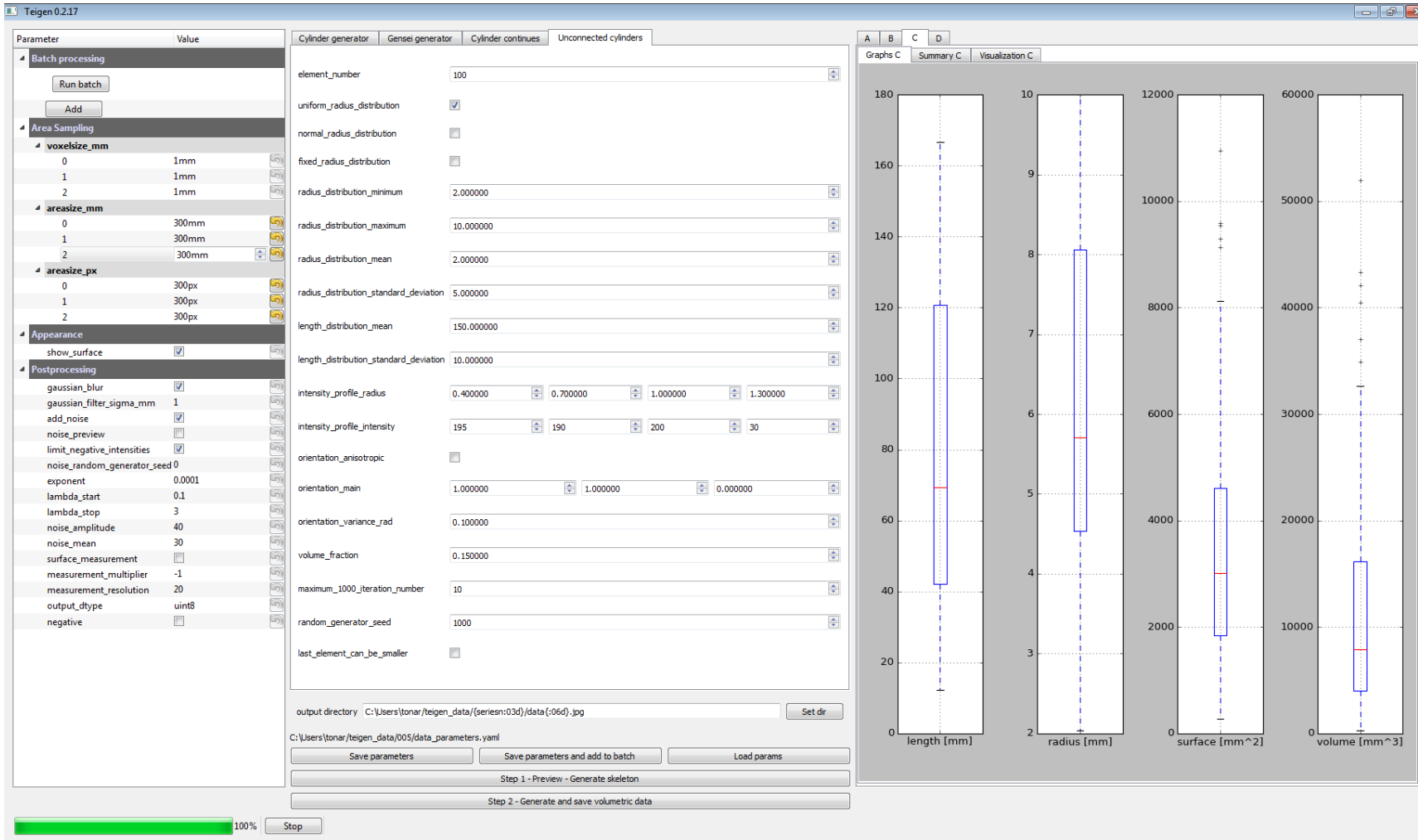
Load params

Step 1 - Preview - Generate skeleton

Step 2 - Generate and save volumetric data

100%

Stop





Teigen 0.2.17

Parameter

Value

Batch processing

Run batch

Add

Area Sampling

voxelsize\_mm

0

1mm

1

1mm

2

1mm

aresize\_mm

0

300mm

1

300mm

2

300mm

aresize\_px

0

300px

1

300px

2

300px

Appearance

show\_surface

Postprocessing

gaussian\_blur

gaussian\_filter\_sigma\_mm

1

add\_noise

noise\_preview

limit\_negative\_intensities

noise\_random\_generator\_seed

0

exponent

0.0001

lambda\_start

0.1

lambda\_stop

3

noise\_amplitude

40

noise\_mean

30

surface\_measurement

measurement\_multiplier

-1

measurement\_resolution

20

output\_dtype

uint8

negative

Cylinder generator

Gensei generator

Cylinder continues

Unconnected cylinders

element\_number

100

uniform\_radius\_distribution

☒

normal\_radius\_distribution

☐

fixed\_radius\_distribution

☐

radius\_distribution\_minimum

2.000000

radius\_distribution\_maximum

10.000000

radius\_distribution\_mean

2.000000

radius\_distribution\_standard\_deviation

5.000000

length\_distribution\_mean

150.000000

length\_distribution\_standard\_deviation

10.000000

intensity\_profile\_radius

0.400000

0.700000

1.000000

1.300000

intensity\_profile\_intensity

195

190

200

30

orientation\_anisotropic

☐

orientation\_main

1.000000

1.000000

0.000000

orientation\_variance\_rad

0.100000

volume\_fraction

0.150000

maximum\_1000\_iteration\_number

10

random\_generator\_seed

1000

last\_element\_can\_be\_smaller

☐

output\_directory

C:\Users\tonar\teigen\_data\seriesn:03d\data(:06d).jpg

Set dir

C:\Users\tonar\teigen\_data\005\data\_parameters.yaml

Save parameters

Save parameters and add to batch

Load params

Step 1 - Preview - Generate skeleton

Step 2 - Generate and save volumetric data

100%

Stop

A

B

C

D

Graphs C

Summary C

Visualization C

	length [mm]	radius [mm]	surface [mm^2]	volume [mm^3]
mean	81.9487545497	6.12591035536	3587.68376712	11764.7184661
std	47.8644398978	2.23079639823	2306.27586275	10799.0898717
min	12.3253913783	2.03469356959	276.65291985	278.223579392
25%	42.1977806325	4.53746024993	1845.30088212	3989.75168567
50%	69.4306301508	5.71180473516	3014.58355404	7910.38532356
75%	120.77496663	8.05536676887	4616.51613452	16134.9908616
max	166.713334465	9.99921444204	10948.0755644	51947.9719283

ength d. [mm^-2]	volume d. []	urface d. [mm^-1]
0.00030351390574	0.043573031356	0.013287717656

length [mm]	volume [mm^3]	surface [mm^2]	ea volume [mm^4]	count []	neric volume [mm]	neric surface
8194.87545497	1176471.84661	358768.376712	27000000.0	100.0	1156246.93267	357007.509415

Save in one row

Teigen 0.2.17

Parameter

Value

Batch processing

Run batch

Add

Area Sampling

voxelsize\_mm

0

1mm

1

1mm

2

1mm

areasize\_mm

0

300mm

1

300mm

2

300mm

areasize\_px

0

300px

1

300px

2

300px

Appearance

show\_surface

☒

Postprocessing

gaussian\_blur

☒

gaussian\_filter\_sigma\_mm

1

add\_noise

☒

noise\_preview

☐

limit\_negative\_intensities

☒

noise\_random\_generator\_seed

0

exponent

0.0001

lambda\_start

0.1

lambda\_stop

3

noise\_amplitude

40

noise\_mean

30

surface\_measurement

☐

measurement\_multiplier

-1

measurement\_resolution

20

output\_dtype

uint8

negative

☐

Cylinder generator

element\_number

100

uniform\_radius\_distribution

☒

normal\_radius\_distribution

☐

fixed\_radius\_distribution

☐

radius\_distribution\_minimum

2.000000

radius\_distribution\_maximum

10.000000

radius\_distribution\_mean

2.000000

radius\_distribution\_standard\_deviation

5.000000

length\_distribution\_mean

150.000000

length\_distribution\_standard\_deviation

10.000000

intensity\_profile\_radius

0.400000

0.700000

1.000000

1.300000

intensity\_profile\_intensity

195

190

200

30

orientation\_anisotropic

☐

orientation\_main

1.000000

1.000000

0.000000

orientation\_variance\_rad

0.100000

volume\_fraction

0.150000

maximum\_1000\_iteration\_number

10

random\_generator\_seed

1000

last\_element\_can\_be\_smaller

☐

output directory

C:\Users\tonar\teigen\_data\seriesn:03d\data{:06d}.jpg

Set dir

C:\Users\tonar\teigen\_data\005\data\_parameters.yaml

Save parameters

Save parameters and add to batch

Load params

Step 1 - Preview - Generate skeleton

Step 2 - Generate and save volumetric data

100%

Stop

A

B

C

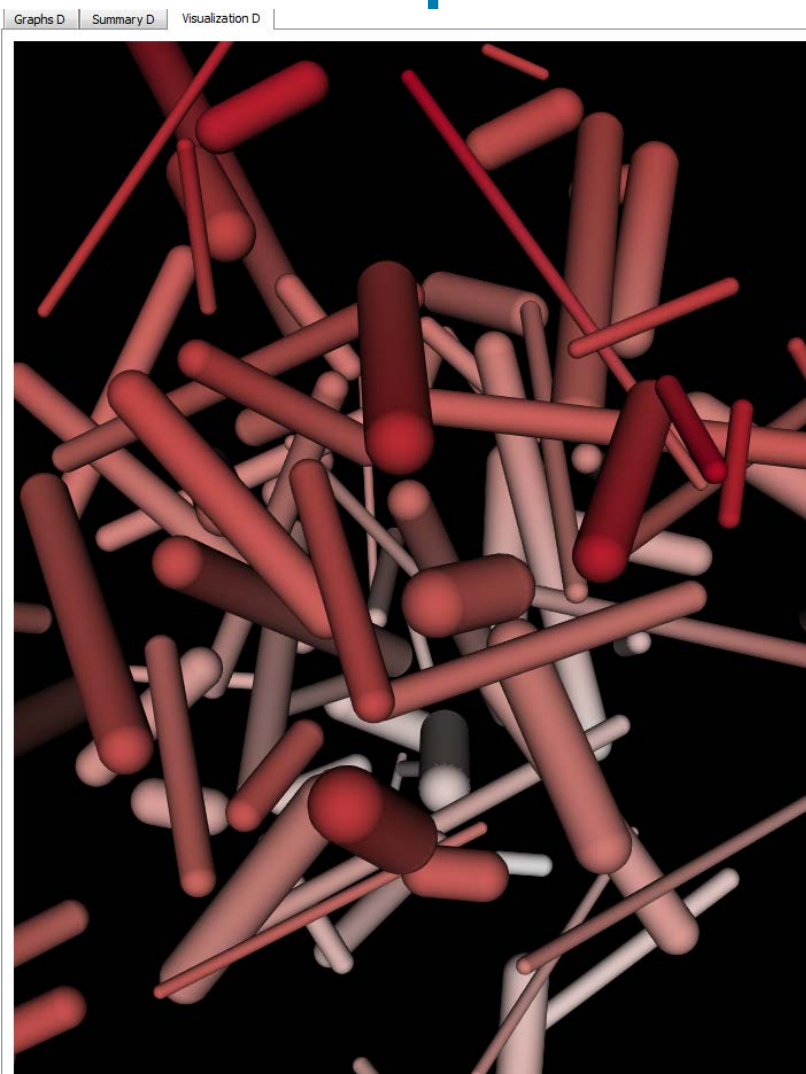
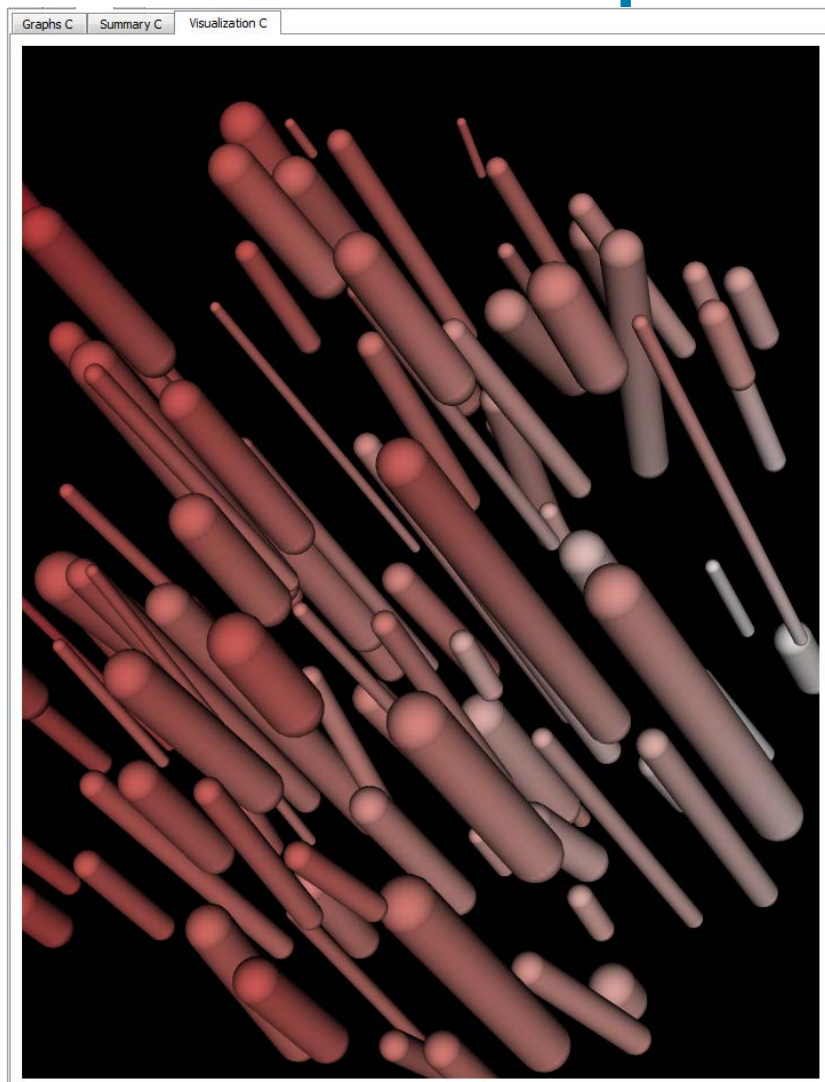
D

Graphs C

Summary C

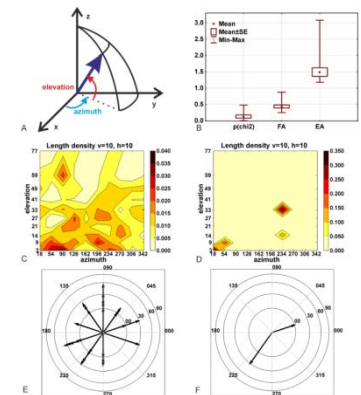
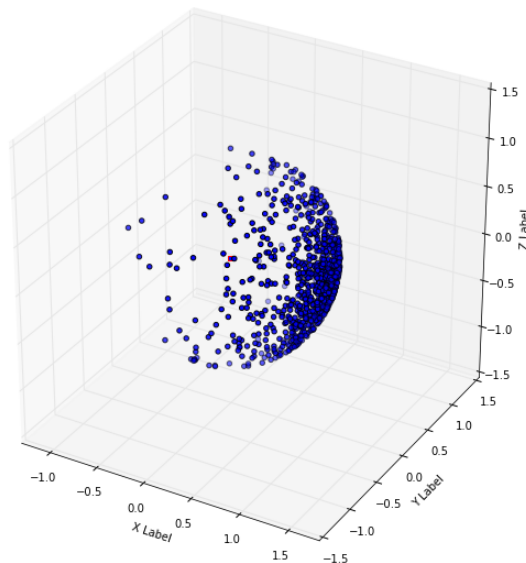
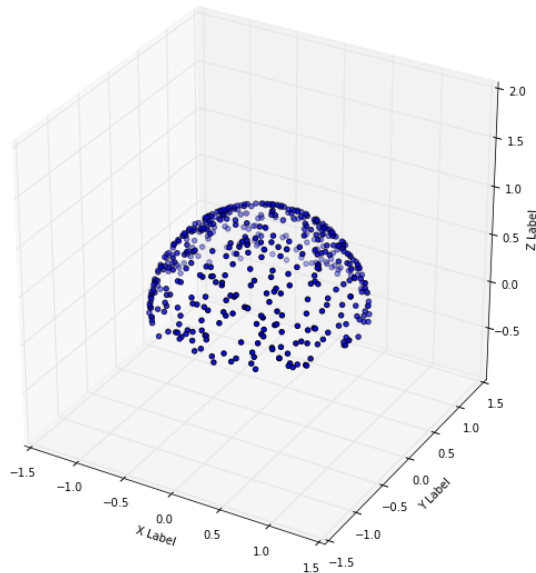
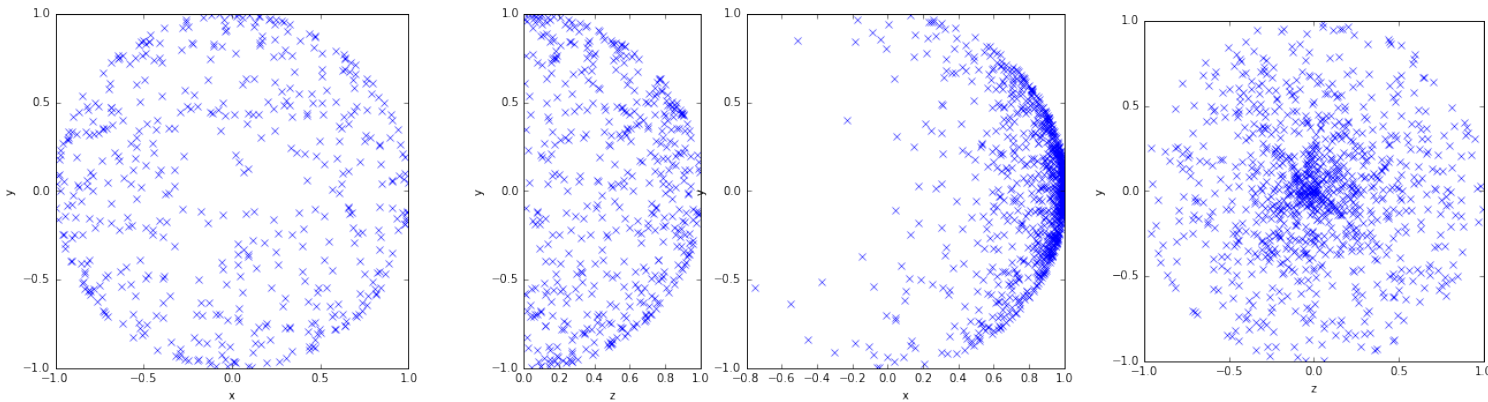
Visualization C

# Izotropie a anizotropie





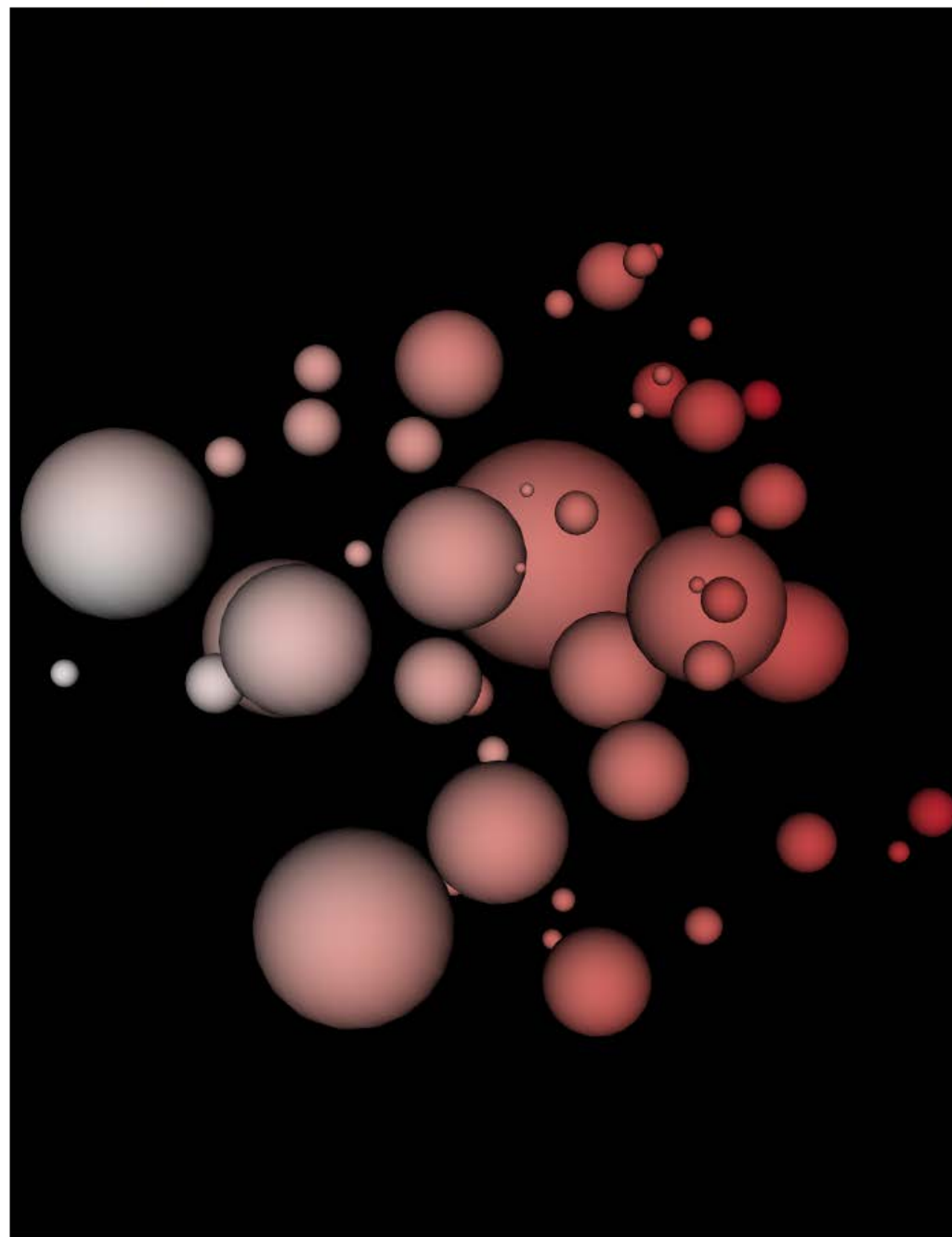
# Izotropie a anizotropie



How to assess, visualize and compare the anisotropy of linear structures reconstructed from optical sections—A study based on histopathological quantification of human brain microvessels

Petra Kochová<sup>a,\*</sup>, Robert Cimrman<sup>a</sup>, Jiří Janáček<sup>b</sup>, Kirsti Witter<sup>c</sup>, Zbyněk Tonar<sup>d,e</sup>

<sup>a</sup>Department of Mechanics, Faculty of Applied Sciences, University of West Bohemia, Univerzitní 8, 306 14 Pilsen, Czech Republic;  
<sup>b</sup>Institute of Physiology, Academy of Sciences of the Czech Republic, Videlská 1083, 142 20 Prague, Czech Republic;  
<sup>c</sup>Institute of Anatomy, Histology and Embryology, Department for Pathobiology, University of Veterinary Medicine Vienna, Veterinärplatz 1, A-1210 Vienna, Austria;  
<sup>d</sup>European Centre of Excellence NTD—New Technologies for Information Society, Faculty of Applied Sciences, University of West Bohemia, Univerzitní 22, 306 14 Pilsen, Czech Republic;  
<sup>e</sup>Department of Histology and Embryology, Faculty of Medicine in Pilsen, Charles University in Prague, Karlovarská 48, 301 66 Pilsen, Czech Republic



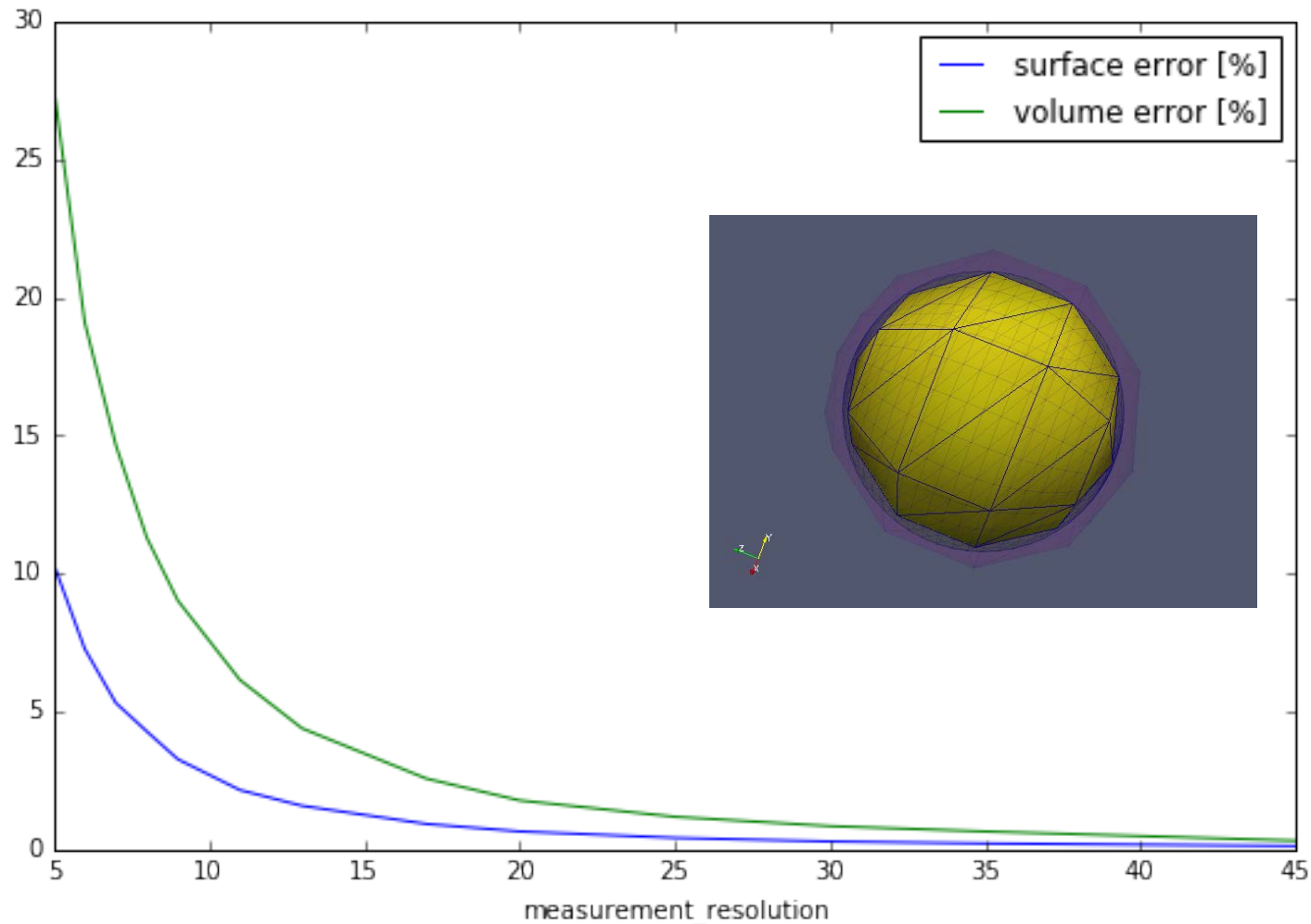
# Míra shody při použití různých SW a metod

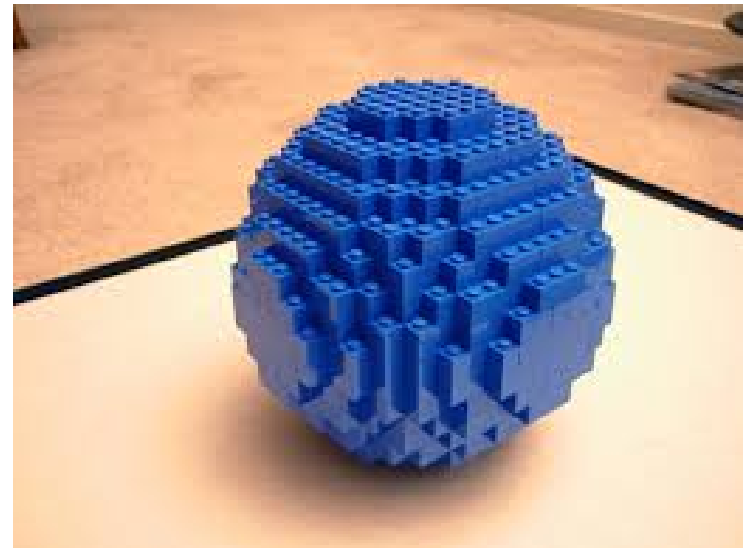
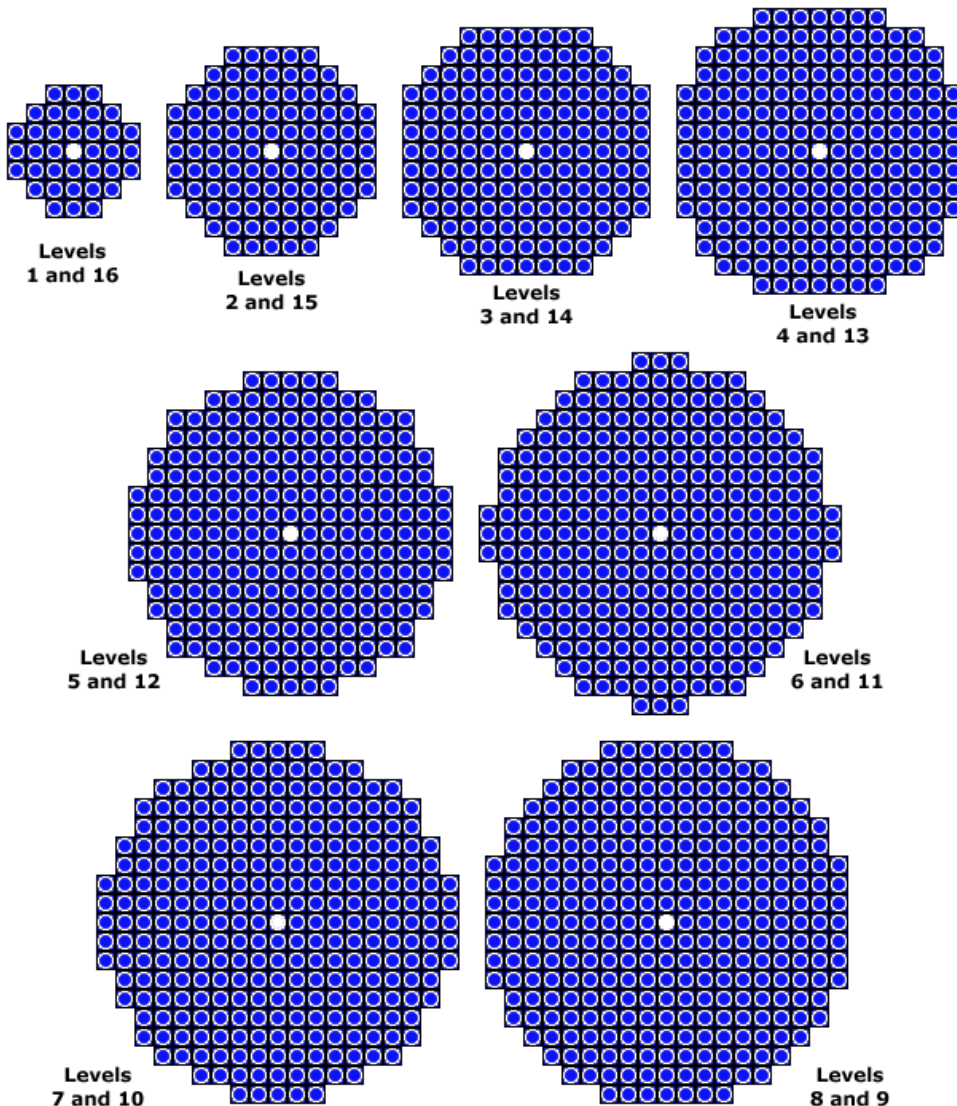
	volume (mm <sup>3</sup> )	<i>relative error</i>	surface (mm <sup>2</sup> )	<i>relative error</i>
known (analytic geometry)	4105593	-	436449	-
calculated (Teigen triangulation)	4029915	<b>1.84</b>	433681	<b>0.63</b>
estimated using Fiji 3D Manager (ImageJ)	4405818	<b>7.31</b>	453426	<b>3.89</b>
estimated using pointgrid in Ellipse SW	4388875	<b>6.90</b>	-	-
estimated using thresholding in Ellipse SW	4390000	<b>6.95</b>	470919	<b>7.90</b>
estimated using Bruker micro-CT SW	4271889	<b>4.05</b>	486237	<b>11.41</b>

relative percent error =  $100 * |(value - estimate) / value|$

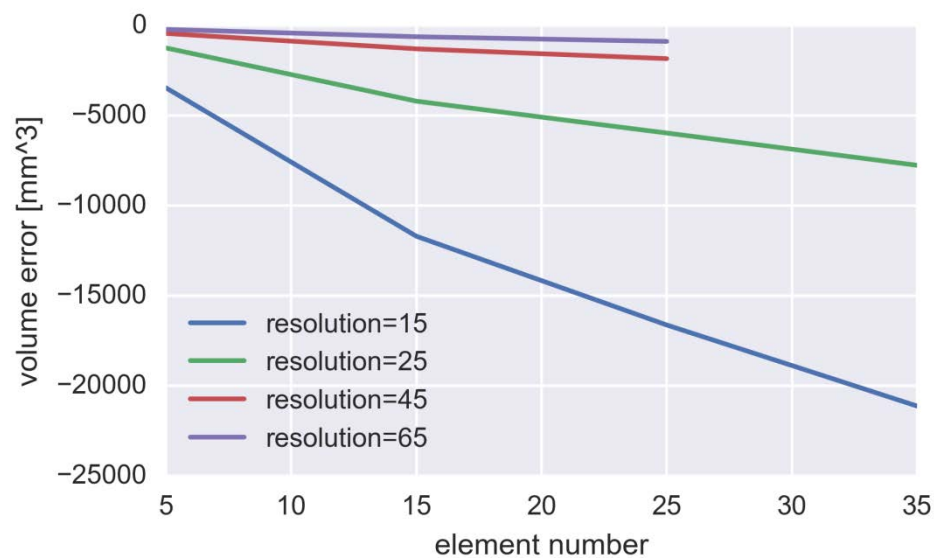
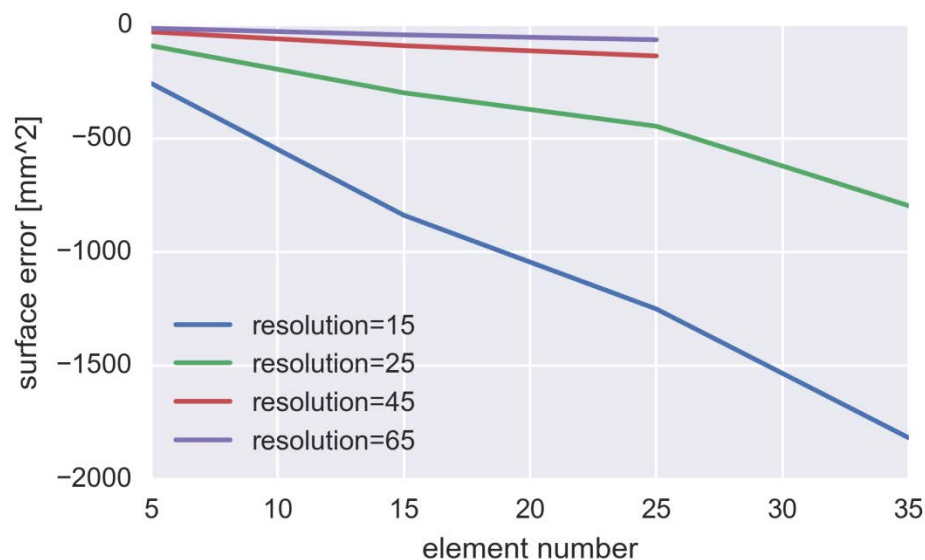


# Analytické počítání povrchů a objemů geometrických primitiv vs. numerická triangulace



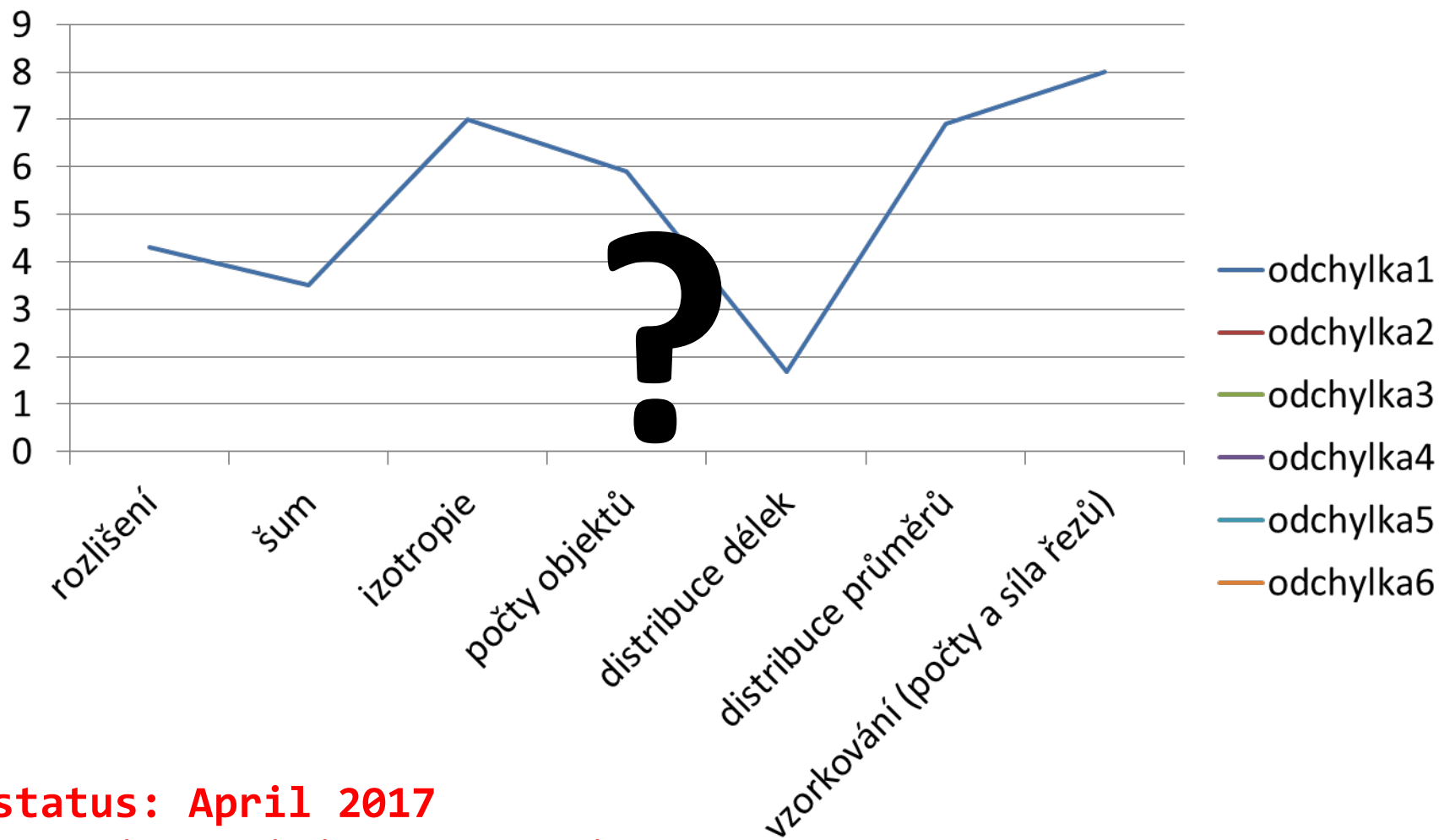


# Vliv rozlišení na numerickou chybu





# nutno provést analýzu citlivosti



status: April 2017

location: Bioimplantologie Brno

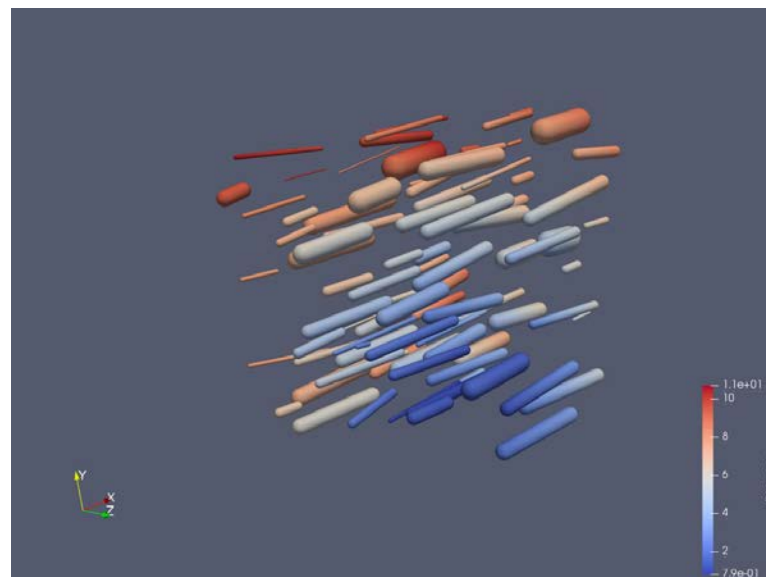
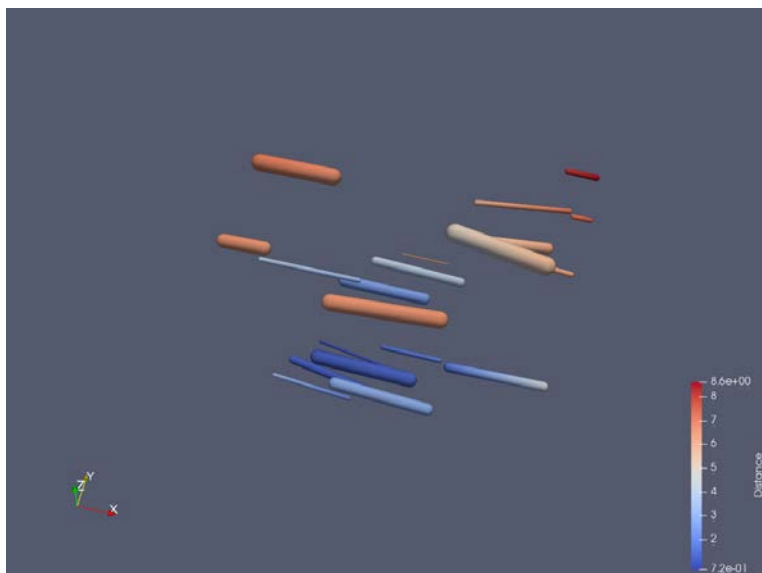
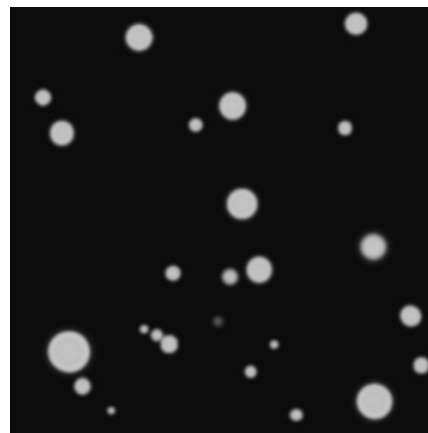
# Analyticky spočítaná data vs. SW mikro-CT Bruker

- standardně vzorek  $10 \times 10 \times 10$  mm
- voxel  $0,02 \times 0,02 \times 0,02$  mm
- 6 parametrů po 10 hodnotách = 60 sad obrazových sérií:

1. poloměr válců
2. délky válců
3. uměle přidaný šum
4. rozlišení
5. míra izotropie
6. počet objektů

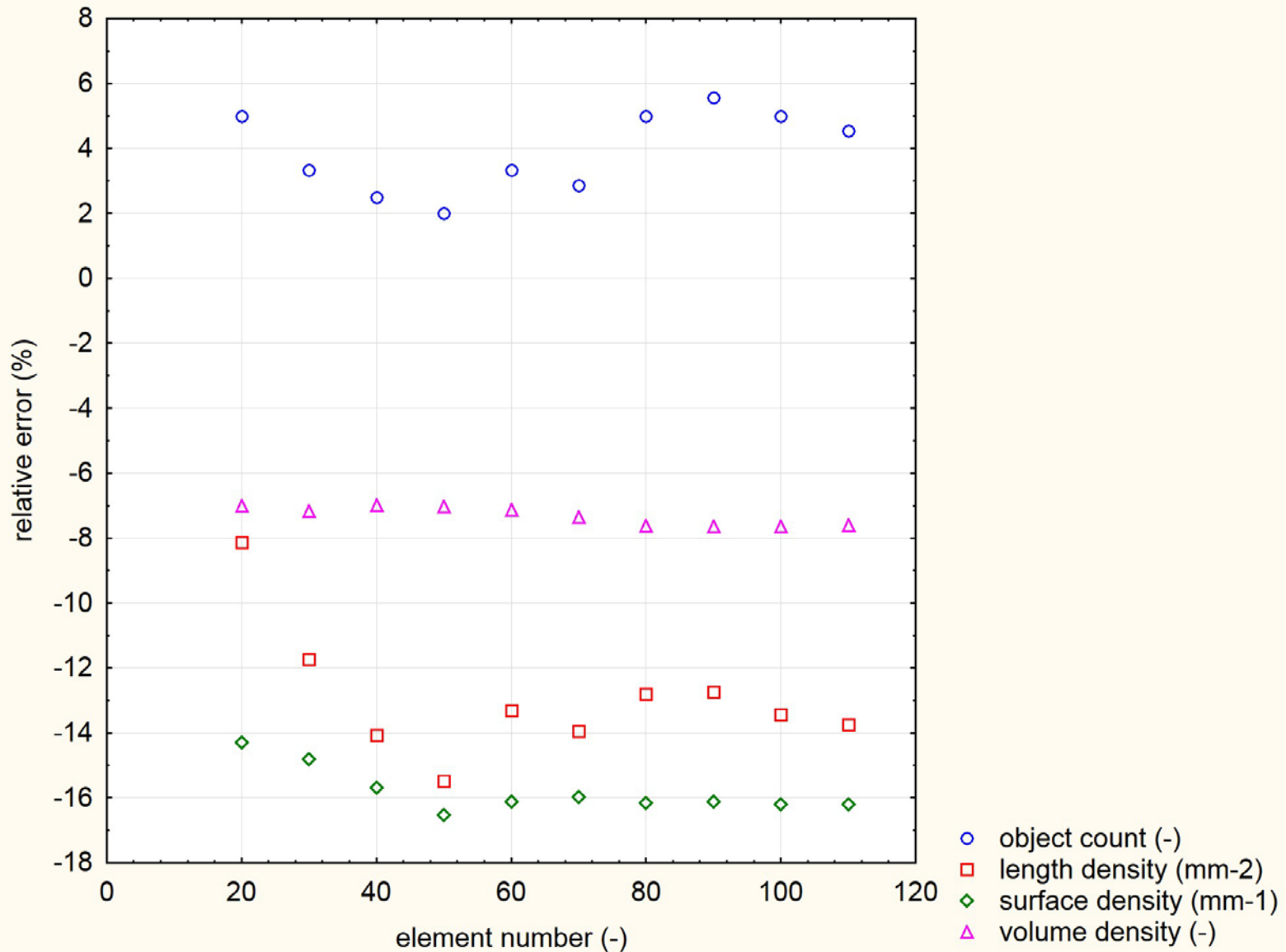


# Různý počet objektů

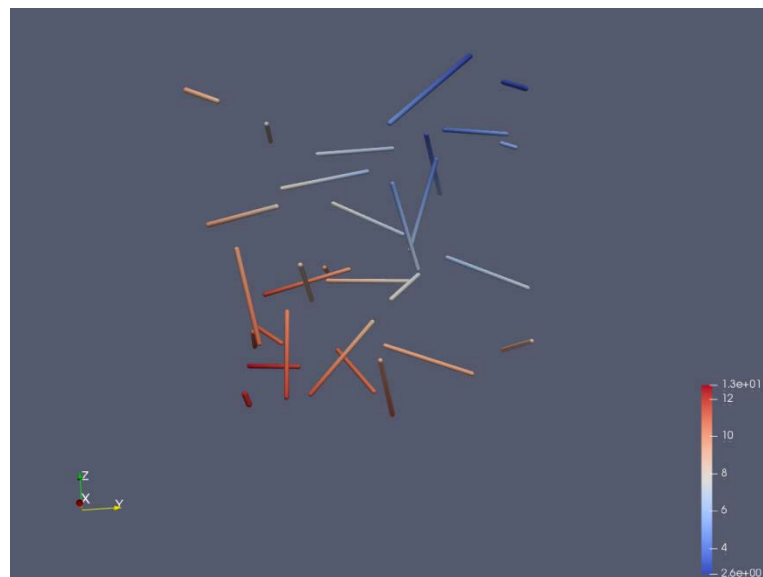
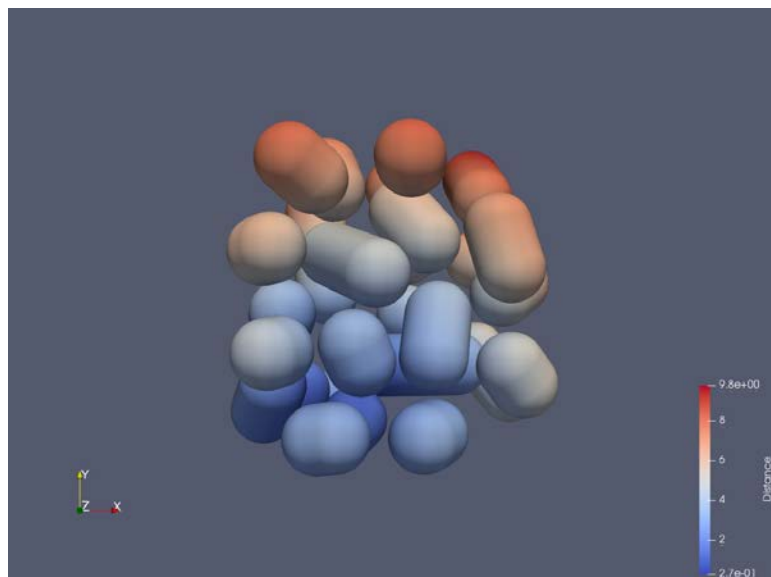
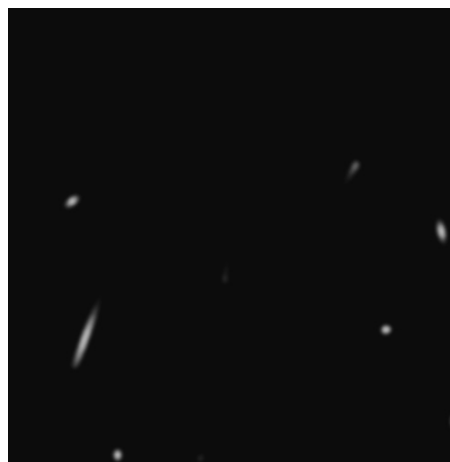
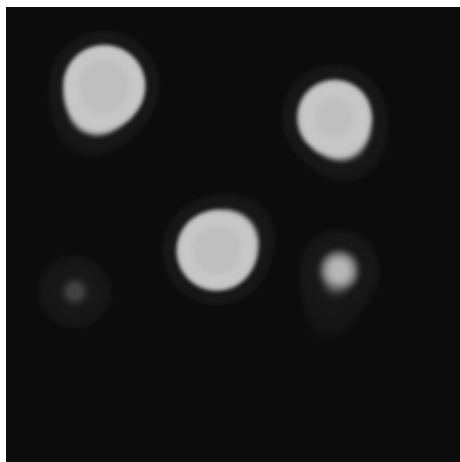




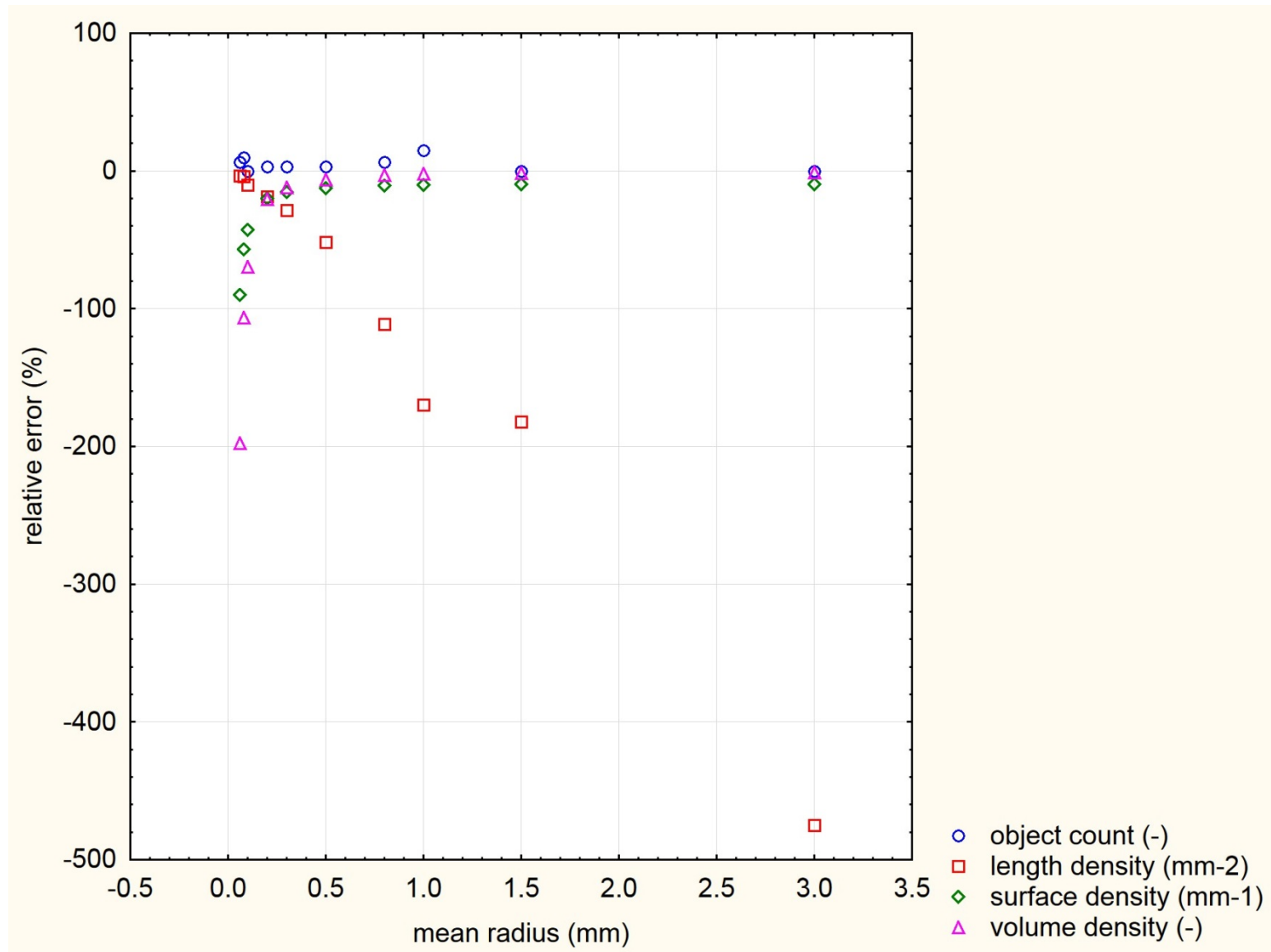
# Míra shody a priori známých dat vs. mikro-CT



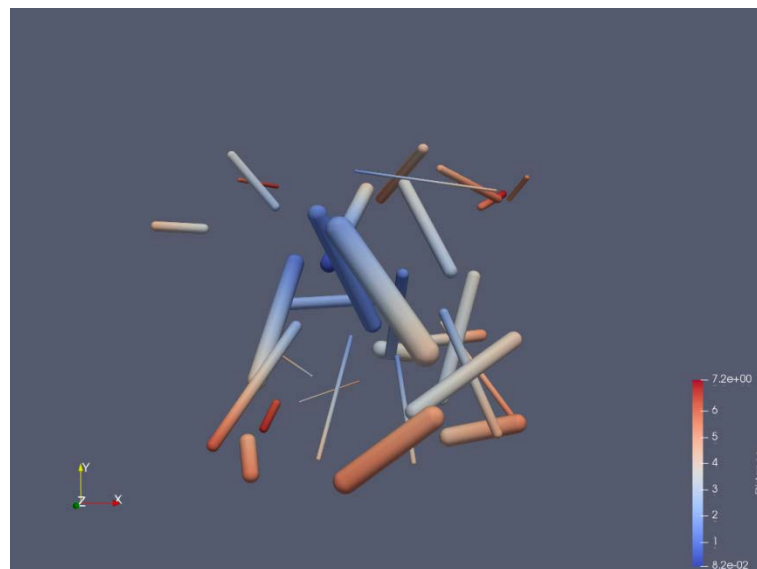
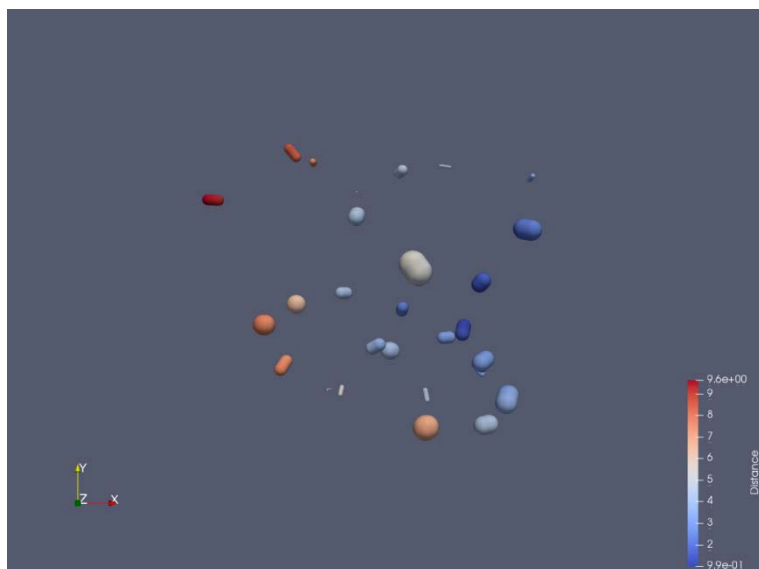
# Různé poloměry válců



# Míra shody a priori známých dat vs. mikro-CT

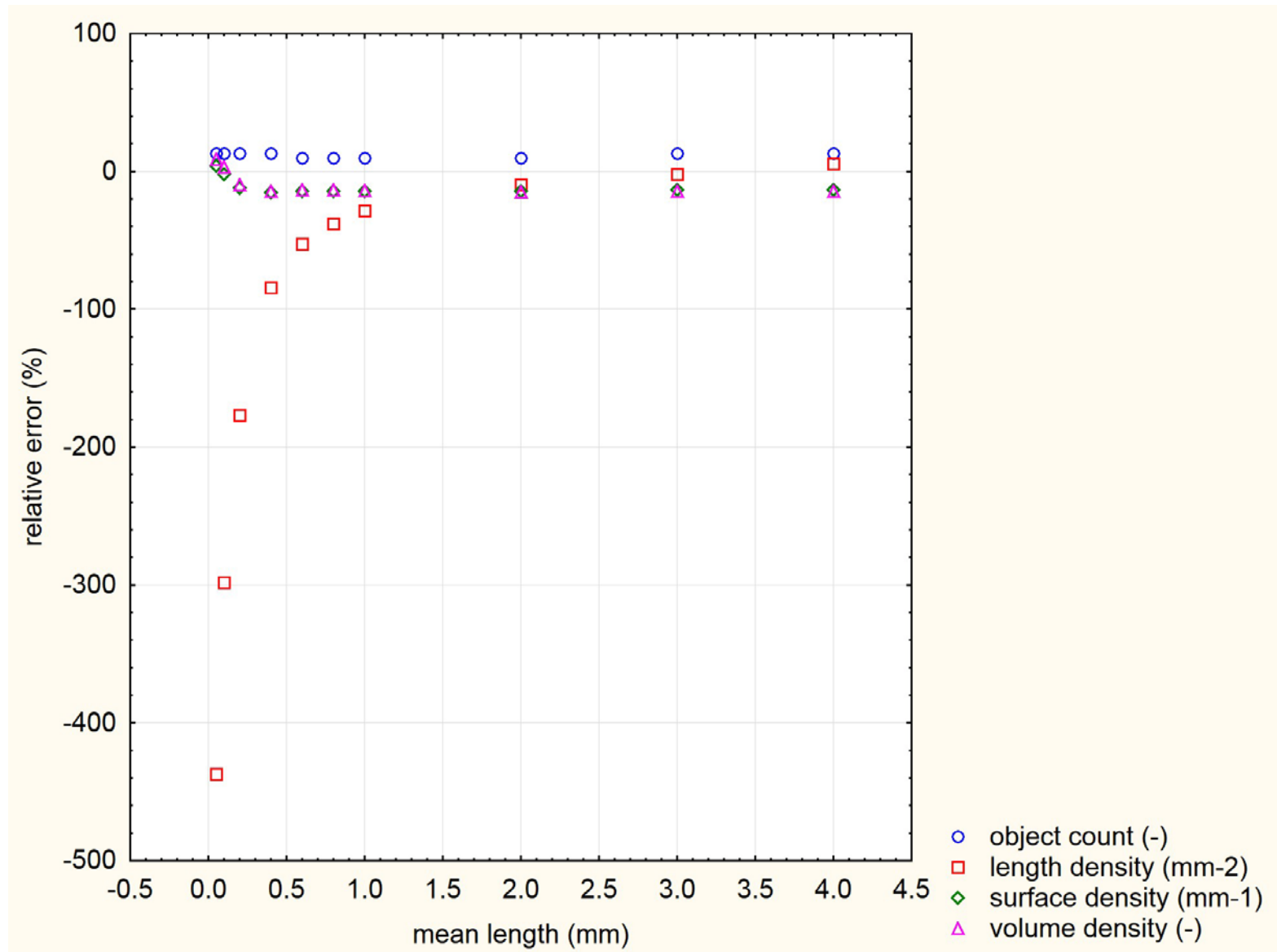


# Různé délky válců

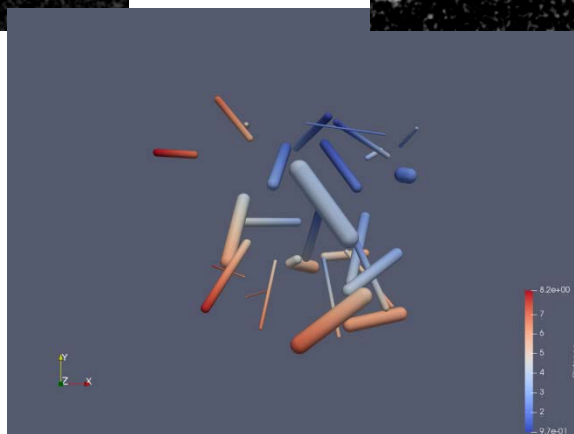
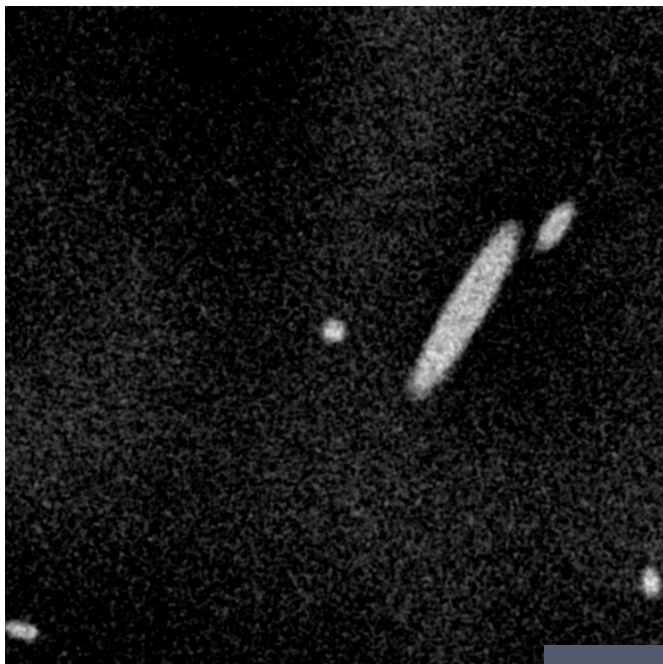




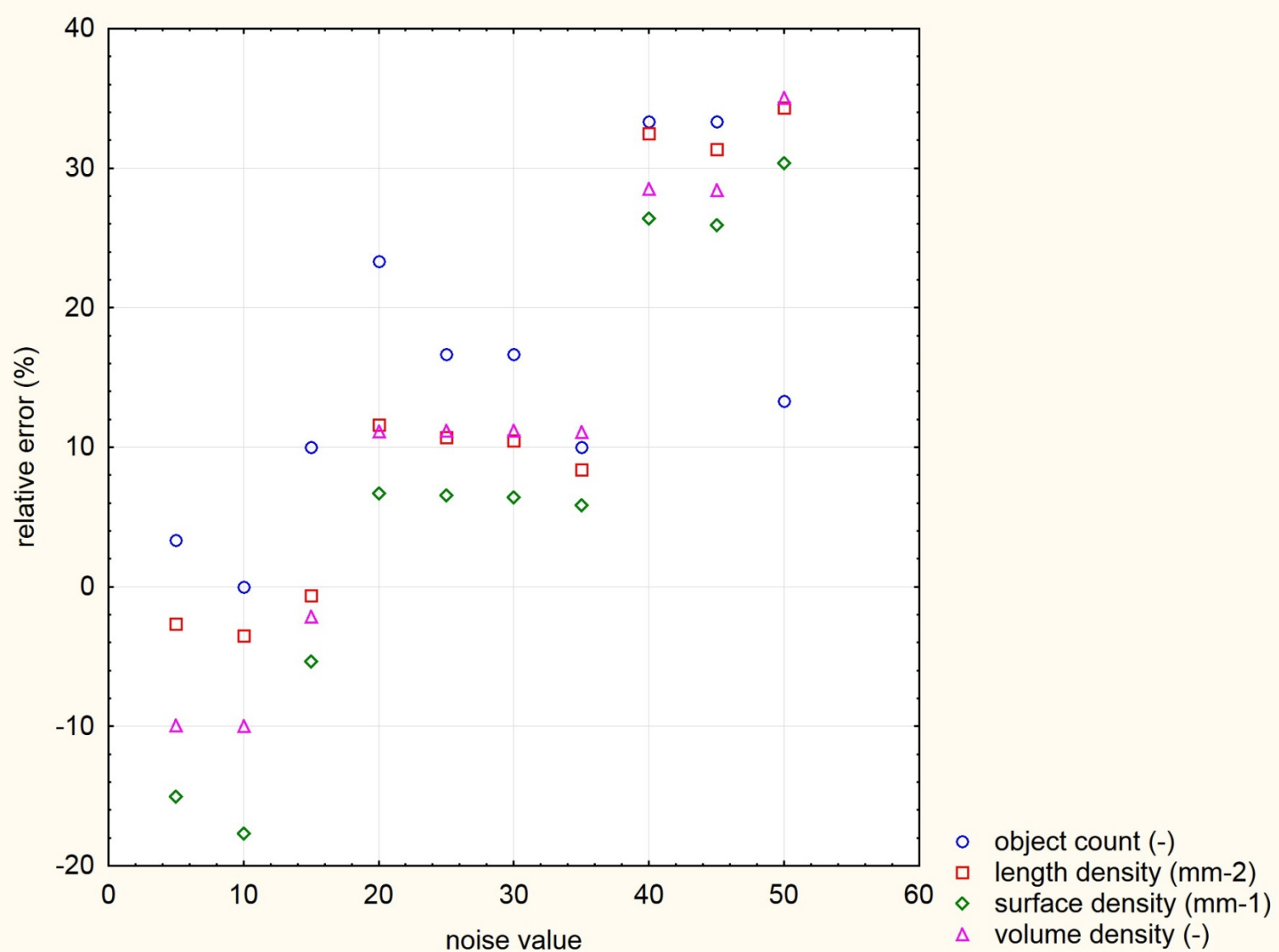
# Míra shody a priori známých dat vs. mikro-CT



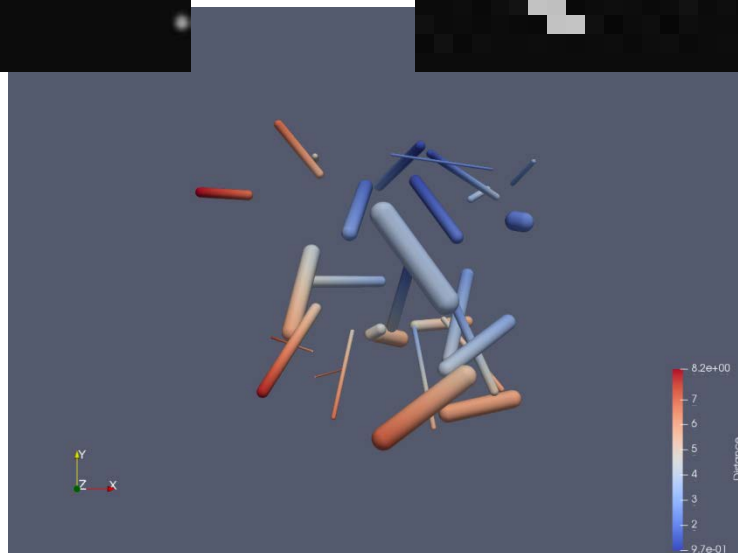
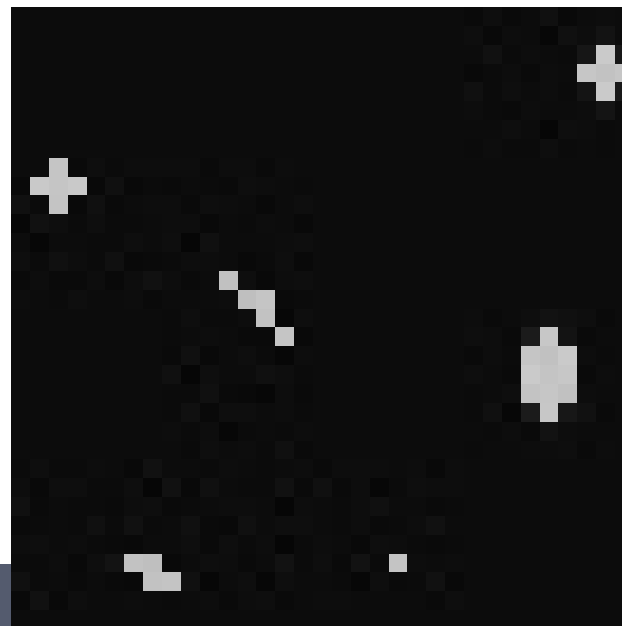
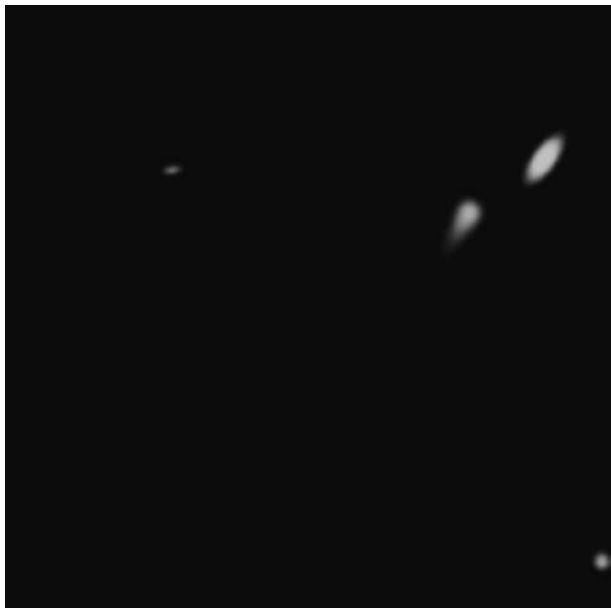
# Různý přidaný šum



# Míra shody a priori známých dat vs. mikro-CT

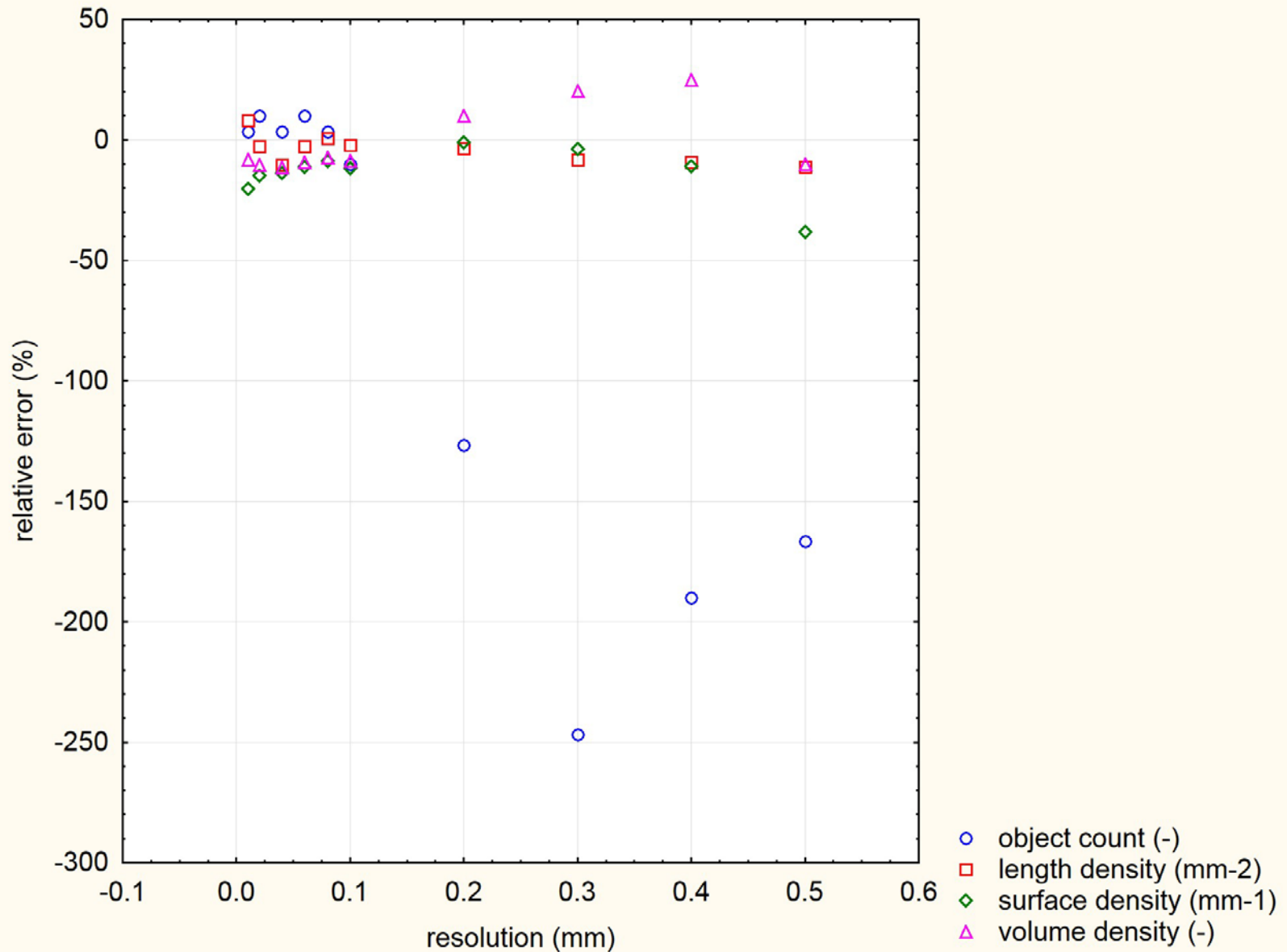


# Různé rozlišení

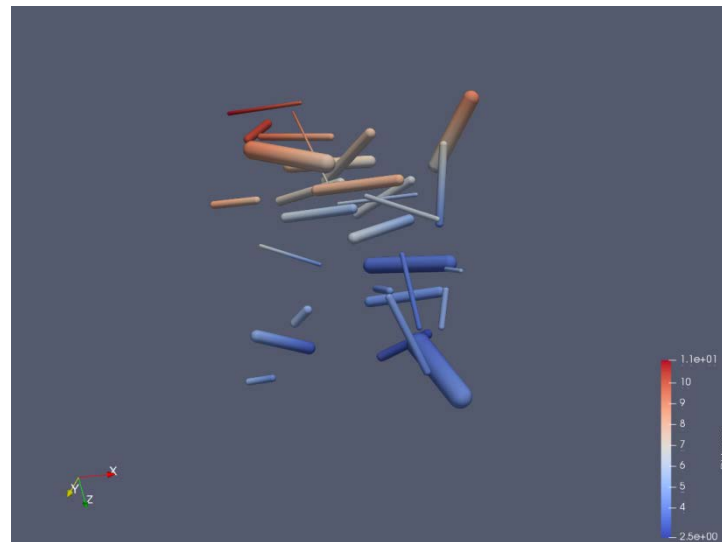
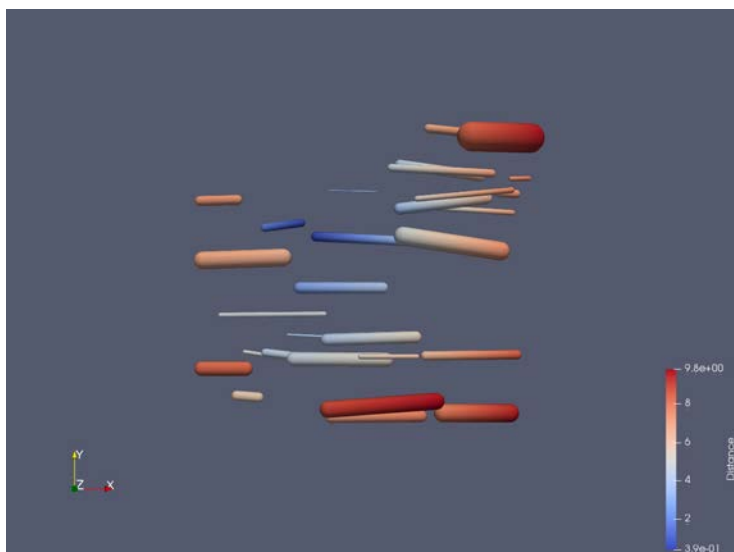
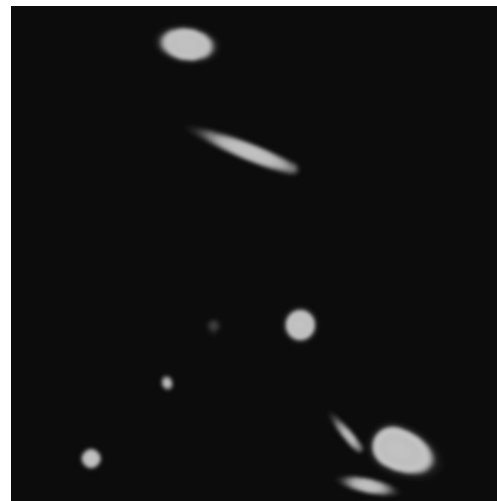




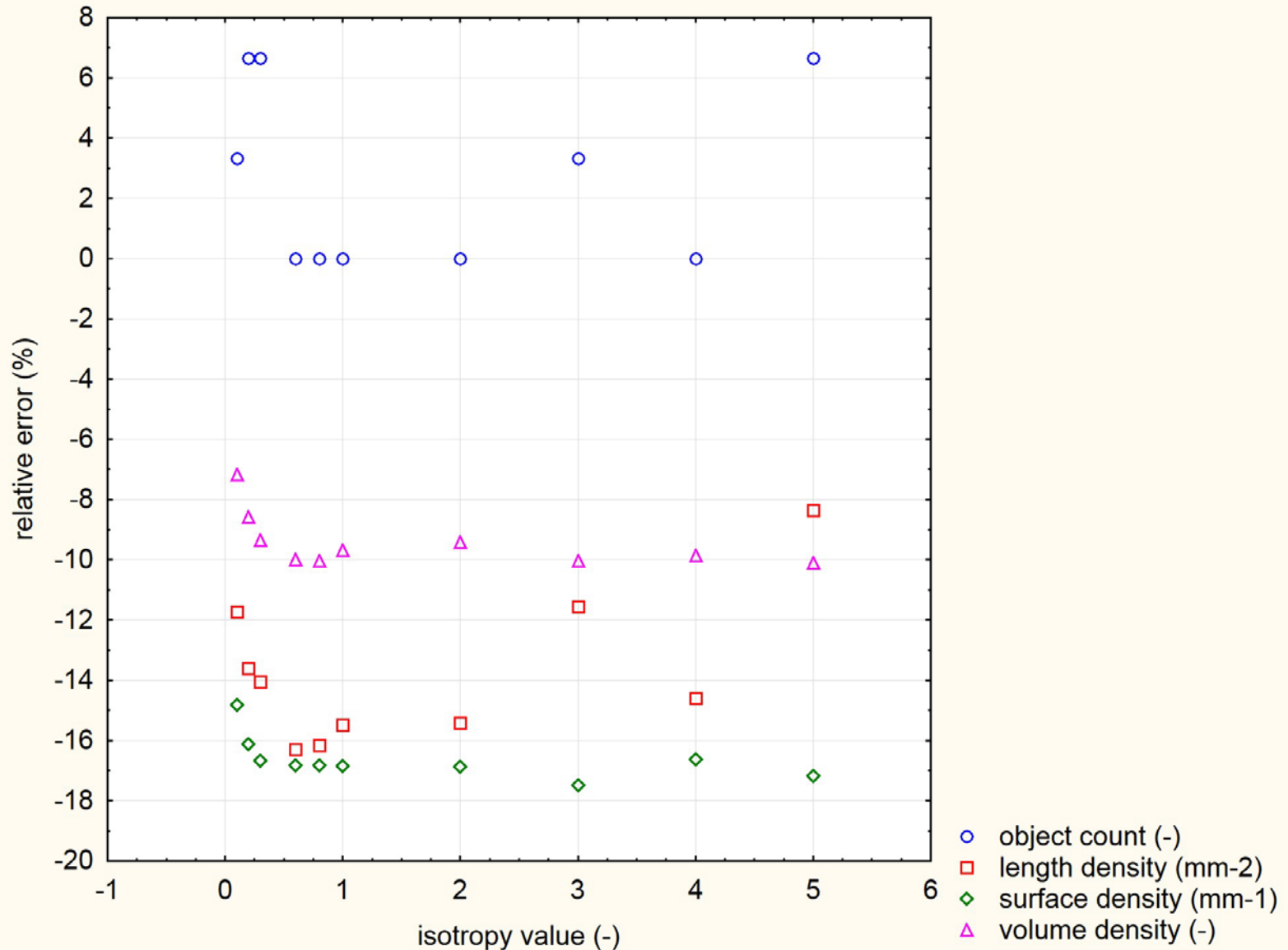
# Míra shody a priori známých dat vs. mikro-CT

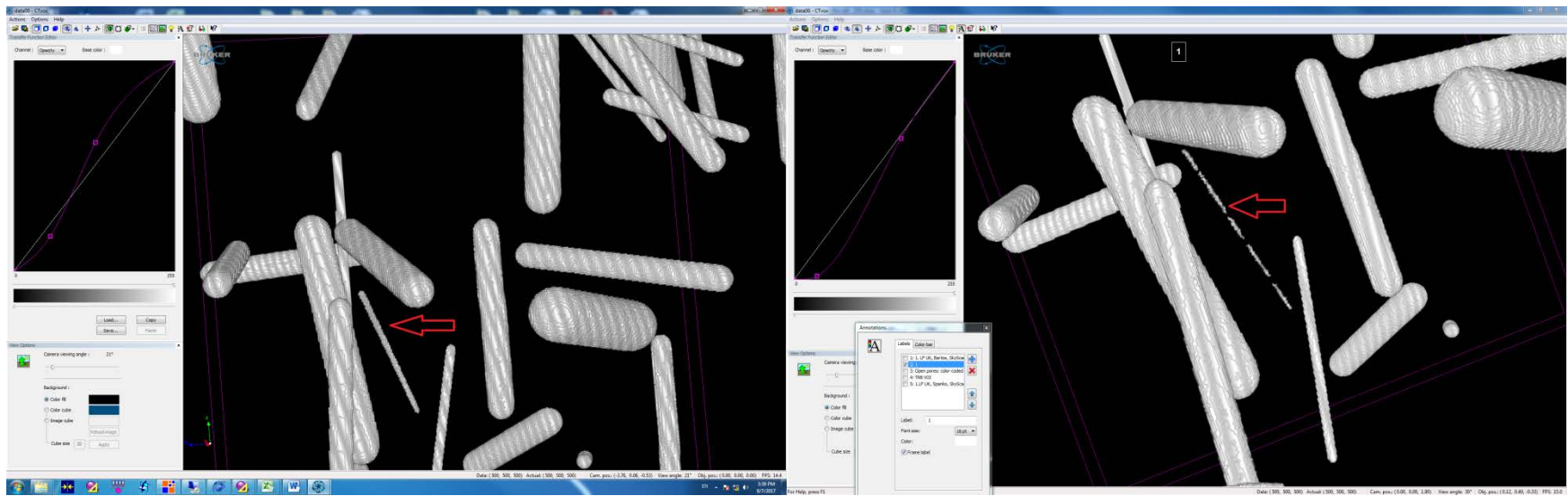


# Různá míra izotropie



# Míra shody a priori známých dat vs. mikro-CT





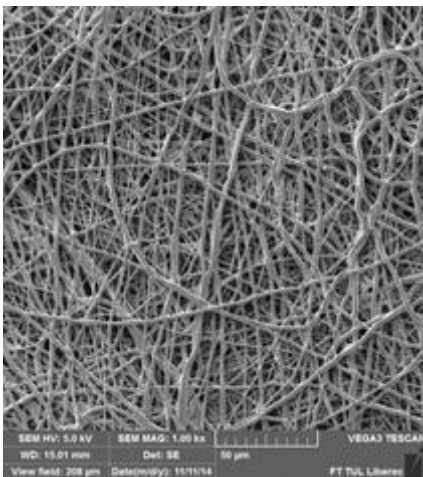


# Distribuce průměrů realistická, ale zaplnění prostoru dosud nedostižné...

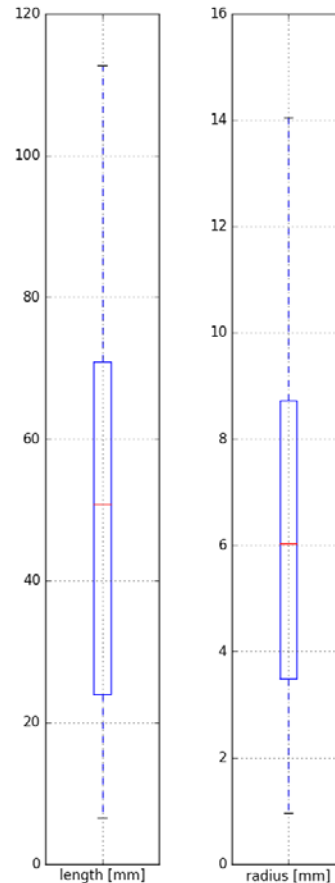
- zadání: průměr vláken

tubular PLC:

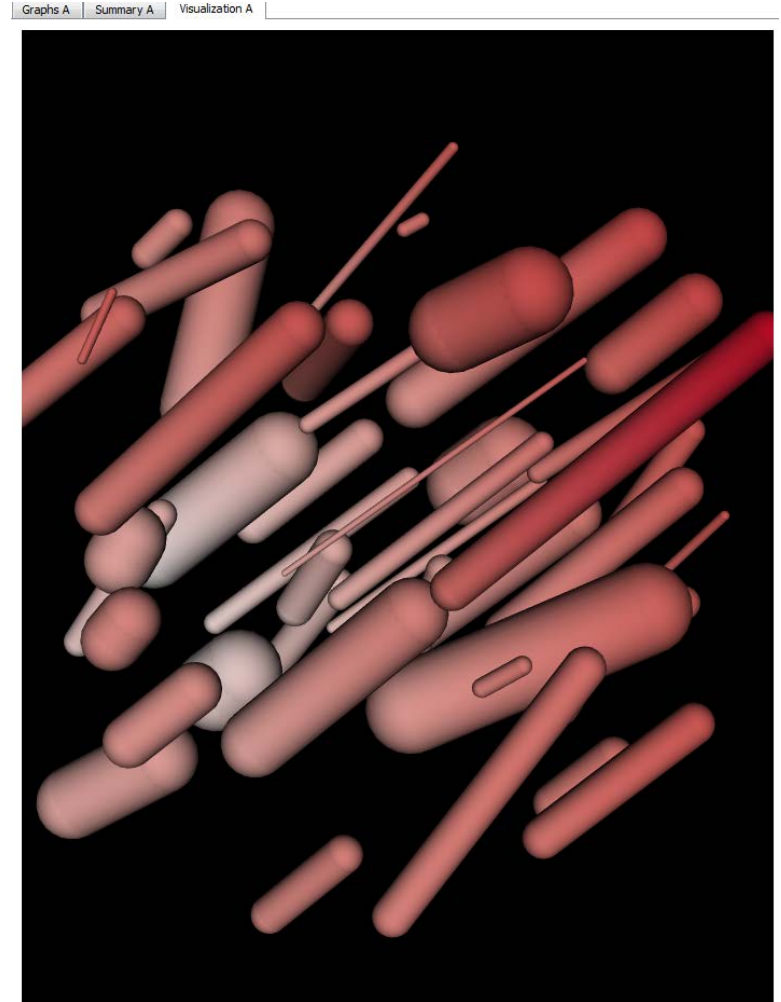
- Min 0,91  $\mu\text{m}$
- Max 14,05  $\mu\text{m}$
- Průměr 5,4  $\mu\text{m}$
- SD 2,1  $\mu\text{m}$
- Medián 5,5  $\mu\text{m}$



zaplnění prostoru cca 80 %



- simulace



zaplnění prostoru 6,03 %

## Práce pokračuje...

- generátor **kolidujících** a **větvených** struktur
- problém s vyšším **zaplněním prostoru** srovnatelným s **reálnými** materiály
- generátor **porozit**
- ***ukazatel průběhu***
- **dávkové zpracování**

# Shrnutí – software Teigen

- nezávislý na **platformě**
- **volně dostupný** pro nekomerční použití
- s analyticky počítaným i verifikovaným **numerickým** odhadem **objemů, povrchů a délek**
- bude následovat
  - implementace dalších generátorů
    - **kolidující objekty** s vlivem vzájemných kontaktů, **větvení**
    - **porozity**
  - popis **doporučených postupů** pro **minimalizaci chyb** při segmentaci dat v mikro-CT
  - nalezení a popis **rizikových postupů** ohrožujících validitu vyhodnocování obrazových dat v mikro-CT

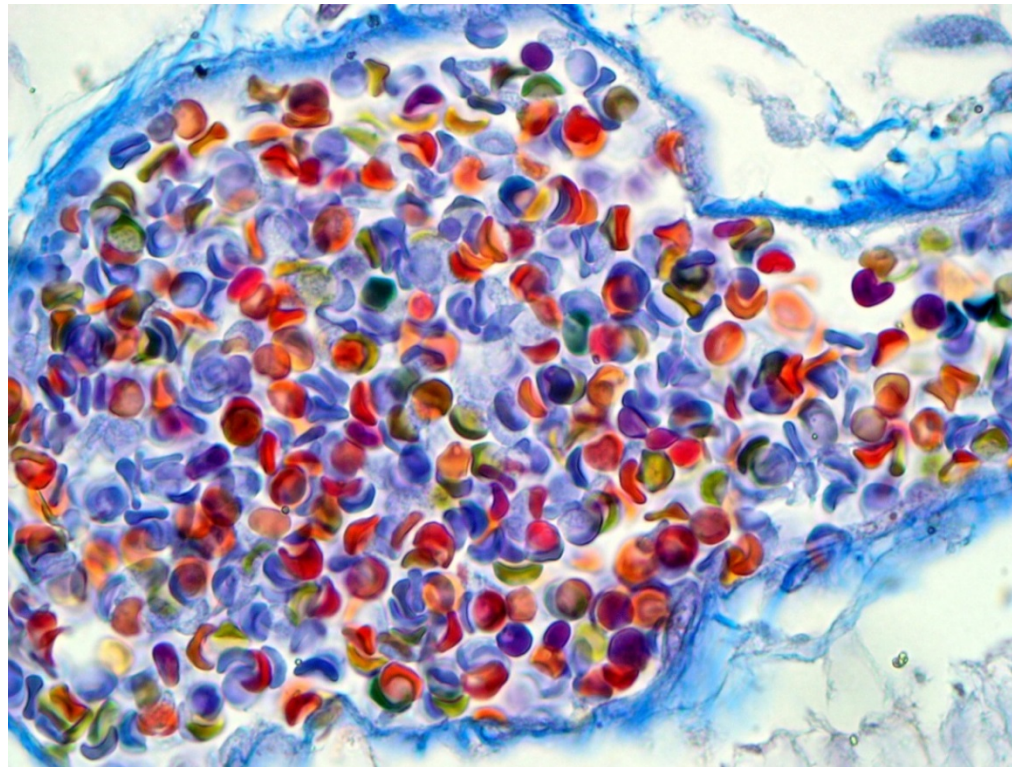
# Spolupráce a inspirace:

- **Technická univerzita v Liberci**
  - Katedra netkaných textilií a nanovláknenných materiálů
- **Ústav struktury a mechaniky hornin AV ČR, v.v.i.**
  - Oddělení kompozitních a uhlíkových materiálů
- **Ústav experimentální medicíny AV ČR, v.v.i**
  - Oddělení tkáňového inženýrství
- **1. lékařská fakulta Univerzity Karlovy v Praze a Všeobecná fakultní nemocnice v Praze**
  - Stomatologická klinika
- **Biomedicínské centrum, Lékařská fakulta Univerzity Karlovy v Plzni**
  - Laboratoř studia interakcí buněk s materiálem
  - Laboratoř nádorové léčby a regenerace tkáně

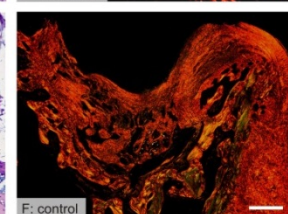
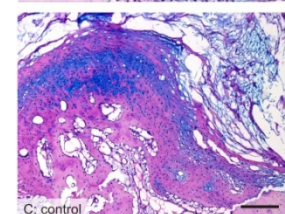
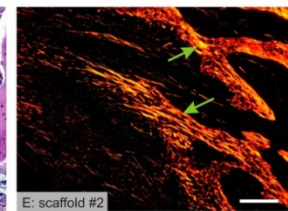
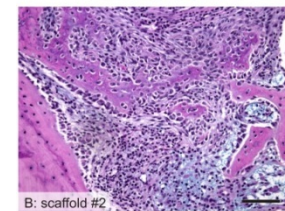
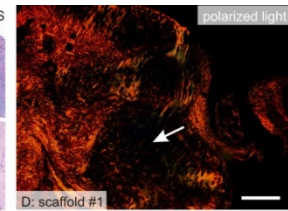
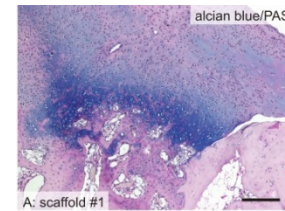
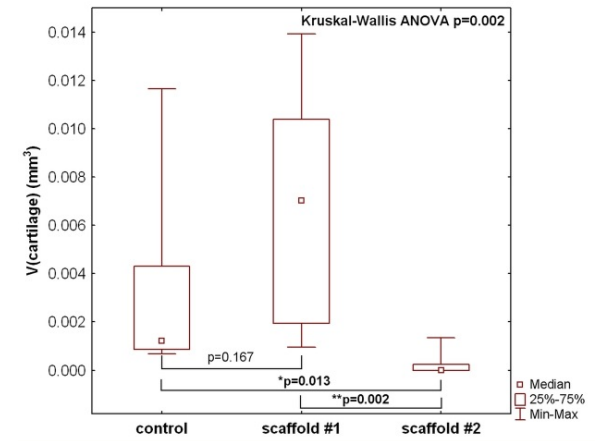
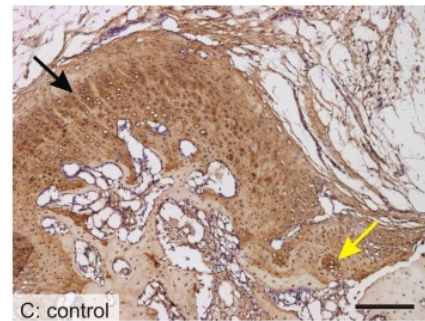
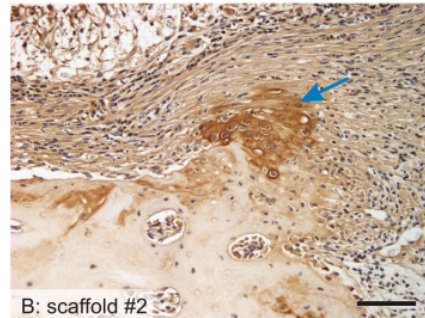
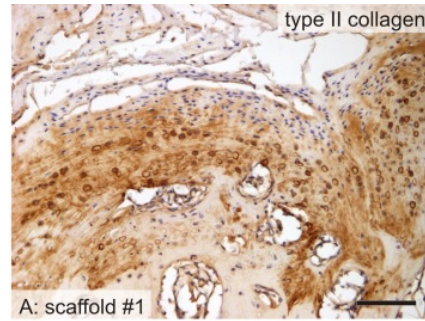
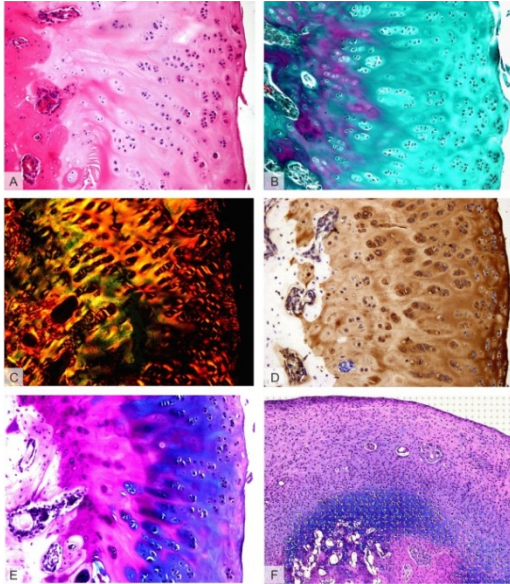
*projekty:*  
*AZV 15-25813A*  
*NPU LO10503*



# Děkuji Vám za pozornost!

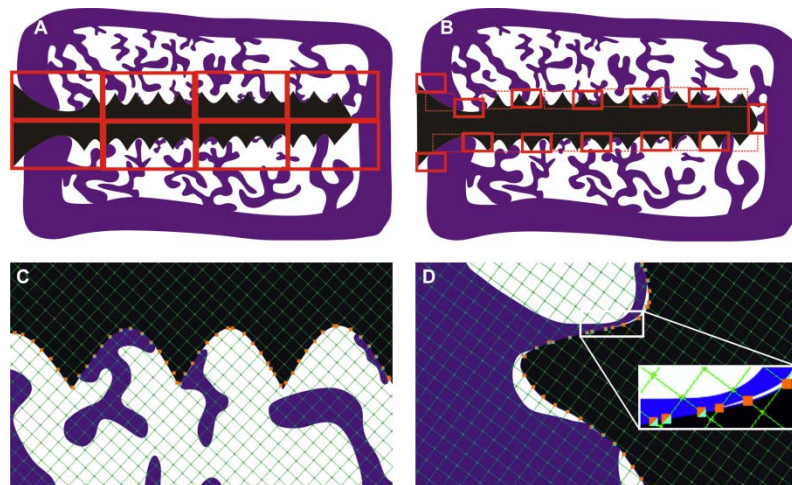
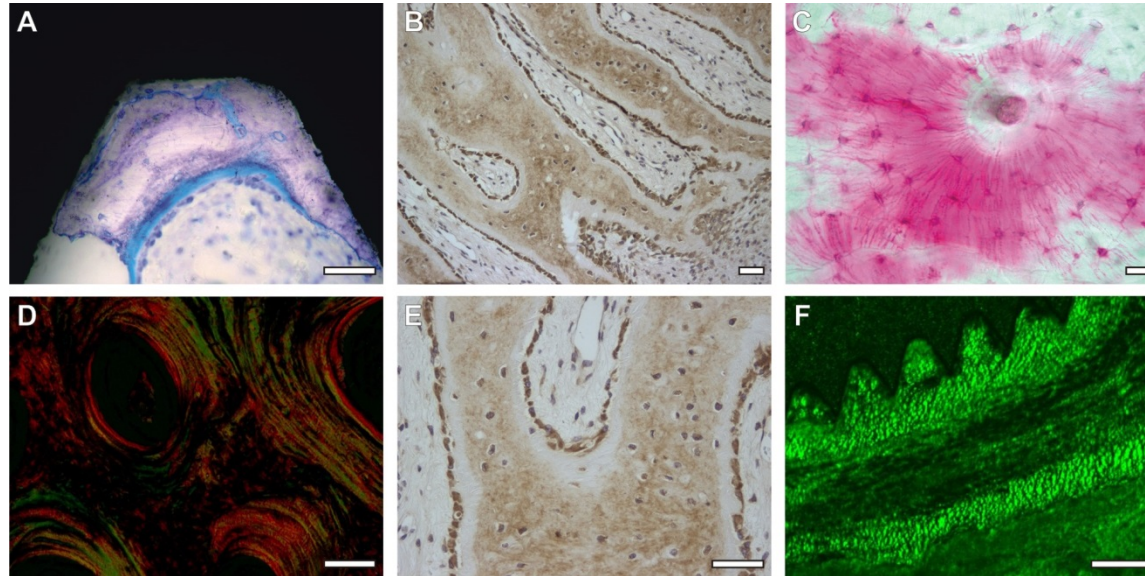


# Diferenciace hyalinní chrupavky v osteochondrálním defektu





# Oseointegrace nanostrukturovaných titanových implantátů u zvířecích modelů



## Evaluating the osseointegration of nanostructured titanium implants in animal models: Current experimental methods and perspectives (Review)

Vaclav Babuska<sup>a)</sup>

Department of Medical Chemistry and Biochemistry, Faculty of Medicine in Pilsen, Charles University in Prague, Karlovarska 48, 301 66 Pilsen, Czech Republic

Omid Moztarzadeh

Department of Stomatology and Department of Anatomy, Faculty of Medicine in Pilsen, University Hospital and Charles University in Prague, alej Svobody 80, 301 00 Pilsen, Czech Republic

Tereza Kubikova

Department of Histology and Embryology and Biomedical Center, Faculty of Medicine in Pilsen, Charles University in Prague, Karlovarska 48, 301 66 Pilsen, Czech Republic

Amin Moztarzadeh

Department of Medical Chemistry and Biochemistry, Faculty of Medicine in Pilsen, Charles University in Prague, Karlovarska 48, 301 66 Pilsen, Czech Republic

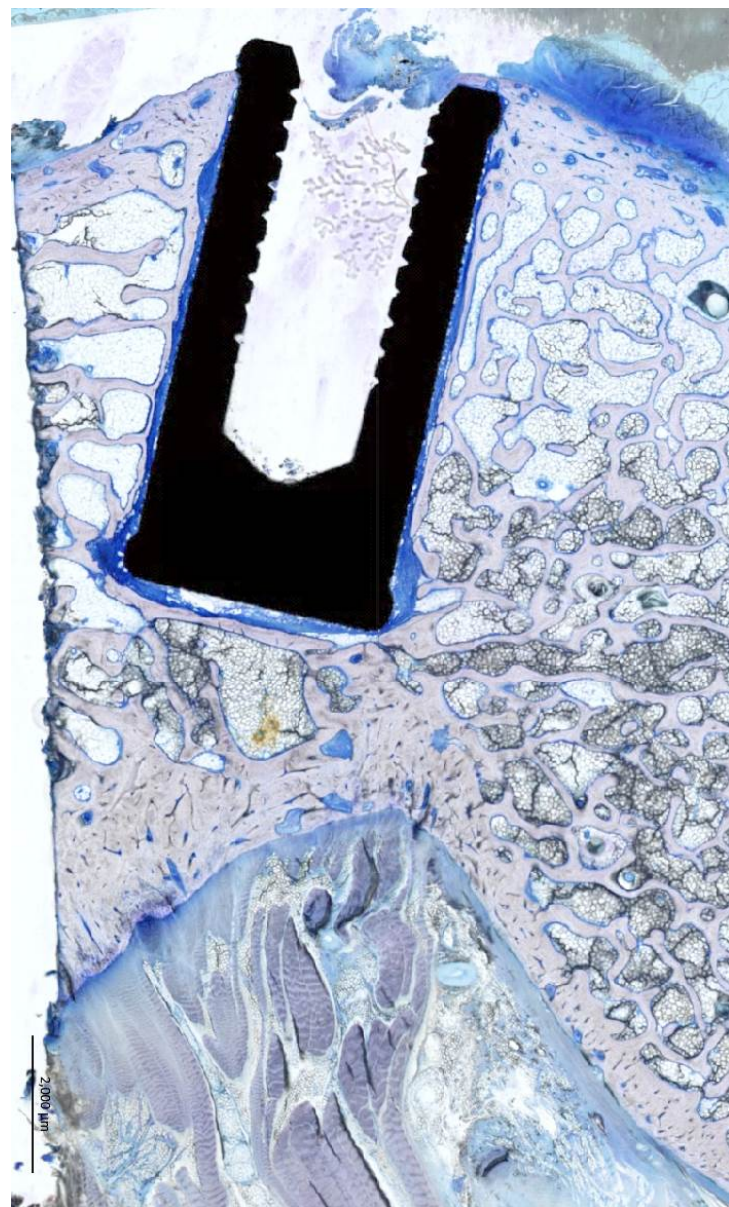
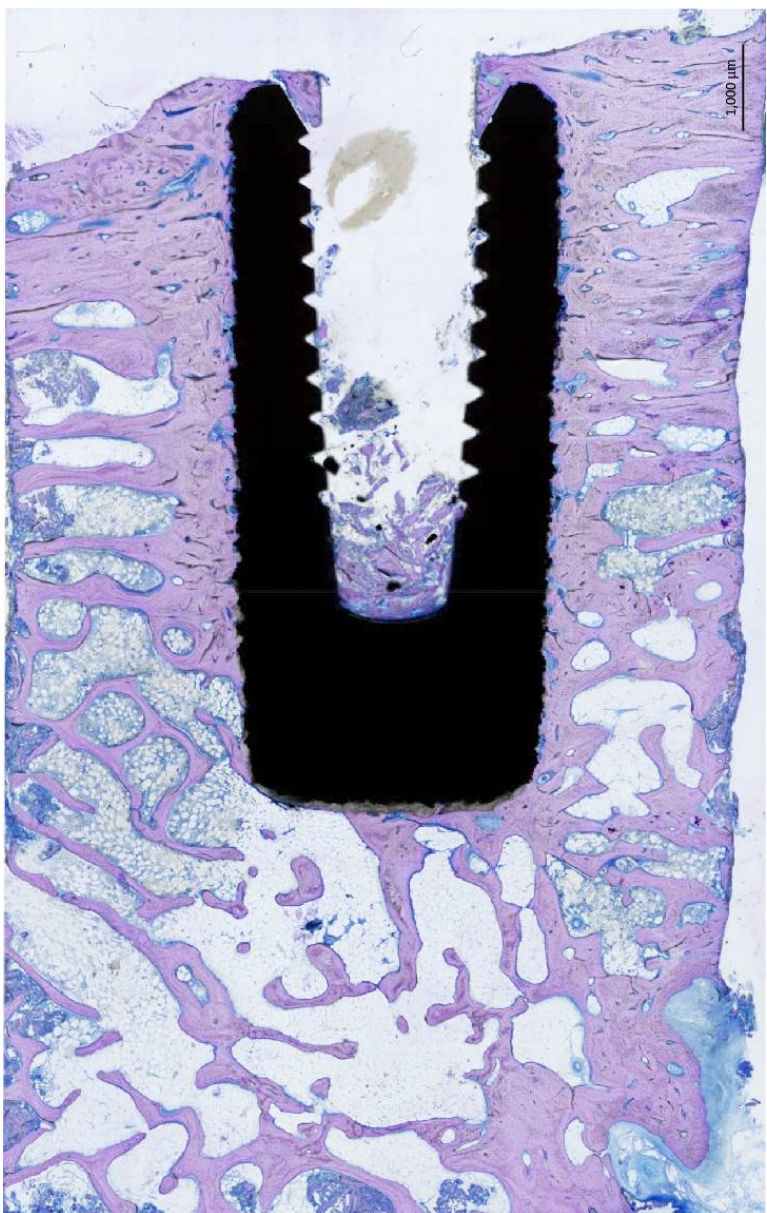
Daniel Hrusak

Department of Stomatology, Faculty of Medicine in Pilsen, University Hospital and Charles University, alej Svobody 80, 301 00 Pilsen, Czech Republic

Zbynek Tonar

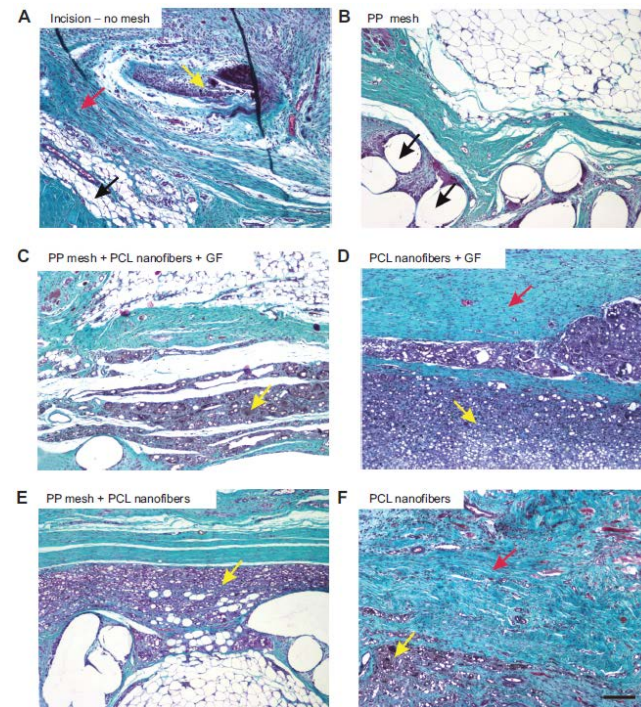
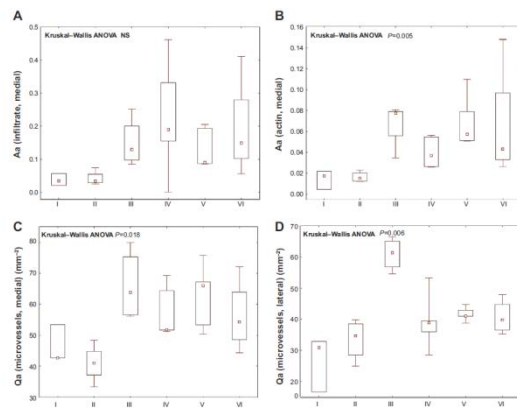
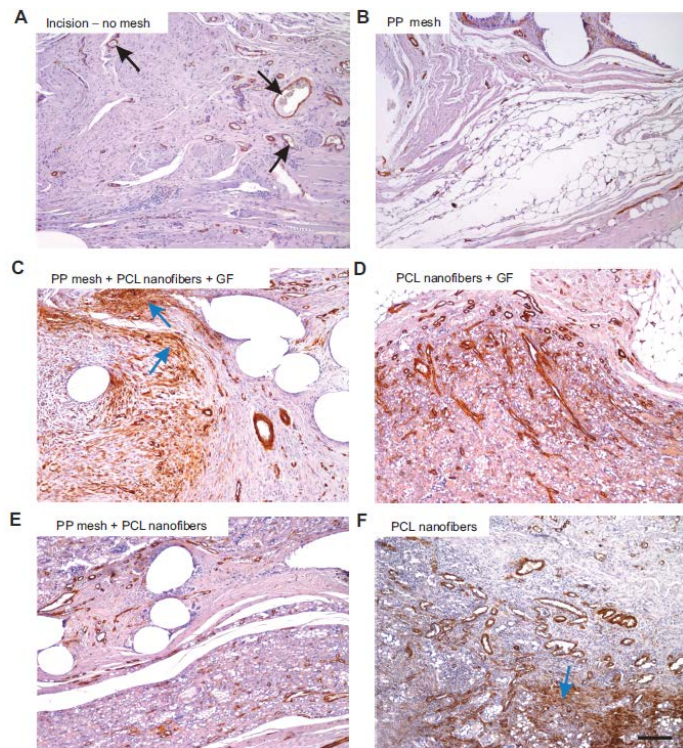
Department of Histology and Embryology and Biomedical Center, Faculty of Medicine in Pilsen, Charles University in Prague, Karlovarska 48, 301 66 Pilsen, Czech Republic







# Kvalita jizvy břišní stěny při aplikaci nanovláknenné sítě



International Journal of Nanomedicine

Dovepress

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ORIGINAL RESEARCH

## Abdominal closure reinforcement by using polypropylene mesh functionalized with poly-ε-caprolactone nanofibers and growth factors for prevention of incisional hernia formation

This article was published in the following Dove Press journal:  
International Journal of Nanomedicine  
9 July 2014  
Number of times this article has been viewed

Martin Plencner<sup>1,2,8</sup>  
Barbora East<sup>3,6</sup>  
Zbyněk Tonar<sup>4</sup>  
Martin Otáhal<sup>5</sup>  
Eva Prosecká<sup>1,2</sup>  
Michala Rampichová<sup>3,6</sup>  
Tomáš Krejčí<sup>7</sup>  
Andrej Litvinec<sup>2,7</sup>  
Matej Buzgo<sup>2,4</sup>  
Andrea Mičková<sup>1,2,4</sup>  
Alois Nečas<sup>8</sup>  
Jiří Hoch<sup>7</sup>  
Evžen Amler<sup>1,2,9</sup>

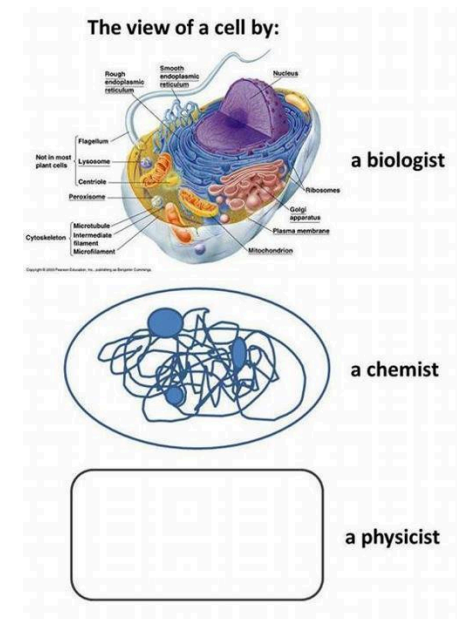
**Abstract:** Incisional hernia affects up to 20% of patients after abdominal surgery. Unlike other types of hernia, its prognosis is poor, and patients suffer from recurrence within 10 years of the operation. Currently used hernia-repair meshes do not guarantee success, but only extend the recurrence-free period by about 5 years. Most of them are nonresorbable, and these implants can lead to many complications that are in some cases life-threatening. Electrospun nanofibers of various polymers have been used as tissue scaffolds and have been explored extensively in the last decade, due to their low cost and good biocompatibility. Their architecture mimics the natural extracellular matrix. We tested a biodegradable polyester poly-ε-caprolactone in the form of nanofibers as a scaffold for fascia healing in an abdominal closure-reinforcement model for prevention of incisional hernia formation. Both in vitro tests and an experiment on a rabbit model showed promising results.

**Keywords:** nanofibers, growth factors, surgical mesh, hernia regeneration, in vivo



# Co histologie „umí říci“ a co ne

- **kvalita a kvantita** mikroanatomického **složení**
- buněčný **fenotyp**
- zastoupení **buněk** a složek **mezibuněčné hmoty**
- **přestavba** tkáně oproti původnímu stavu, „**historie**“ vzorku
- **rozmístění** útvarů, buněk, matrix, antigenů... na vhodně orientovaných řezech v měřítku **1  $\mu\text{m}$ -10<sup>3</sup> $\mu\text{m}$**  (xhomogenizace u biochemických vyšetření)
- x 3D informace v omezené míře (cf. mikro-CT)
- x **vysvětlení mechanismů** změn na buněčné úrovni  
→ paralelně biochemická (molek. biol.) analýza
- x **extrapolace strukturálního obrazu** do **mechanických** vlastností → paralelně biomechanické testování



# Mikro-CT – automatická kvantifikace pomocí SW QuantAn

Int J CARS  
DOI 10.1007/s11548-016-1378-3

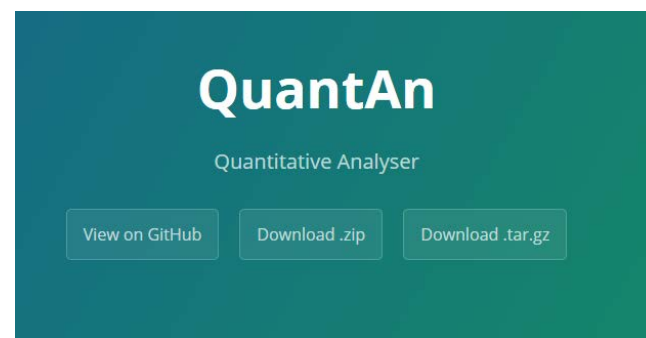
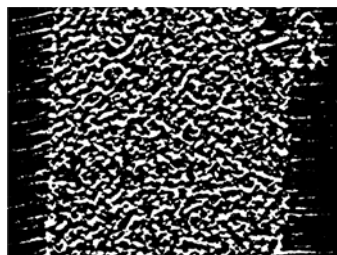


ORIGINAL ARTICLE

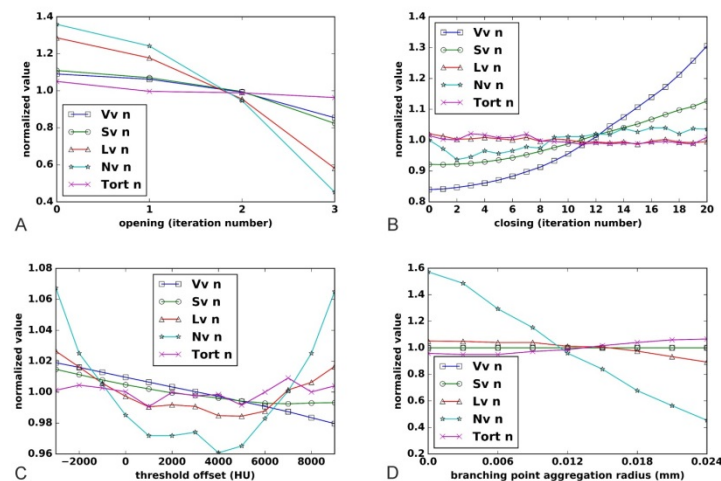
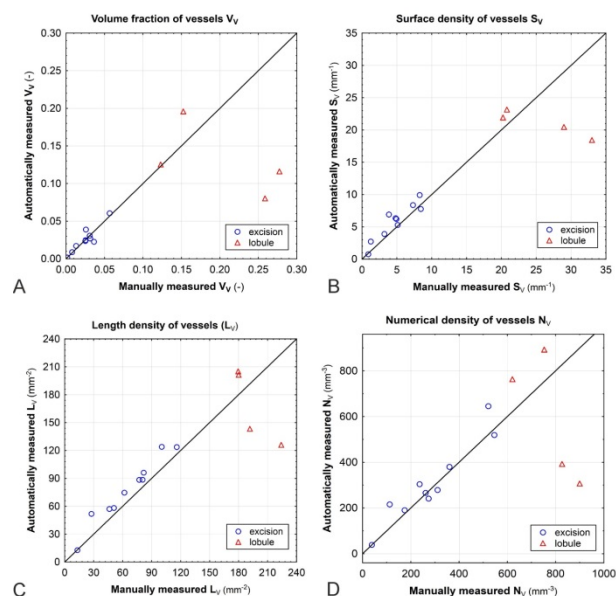
**Stereological quantification of microvessels using semiautomated evaluation of X-ray microtomography of hepatic vascular corrosion casts**

Miroslav Jířík<sup>1,6</sup> · Zbyněk Tonar<sup>1</sup> · Anna Králíčková<sup>2</sup> · Lada Eberlová<sup>3,6</sup> · Hynek Mírka<sup>4,6</sup> · Petra Kochová<sup>1</sup> · Tomáš Gregor<sup>5</sup> · Petr Hošek<sup>6</sup> · Miroslava Svobodová<sup>6</sup> · Eduard Rohan<sup>1</sup> · Milena Králíčková<sup>2,6</sup> · Václav Liška<sup>6,7</sup>

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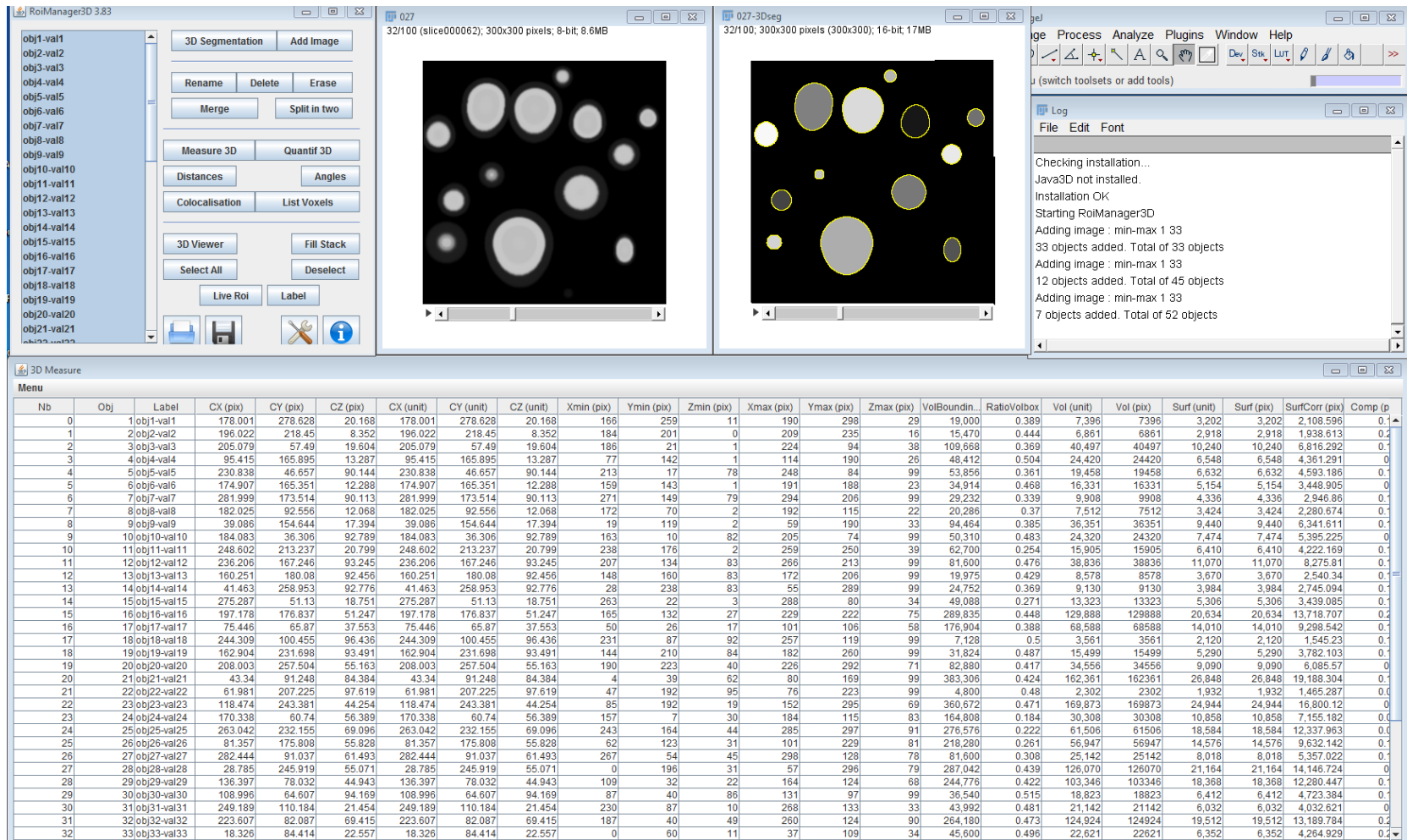
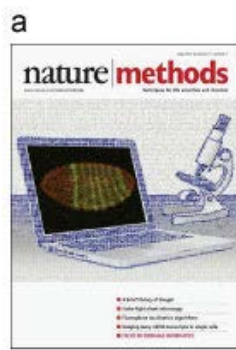


<http://mjirik.github.io/quantan/>



manuální validace - Wilcoxon n.s.

analýza citlivosti



# Mikro-CT – interaktivní kvantifikace ve stereologickém software Ellipse

- jiné techniky binarizace a skeletonizace

## Měření binárního obrazu

*ROI volume:* 1e+006

*Volume:* 334953

*Surface area:* 198346

*Length:* 5503.67

*Euler characteristics:* -647

## Skeleton binárního obrazu

: Thresh, Skeletonization3D 10, 20;

ResampleGeom1D 5

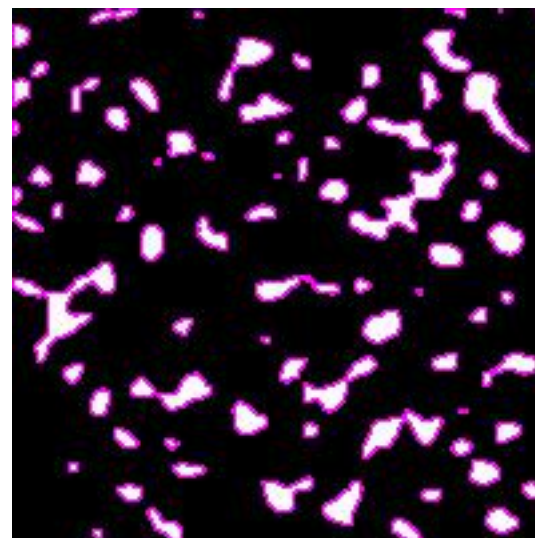
*Total length:* 16310.7

*Total curvature:* 2231.46 radians

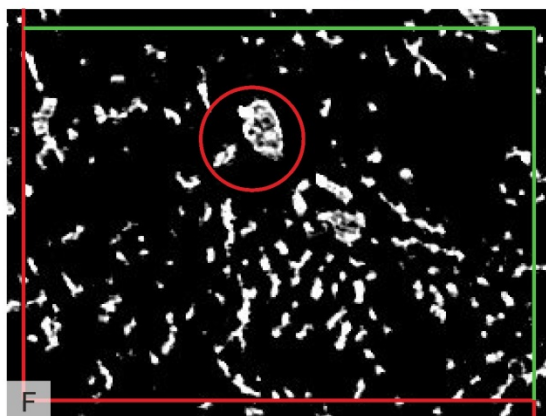
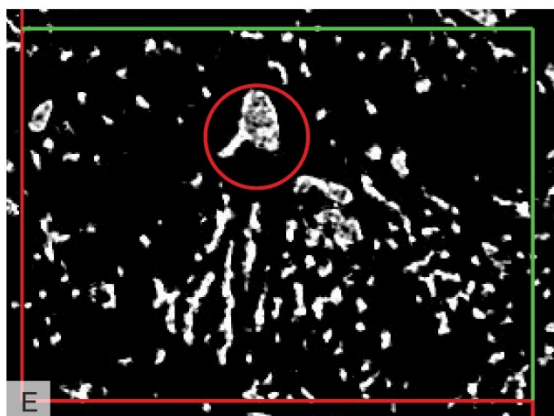
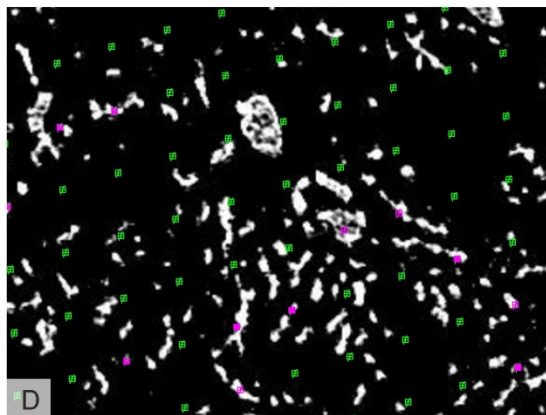
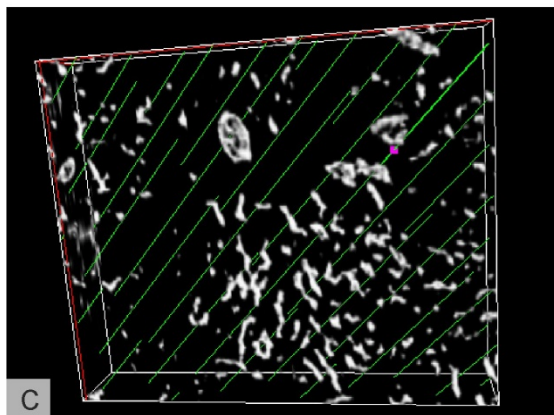
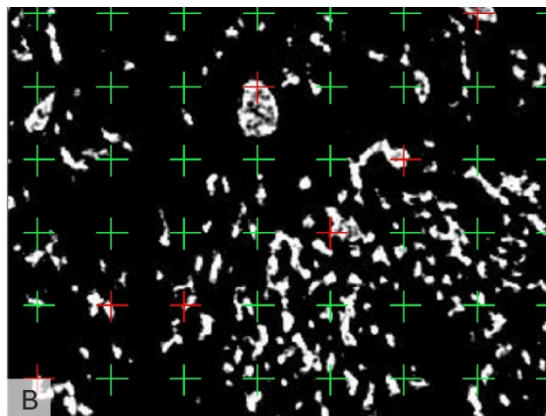
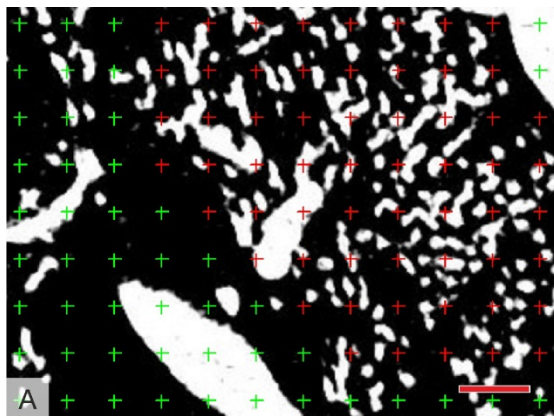
*No. of branchings:* 1022

*No. of ends:* 362

*Euler characteristics:* -416




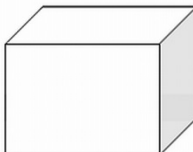

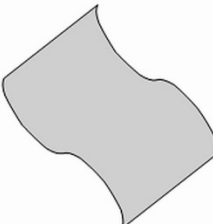

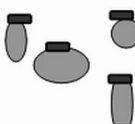
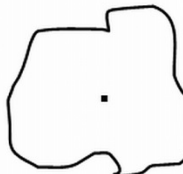
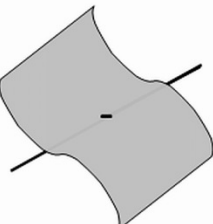
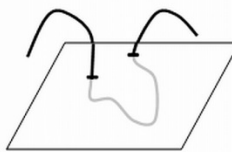
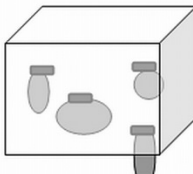


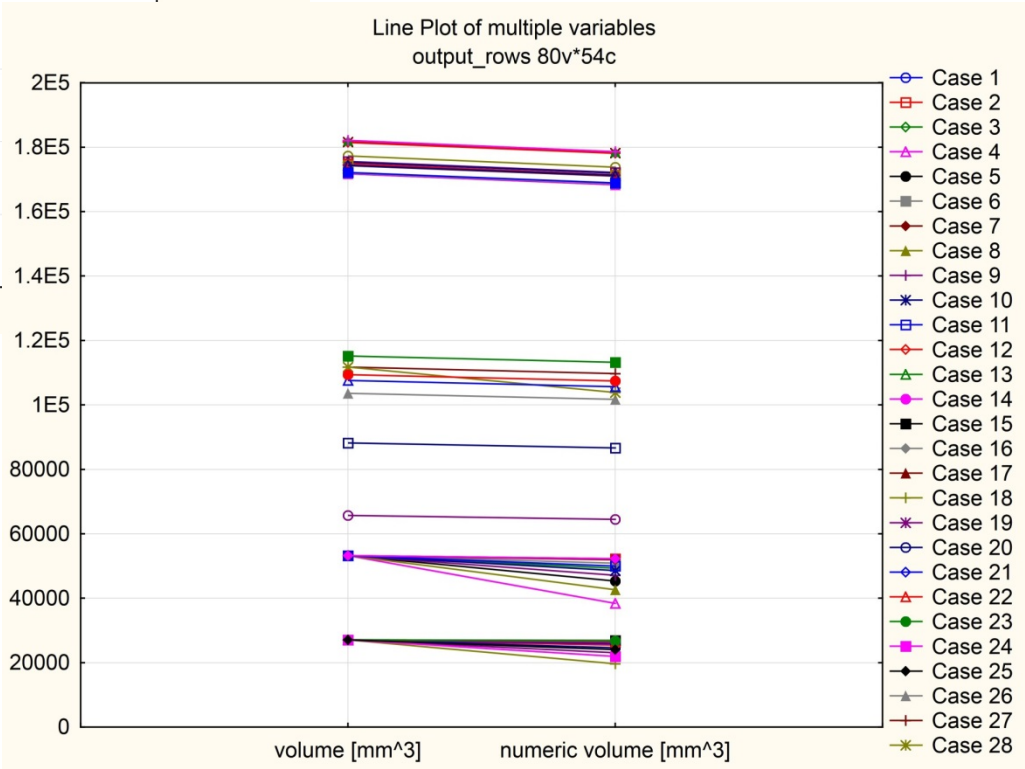
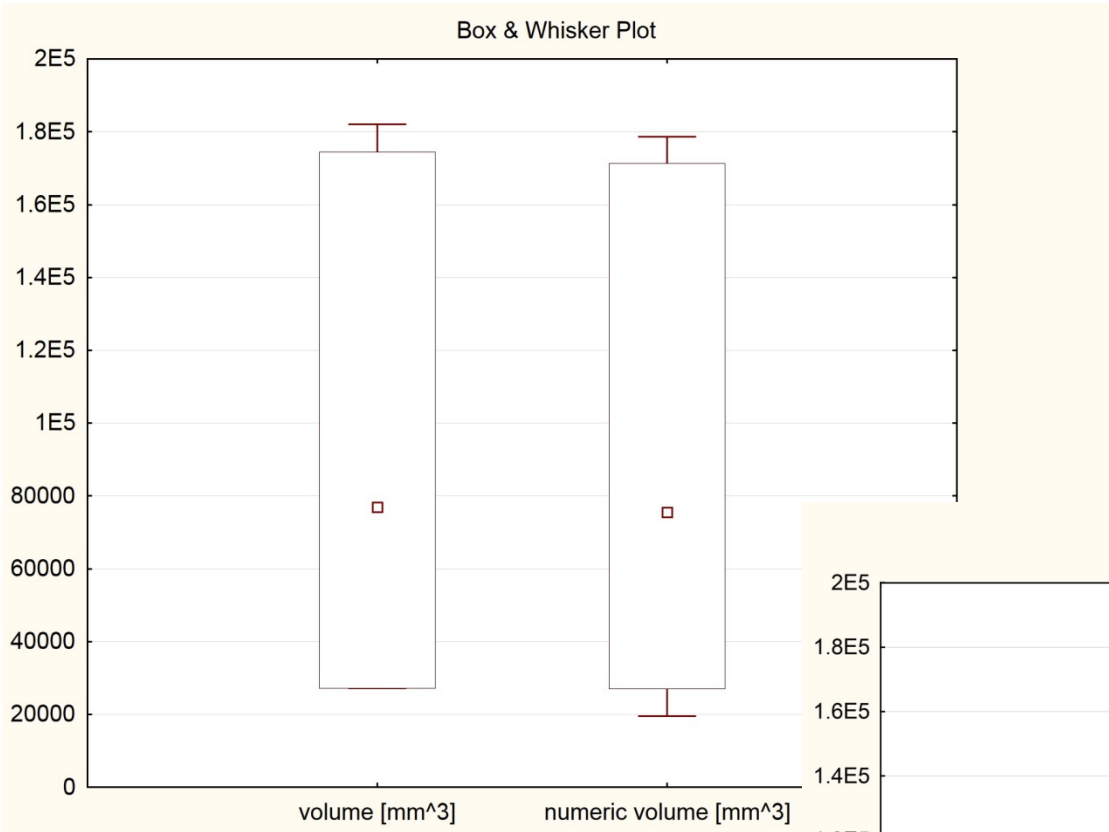




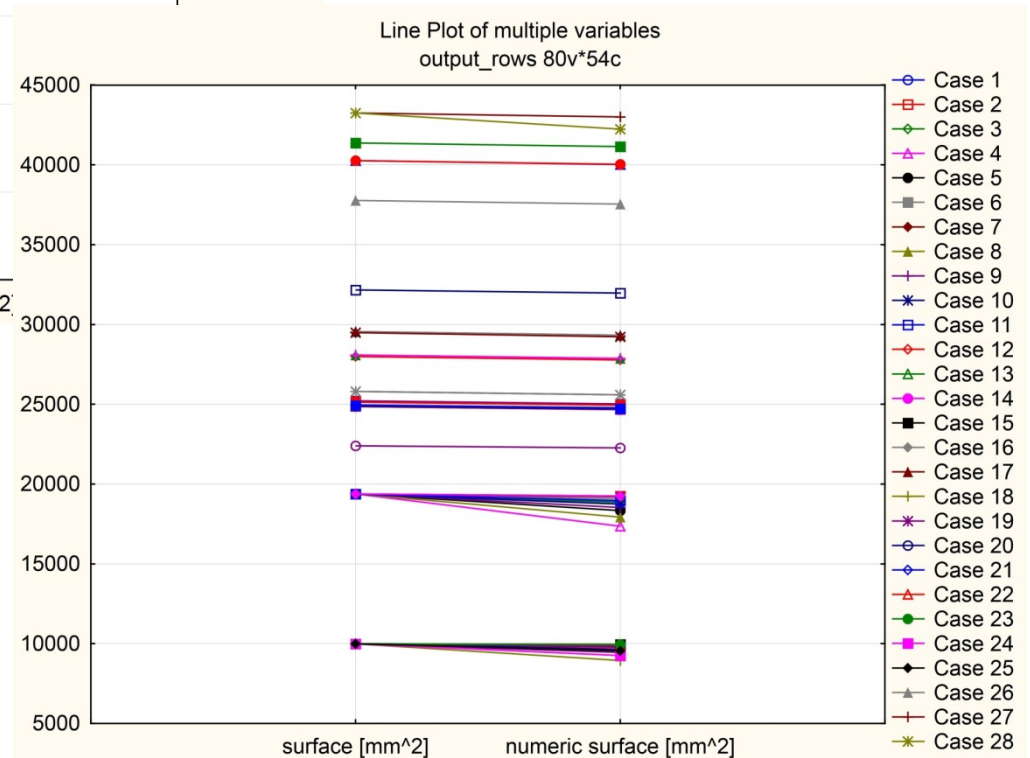
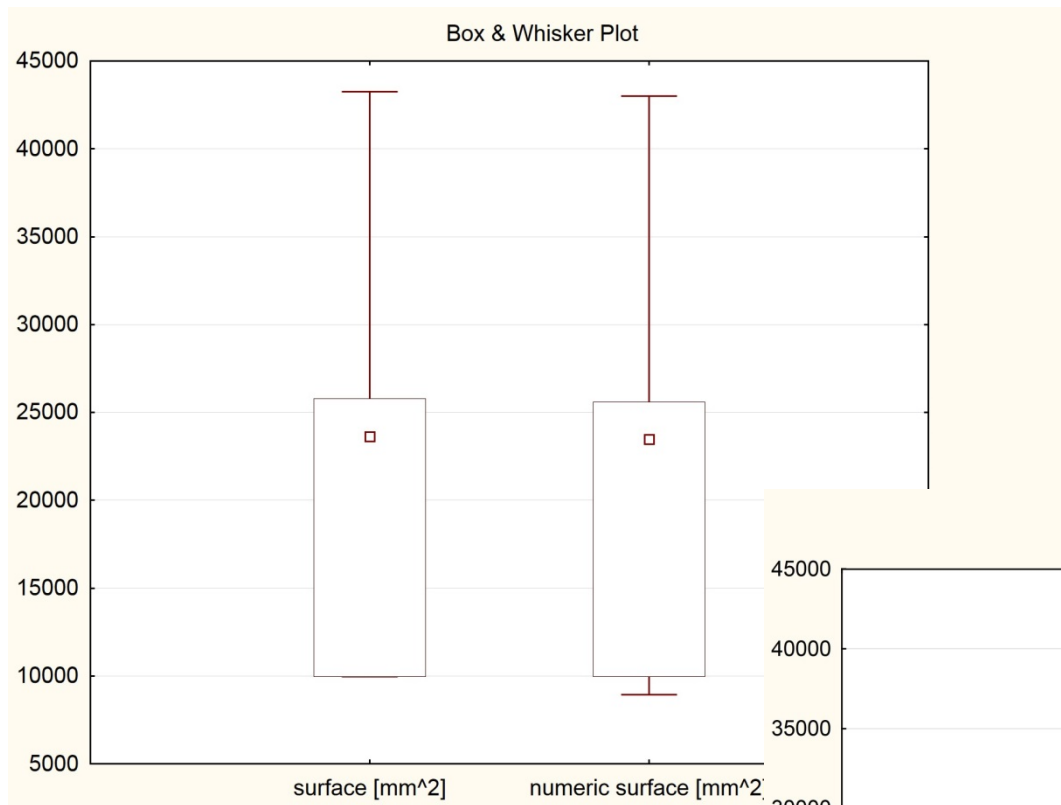


# Rozměry hodnocené veličiny a stereologické sondy

Sonda	 bodová (0D)	 lineární (1D)	 rovinná (2D)	 objemová(3D)
$n$ Veličina	 objem (3D)	 plocha (2D)	 délka (1D)	 počet (0D)
$=$ počítané události	 počet (0D)	 délka (1D)	 plocha (2D)	 objem (3D)



Wilcoxon matched pairs test  $p < 0.001$



Wilcoxon matched pairs test  $p < 0.001$

