

# Study of Effects of Microgravity on Disc Height and Compositional Analysis

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UCSD-Doshisha Medical Imaging Research Center 2<sup>nd</sup>  
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**Department of  
Bioengineering**

UNIVERSITY of CALIFORNIA  
SAN DIEGO  

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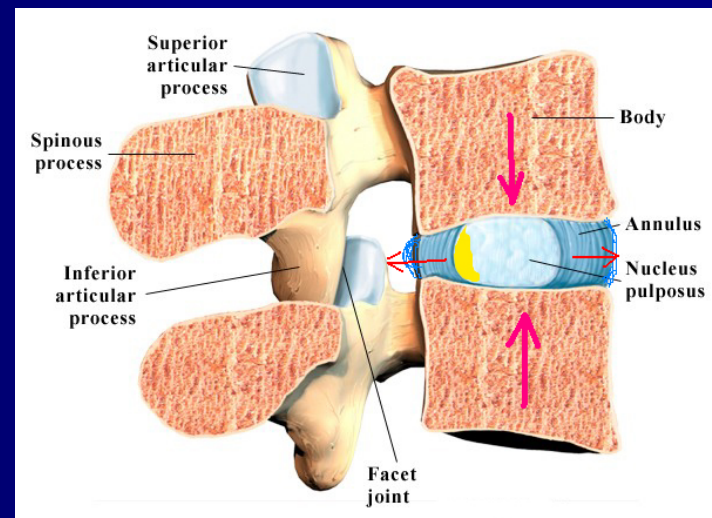
ORTHOPAEDIC SURGERY



D o s h i s h a  
U n i v e r s i t y  
BIOMEDICAL ENGINEERING

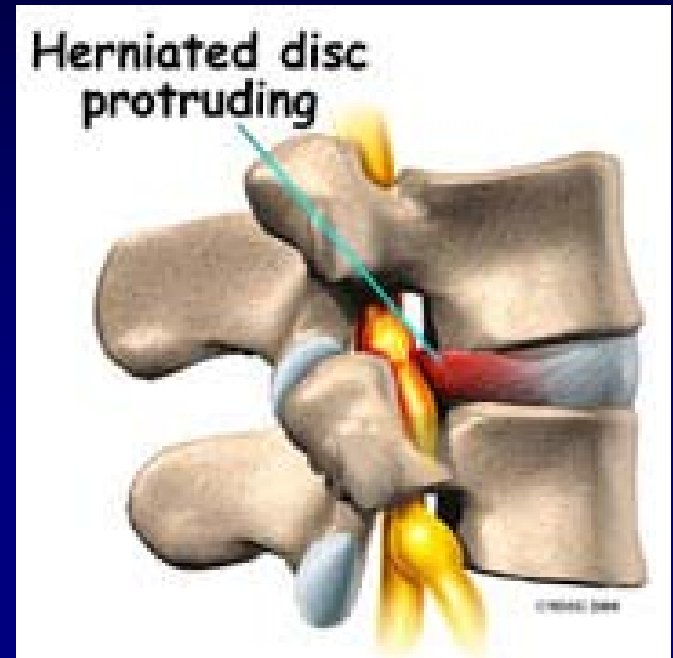
# Disc Herniation and Back Pain

- Commonly occurs in astronauts
- Increases the injury likelihood and inhibits daily life
- Underlying factor: intervertebral disc (IVD) degeneration (NASA)
- Endplates
  - Separates disc and vertebral body
  - Structural and compositional changes during space travel
    - Spinal elongation
    - Imbalance of collagen-proteoglycan ratio (Pedrini-Mille)



# Gravity Effects on Spine

- Spine compressed during return to Earth
- Intervertebral discs compressed and may cause disc herniation (Maynard)
- Compositional and structural changes in trabecular bone (LeBlanc)



# Objectives

- To investigate structural and compositional changes of mice intervertebral discs under microgravity by examining
  - Disc heights
  - Trabecular analyses
- Methods
  - Micro computed tomography ( $\mu$ CT)
  - Tri 3D Bon software and CT Analyser software
  - Mimics 13.0 and 13.1
- Analyses parameters
  - Bone volume ratio (BV/TV)
  - Trabecular number (Tb.N)
  - Trabecular thickness (Tb.Th)
  - Bone mineral density (BMD)
  - Disc height

# Samples

NASA Discovery STS-131 mission mice

Strain: C57Bl/6

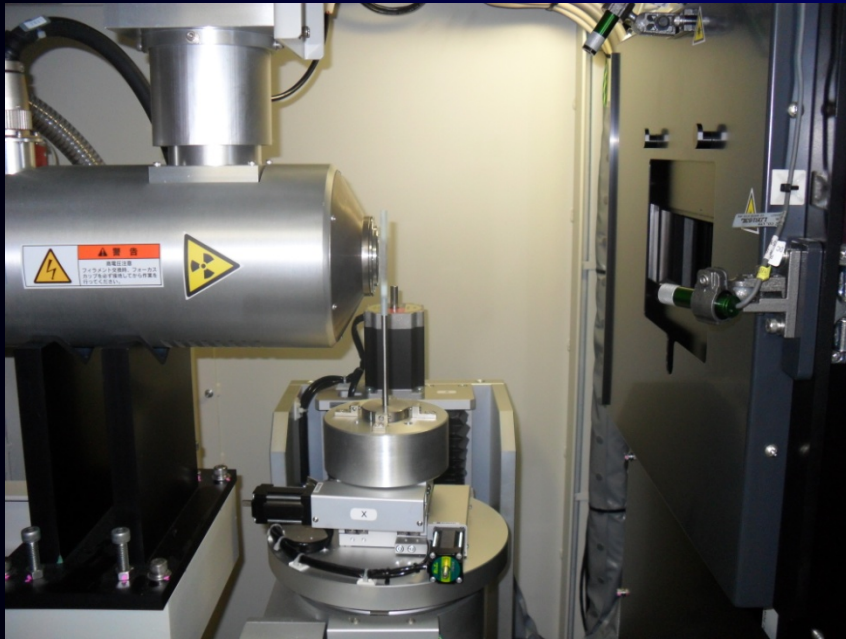
CD45.1 congenic mice

Weigh 25g

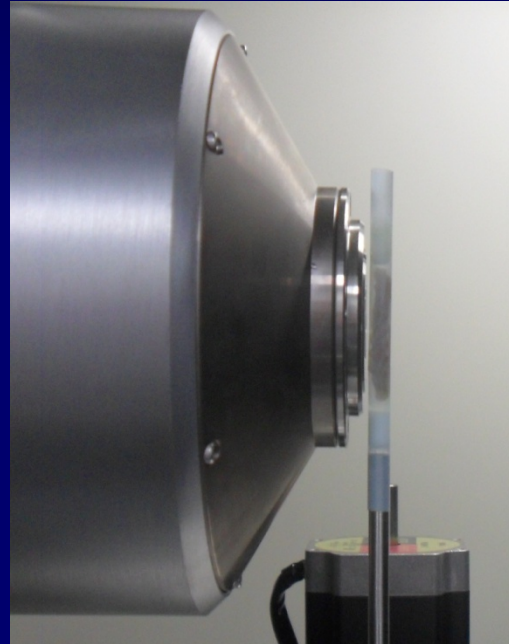


# Image Acquisition

Shimadzu SMX-160CTS



Chamber design



← separator

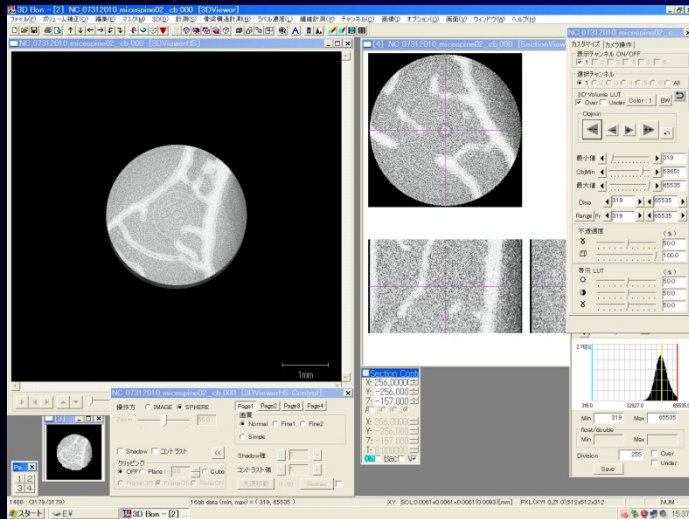
# Micro CT Scanning: High Resolution Imaging

- Conditions
  - 1.59 microns isotropic
  - source-to-object distance (SOD) of 3.5mm
  - Voltage: 65 kV – 72 kV
  - Reconstruction matrix size 512 x 512
  - Field of view (FOV XY) approximately 0.8 mm
- Limitation: incomplete view of endplate



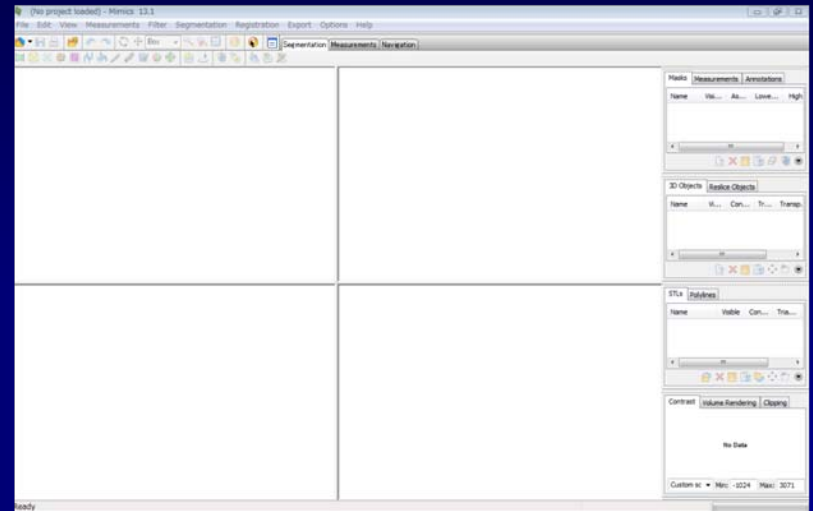
# Image Reconstruction

## 1. Tri/3D Bon (Ratoc System Engineering)



- Import raw data from  $\mu$ CT
- Noise reduction and filter
- Generate 3D model
- Export files as bitmap

## 2. Mimics 13.1 ® (Materialise)

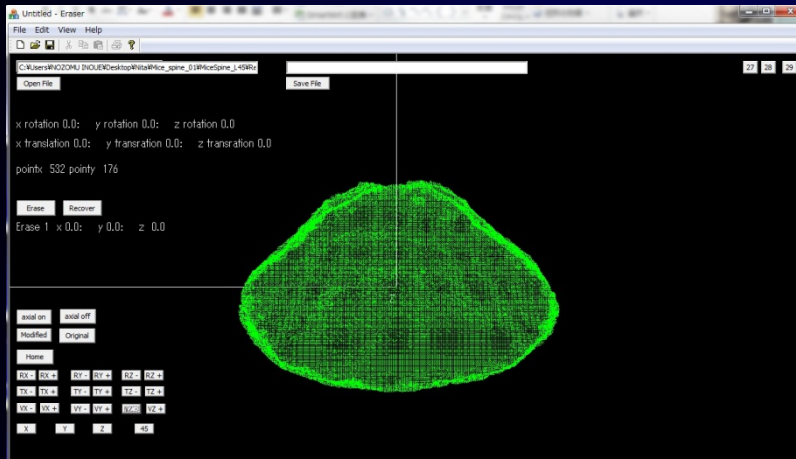


- Import bitmap files
- Threshold and segment
- Generate reconstruction 3D model
- Export point cloud (with Mimics 13.0)



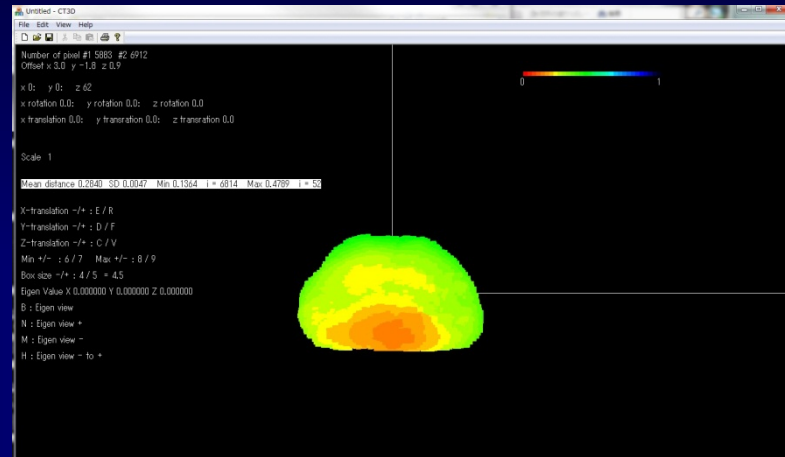
# Disc Height Calculation

## 1. Eraser Program



- Open point cloud data from Mimics
- Erase unnecessary regions
- Generate endplate
- Save files as .txt

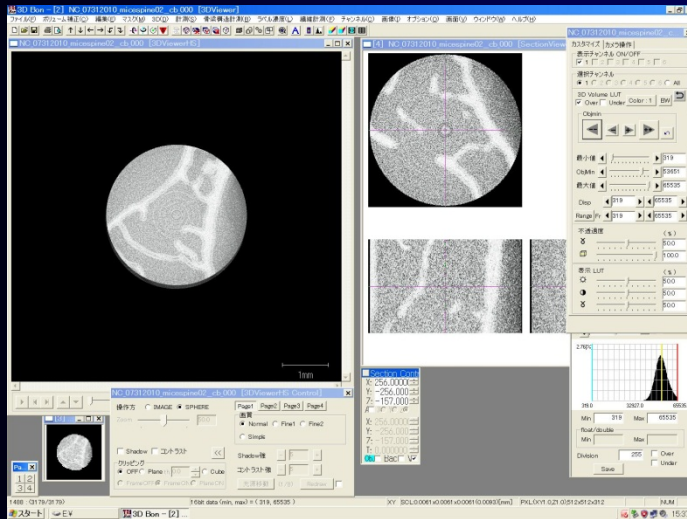
## 2. DHD Program



- Open caudal and cranial erased text files
- Calculate disc height

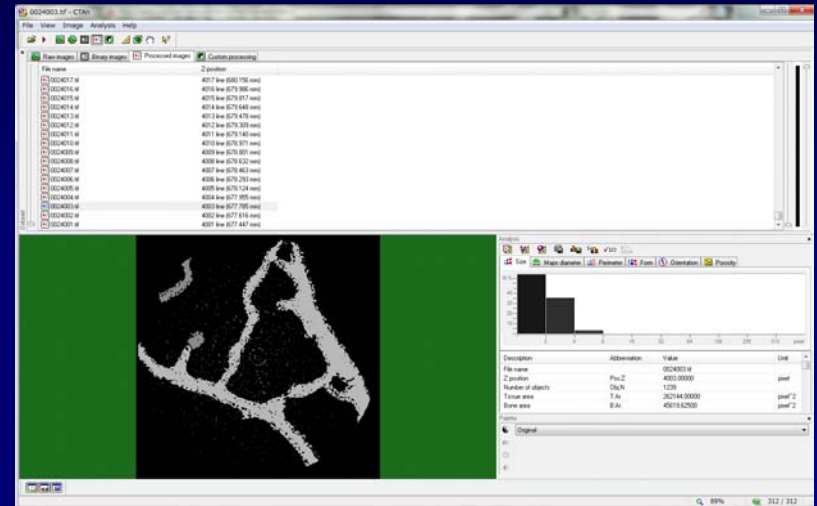
# Trabecular Analysis

## 1. Tri/3D Bon (Ratoc System Engineering)



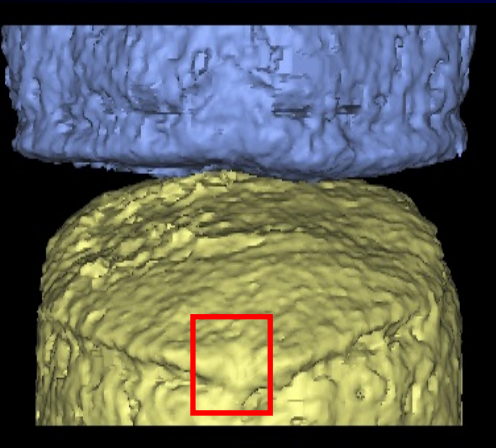
- Import raw data from  $\mu$ CT
- Noise reduction and filter
- Generate 3D model
- Export files as bmp

## 2. CT Analyser Software



- Import reconstructed data
- Select region of interest (ROI)
- Calculate trabecular parameters
- Export analyses as text file

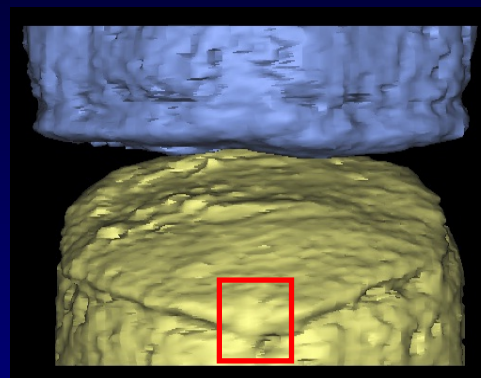
# Results: Disc Height Practice



Resolution level 2  
X/Y: 2 x 0.009 (mm)  
Z: 1 x 0.009 (mm)



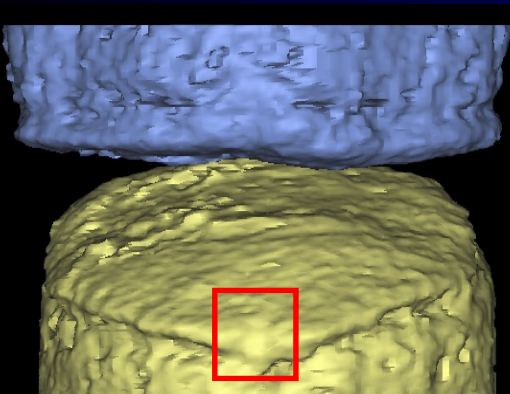
40.8 KB



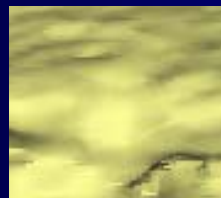
Resolution level 4  
X/Y: 4 x 0.009 (mm)  
Z: 1 x 0.009 (mm)



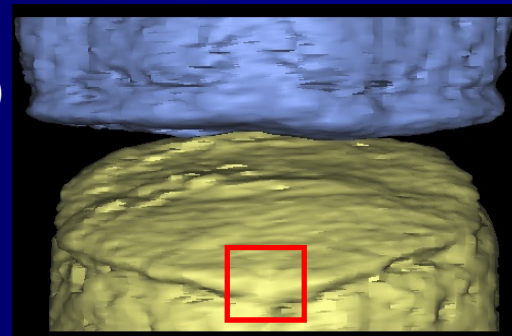
47.7 KB



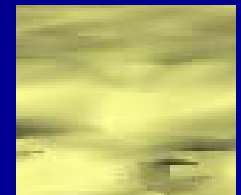
Resolution level 3  
X/Y: 3 x 0.009 (mm)  
Z: 1 x 0.009 (mm)



62.5 KB



Resolution level 5  
X/Y: 5 x 0.009 (mm)  
Z: 1 x 0.009 (mm)



46.4 KB

***X-Y resolution reduction by 2-5x  
appears appropriate for estimating IVD  
height in mice***

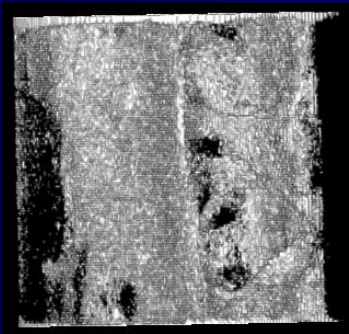
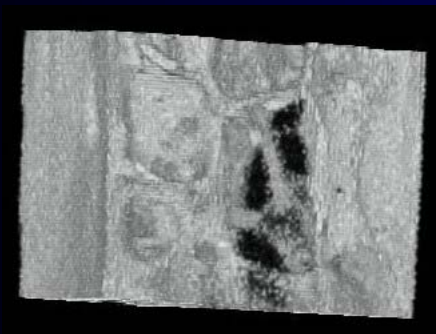
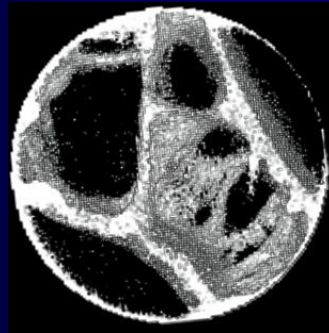
resolution	mean	minimum	maximum
1	n/a	n/a	n/a
2	0.2887	0.1383	0.5271
3	0.284	0.1364	0.4789
4	0.2849	0.136	0.5103
5	0.2898	0.136	0.5469
STDEV	0.00283	0.00110	0.0288

Table 03. Disc heights of L45 of mice spine sample 1 at various resolutions

# Results: Trabecular Bone Analysis

#	Date	type	voltage (kV)	brightness (kV)	FOV XY (mm)	FOV Z (mm)	SOD (mm)	Resolution (microns)
1	07/31/2010	cancellous bone	62	0	3.098	1.895	8.6	512; (6.050)
2	08/04/2010	cancellous bone	60	0	0.873	0.825	3.9	512; (1.705)

- Trabecular bone images of the fourth vertebra at two different resolutions.



Scan #1

Scan #2

# Results: Trabecular Bone Analysis

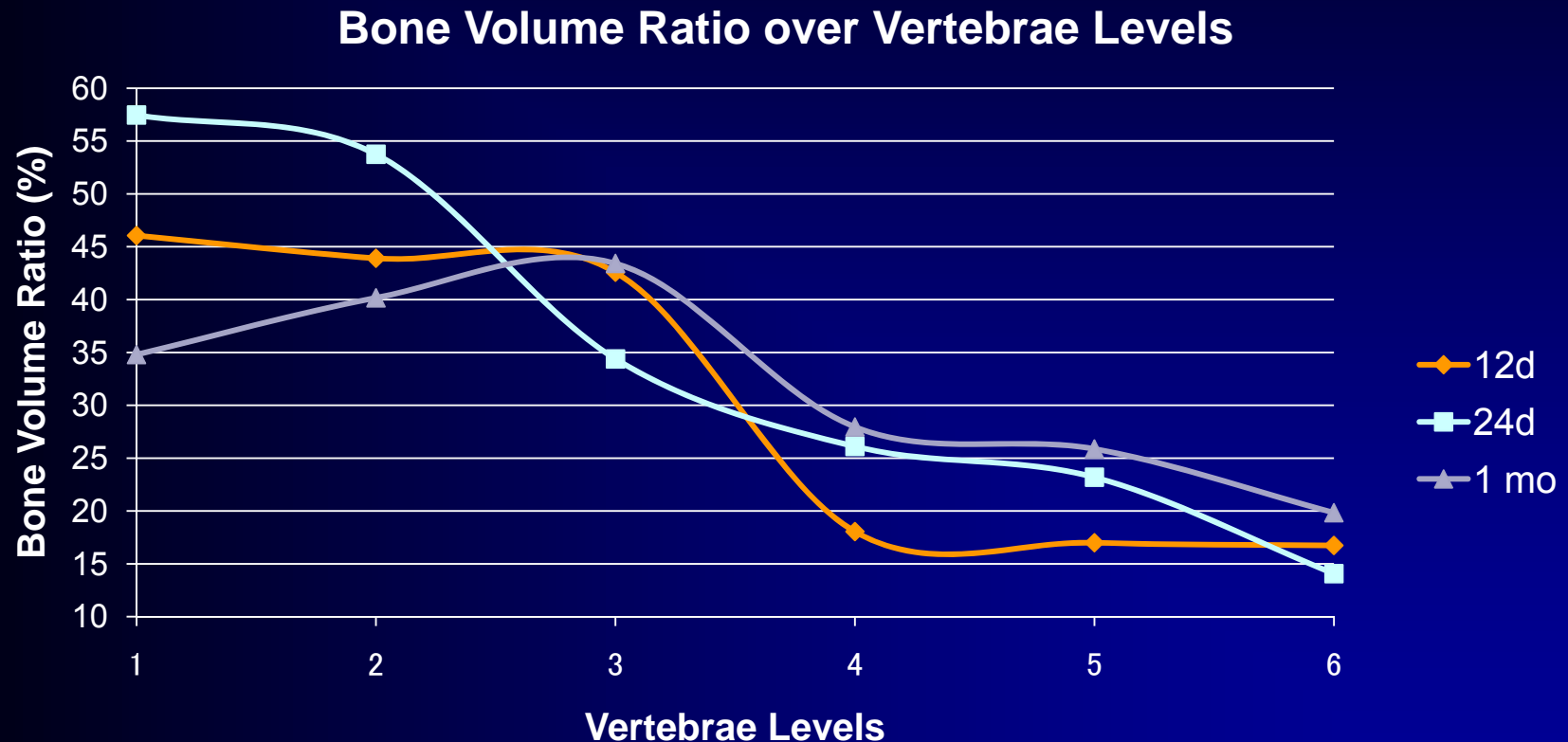


Figure 01. Bone volume ratio of different aged mice spines of twelve days, twenty-four days, and one month over the six lumbar levels.

# Results: Trabecular Bone Analysis

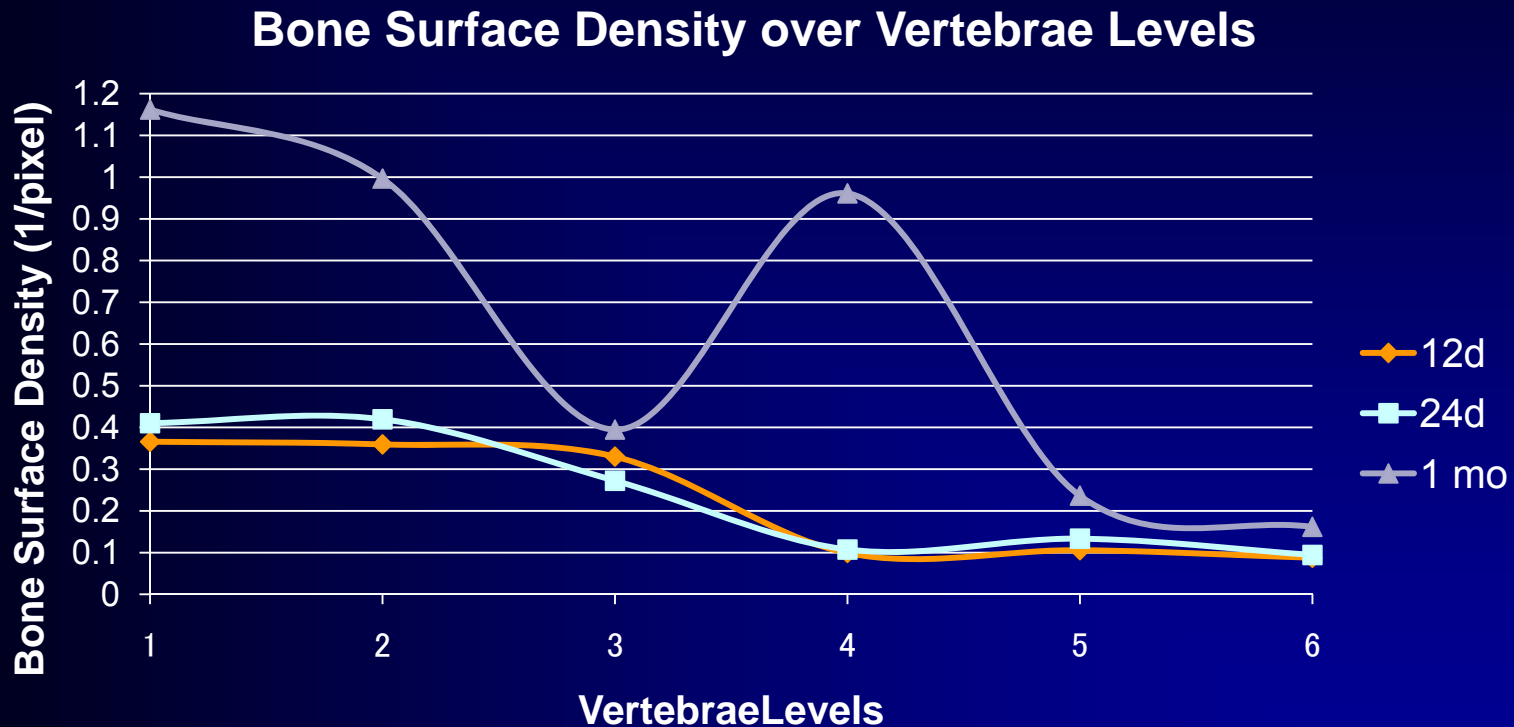


Figure 02. Bone surface density of different aged mice spines of twelve days, twenty-four days, and one month over the six lumbar levels.



# Results: Trabecular Bone Analysis

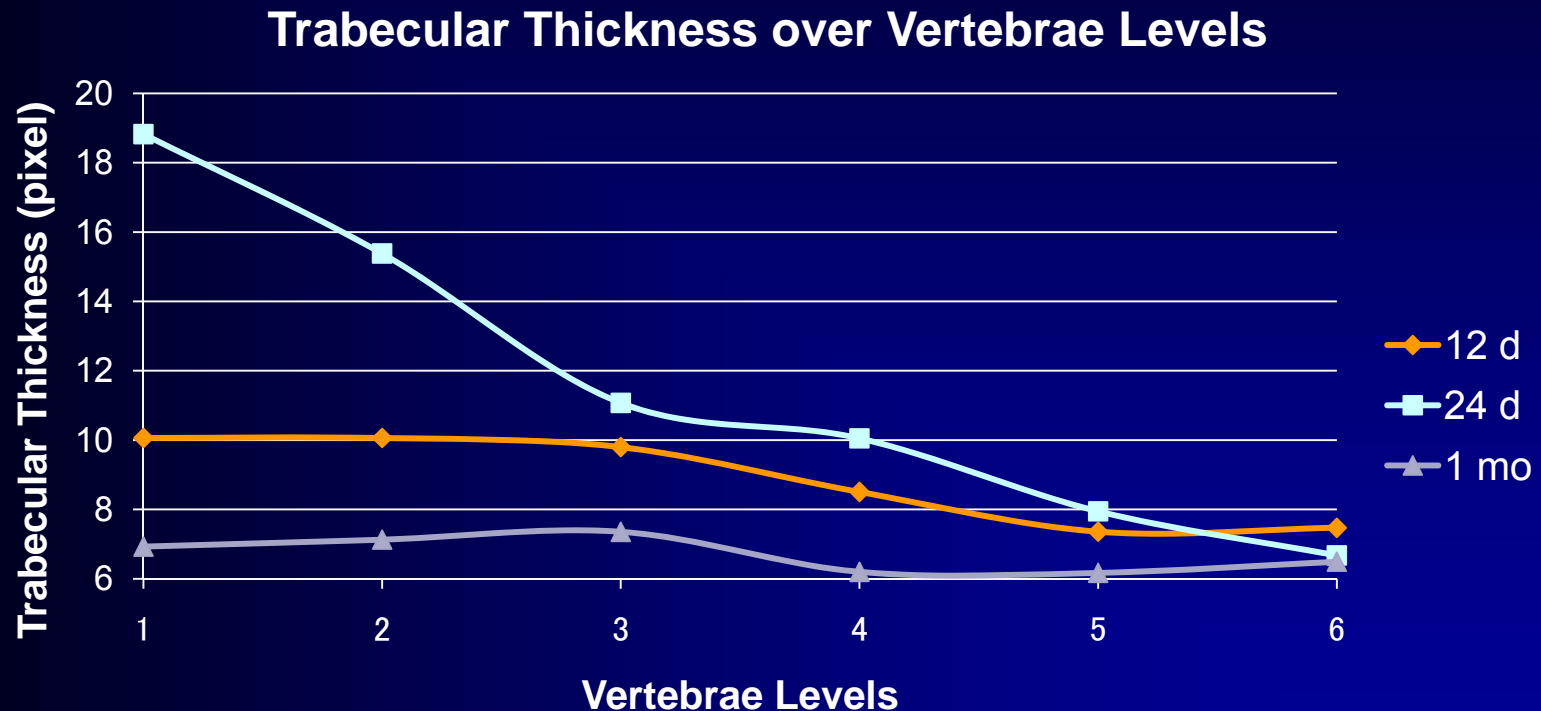


Figure 03. Trabecular thickness of different aged mice spines of twelve days, twenty-four days, and one month over the six lumbar levels.

# Results: Trabecular Bone Analysis

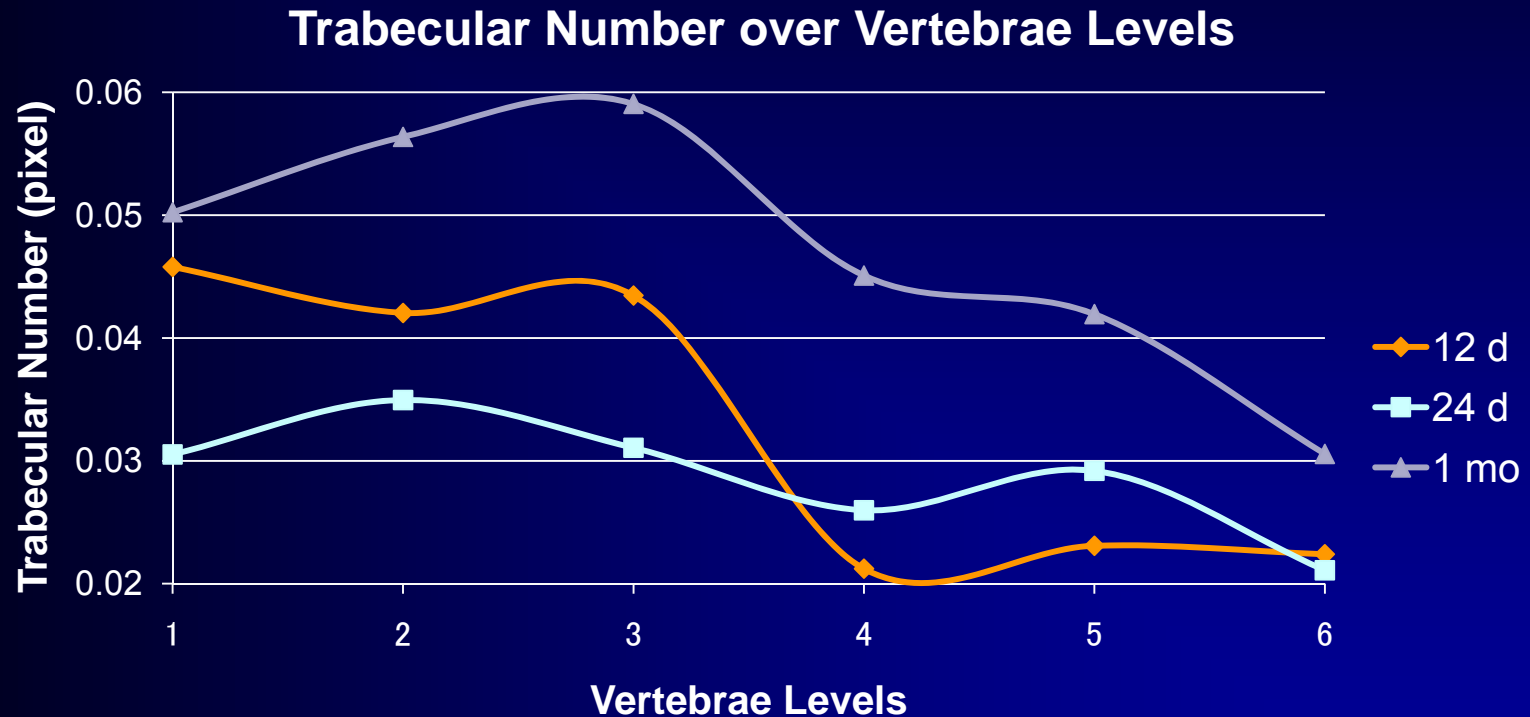


Figure 04. Trabecular number of different aged mice spines of twelve days, twenty-four days, and one month over the six lumbar levels.

# Results: Endplate Imaging

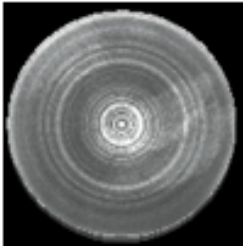
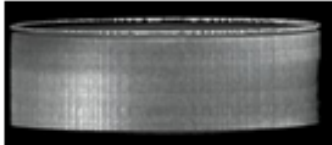
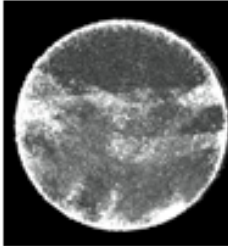
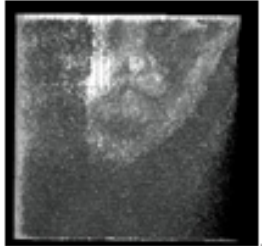
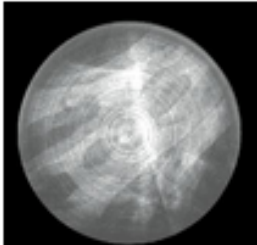
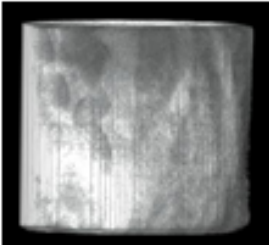
#	date	voltage (kV)	brightness (power)	FOV XY (mm)	FOV Z (mm)	resolution (microns)	
1*	2010/6/8	80	20	0.834	0.730	512; (1.629)	 
2	2010/5/8	72	0	0.817	0.743	512; (1.595)	 
3	2010/5/8	72	0	0.750	0.750	512; (1.465)	 

Table 04. micro CT scanning results of endplates at various voltage-power settings with a source-to-object distance (SOD) of 3.5 mm and a matrix of 512 x 512.

# Results: Endplate Imaging

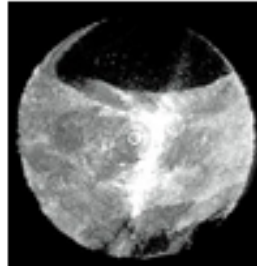
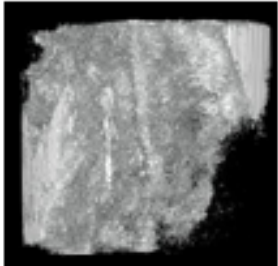
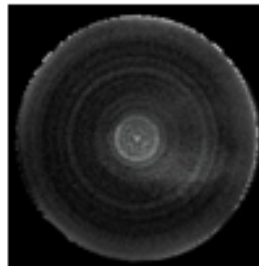
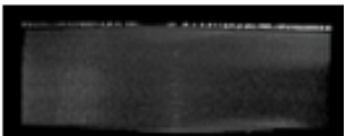
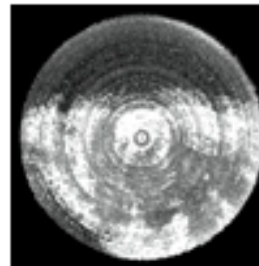
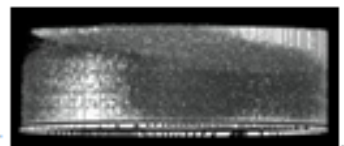
4*	2010/5/8.	65.	55.	0.813.	0.743.	512; (1.588).		
5.	2010/6/8.	65.	0.	0.834.	0.730.	512; (1.629).		
6.	2010/6/8.	60.	0.	0.834.	0.730.	512; (1.629).		
* <u>oscillograph</u> at 50% - 60%+								

Table 05. micro CT scanning results of endplates at various voltage-power settings with a source-to-object distance (SOD) of 3.5 mm and a matrix of 512 x 512.

# Discussion

- Accomplished/Established:

- Trabecular and endplate high resolution scanning protocol
- Mimics software protocol
- Micro CT scanning and reconstruction practice

- Future Goals

- Space mice disc heights calculation and analysis
- Further assessment of parameters of trabecular analyses
- Biochemical analyses of collagen-proteoglycan ratio

# Acknowledgements

## *Laboratories and People*

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