STUDY OF ENDPLATE VASCULAR CHANNELS IN THE VERTEBRAL BODY

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UCSD | Department of Bioengineering

University of California San Diego
Orthopaedic Surgery

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Biomedical Engineering

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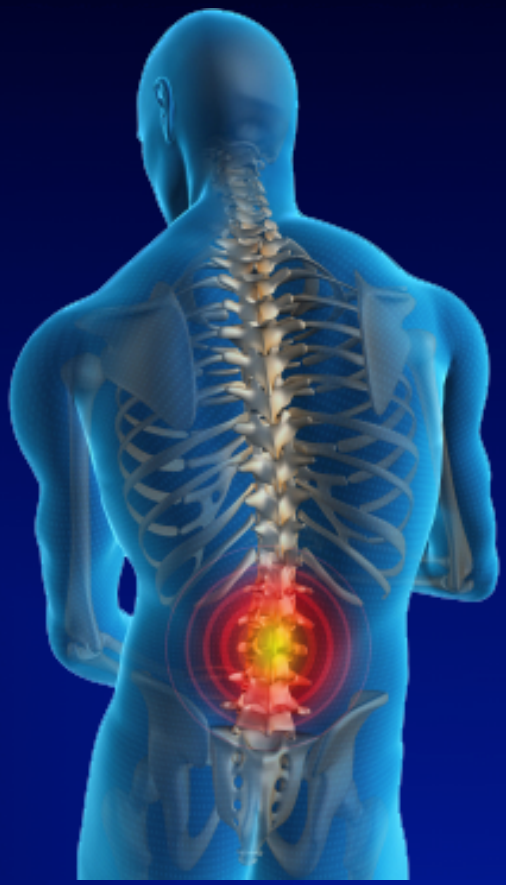
Background

- One of the most prominent diseases in industrialized countries.[1]
- Most adults are affected by spinal pain at some point in their lives.[2]
- Greatly decreases a person's general quality of life.[2]
- In the U.S. 80% of the population has experienced back pain, 40% of those cases are connected to degenerative disc disease, DDD.[3]



Low back pain[4]

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Disc Degeneration

- Uneven distribution of loads across the entire disc
  - Site-specific damage
- Endplate fissures
  - Loss of hydration
- Loss of Nutrients
  - Adult disc is avascular
  - Disc nutrition:
    - Vertebral body (vessels) → bony endplate (capillary network) → cartilage endplate (diffusion) → disc matrix (diffusion) → disc cells

Degenerative Disc Disease

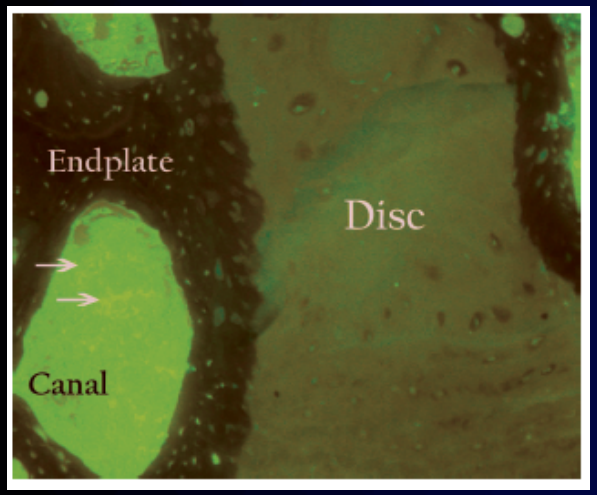
"MRI of the lumbar spine. Sagittal T2 image showing DDD at L5-S1. Note the loss of white signal (dehydration) and loss of disc height."[5]

- Occurs due to both impaired nutrient transport and/or unusual mechanical loading.
- Impaired nutrient transport has more negative consequences.
- Diffusion capacity is decreased as vascular channels in degenerated discs are compromised.[6]

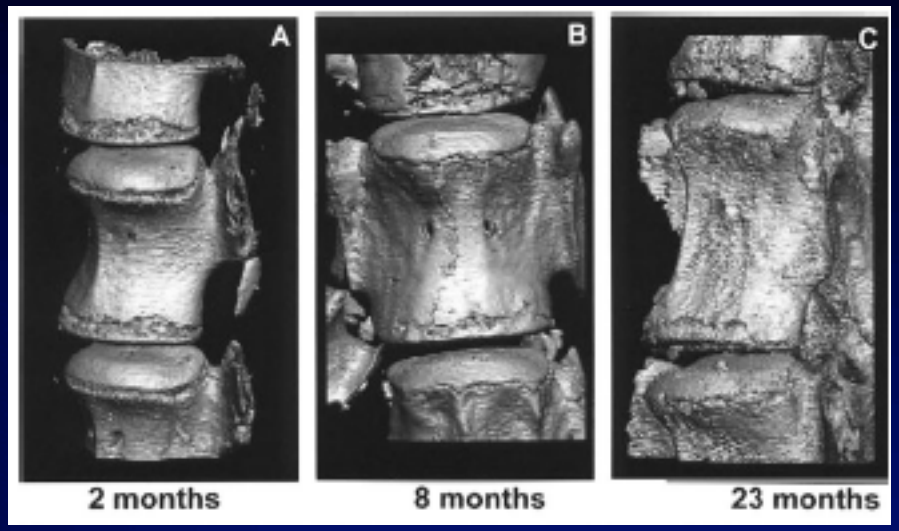
Evaluation of Bony Endplate

- Micro-Computerized Tomography
- Vascular tracer
  - Sodium fluorescein
    - UV microscopy
- Nitrous oxide (as a tracer)
  - Electrochemical measurement
- Immunocytochemistry
- Immunohistochemistry

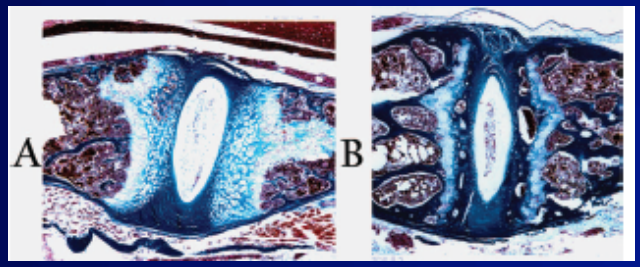
Evaluation of Bony Endplate



Sand rat injected *in vivo* with a fluorescein vascular tracer; red blood cells are indicated by the arrows.[7]



MicroCT 3D images of L5-6 and L6-7 discs of 2, 8, and 23-month old sand rats.[7]



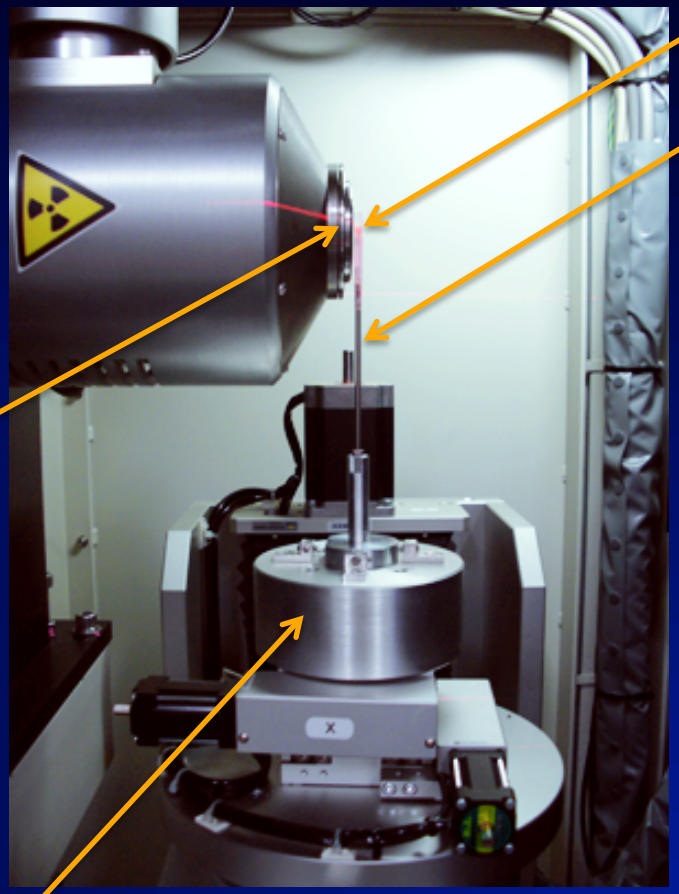
Histologic view of disc and endplates.[7]

Project Outline

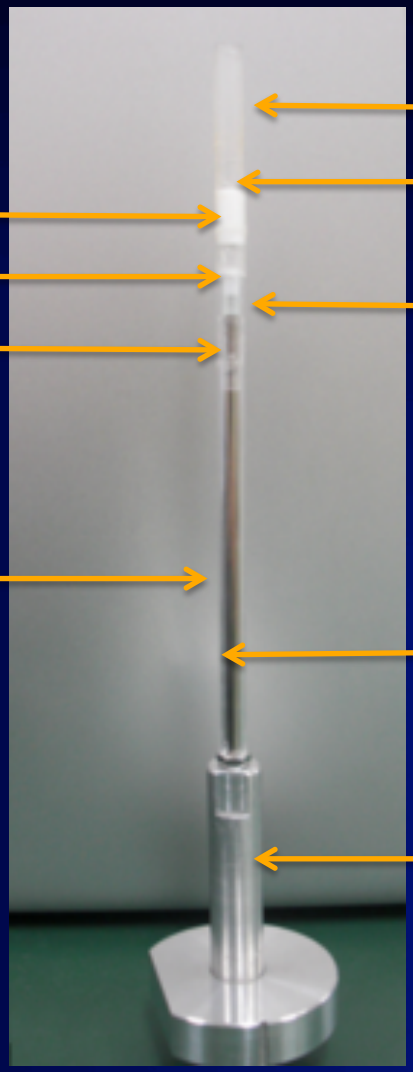
- Overall Aim
  - to evaluate the surface roughness of vertebral endplate in cadaveric human lumbar spines and to determine variation with disc grade, level, and anatomic region by using micro-computed tomography to examine the microstructure of the endplate tissue, specifically the vascular canals, and correlate the variations with different levels of disc degeneration.
- Specific Aim
  - to find the practical resolution for visualizing the microstructure of the vertebral endplate

Scanning Methodology

Shimadzu SMX-160CTS



Sample Holder



5.0mm soft straw

Place sample here

Soft eraser

Hard eraser

4.0mm soft straw

Calibration needle
(stuck into the hard eraser
and stabilized by glue)

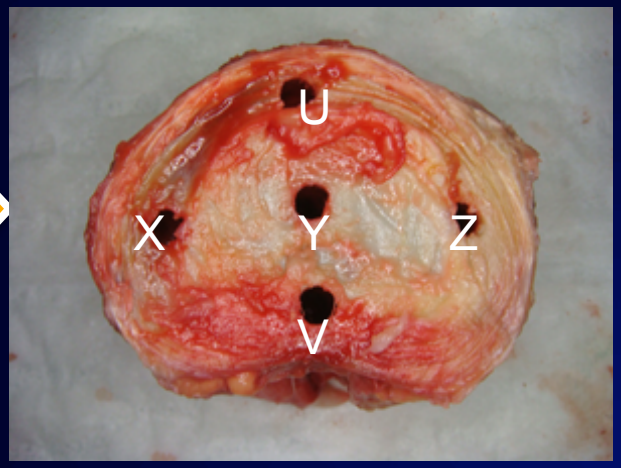
Hard straw
5.0mm outer diameter
4.0mm inner diameter

Original metal rod

Metal base

Samples

Samples
TS593
TS597
TS572
LS009
LS010



	X	Y	Z	U	V
L2i	-	-	-	-	-
L3s	-	-	-	-	-
L4i	-	-	-	-	-
L5s	-	-	-	-	-

- 5 cadaveric spines
- 4.9mm cylindrical cores (of varying lengths) obtained from lumbar superior and inferior vertebral surfaces at L2/3 and L4/5 (L2i, L3s, L4i, and L5s) for each spine
- 5 cores obtained at each vertebral surface
- Total number of samples: 100

Diameter: 4.9mm

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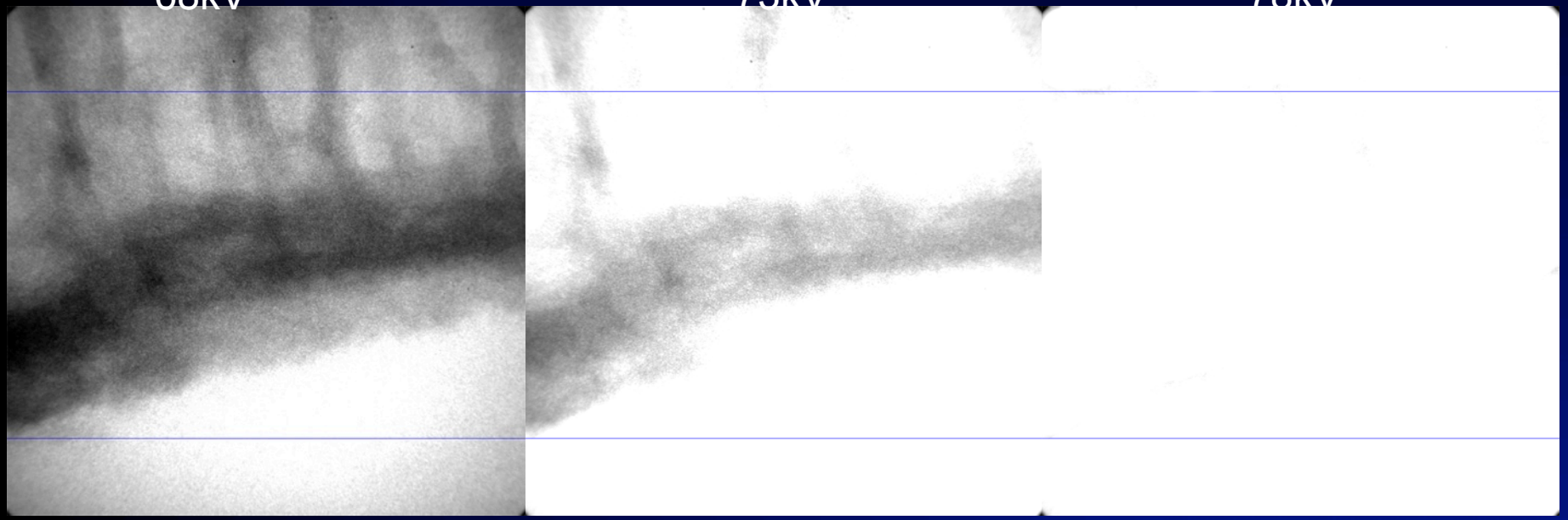
Scoutview Scan

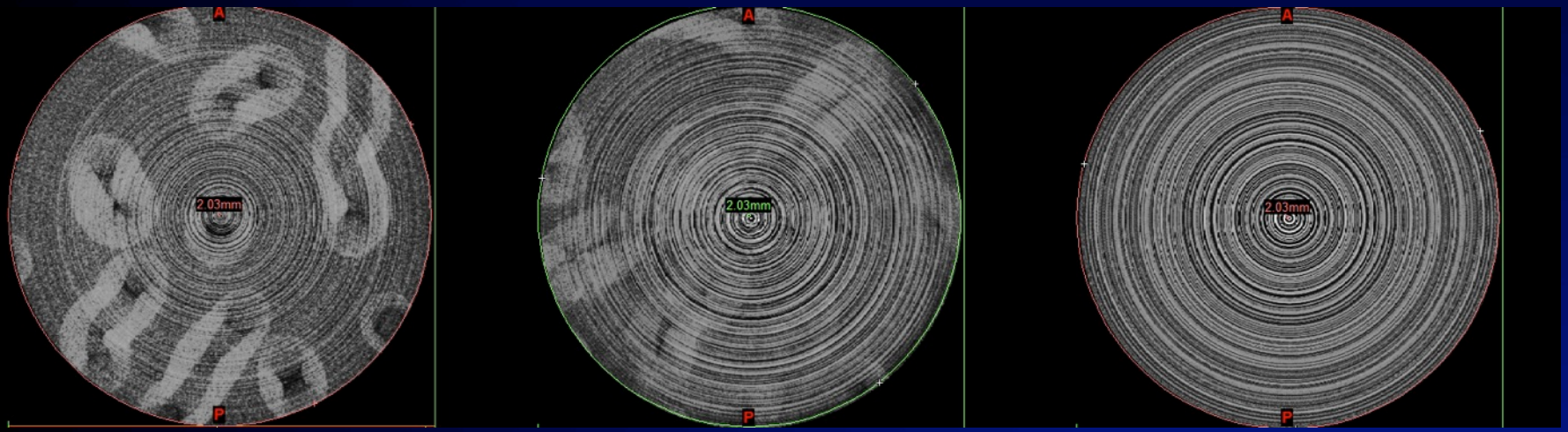


SOD: 10.0mm

SOD: 10.0mm

SOD: 10.0mm

MIMICS (slice)



68kV 73kV 78kV

Settings

Sample used: TS593_L5S_Z

Scan 1	Scan 2	Scan 3
68kV	68kV	68kV
100mA	100mA	100mA
512x512 voxels	512x512 voxels	512x512 voxels
SID: 293.0mm	SID: 293.0mm	SID: 293.0mm
SOD: 10.0mm	SOD: 7.5mm	SOD: 5.0mm
4.35 microns	3.264 microns	2.176 microns
Diameter: 2.2mm	Diameter: 1.66mm	Diameter: 1.1mm

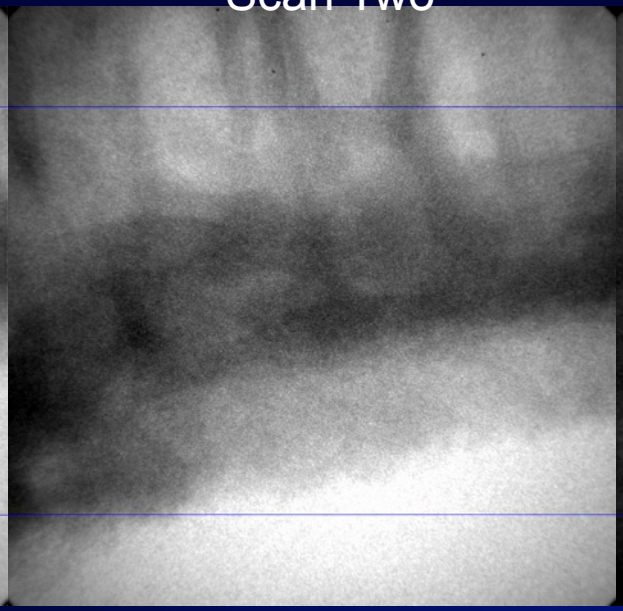
SID: Source to Imagery Distance
SOD: Source to Object Distance

Scoutview Scan

Scan One

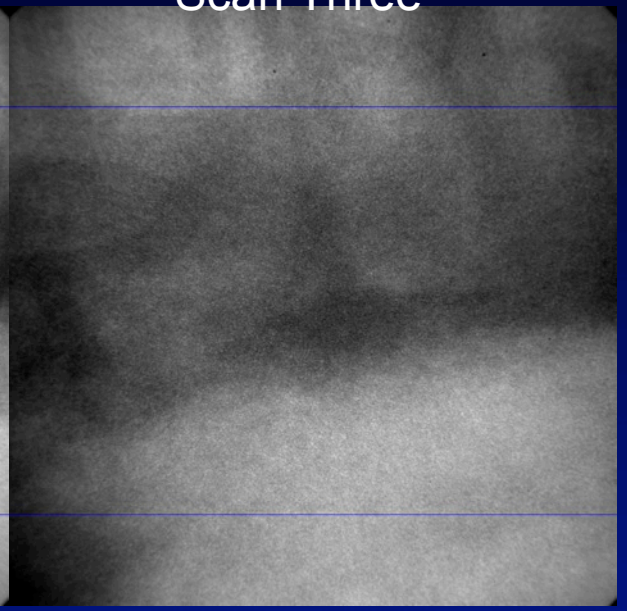
SOD: 10.0mm

Scan Two



SOD: 7.5mm

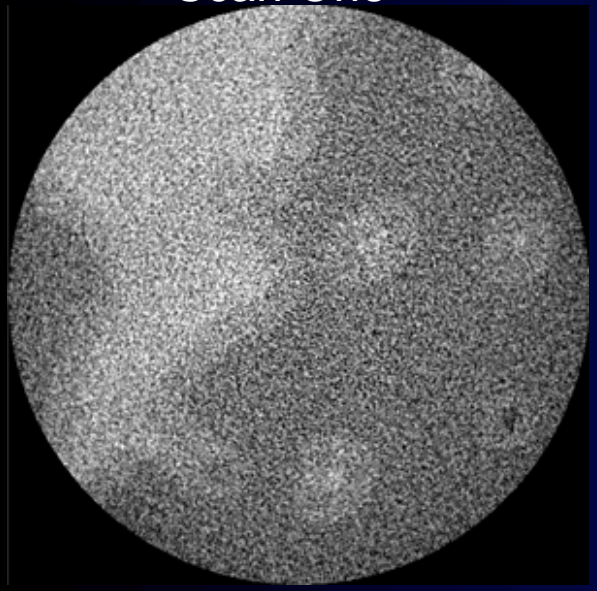
Scan Three



SOD: 5.0mm

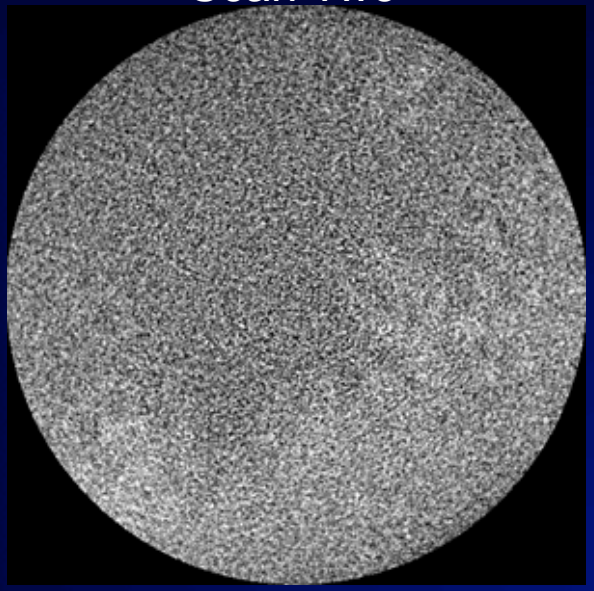
2D CT Scans

Scan One



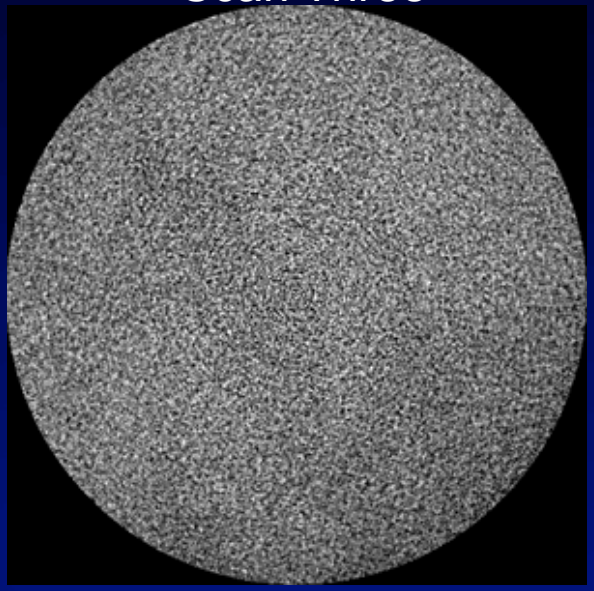
4.351 microns
Diameter: 2.2mm

Scan Two



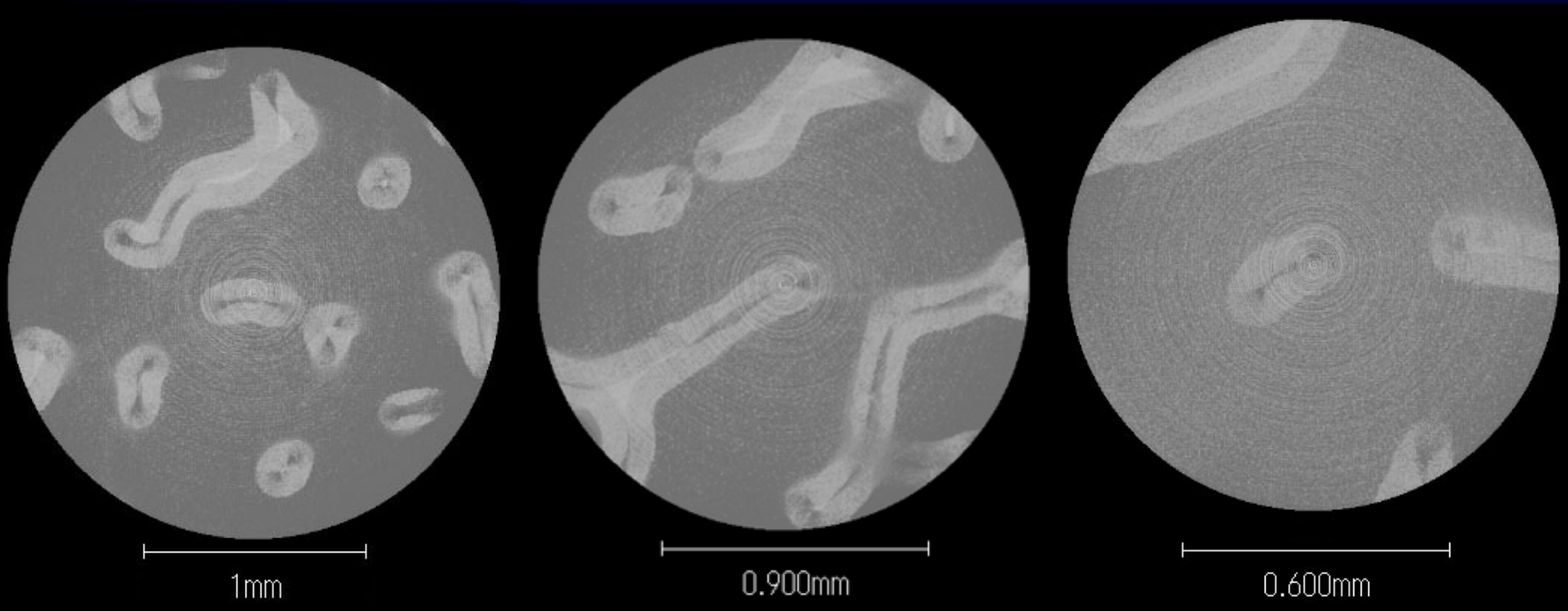
3.264 microns
Diameter: 1.66mm

Scan Three



2.176 microns
Diameter: 1.1mm

3D Bon (Post-Reconstruction)



Scan One
4.351 microns

Scan Two
3.264 microns

Scan Three
2.176 microns

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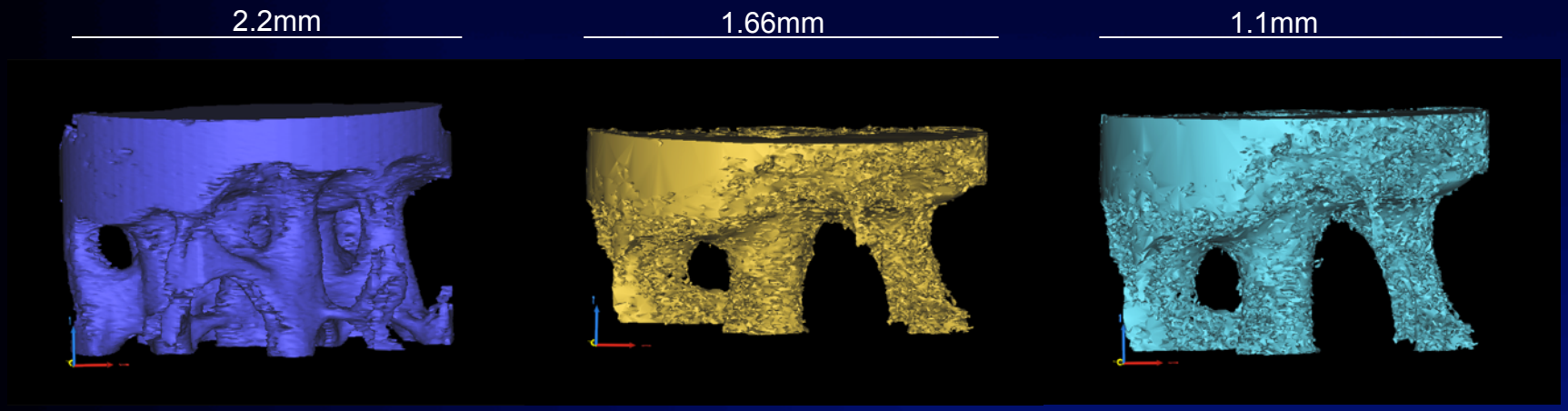
MIMICS (3D Reconstruction)

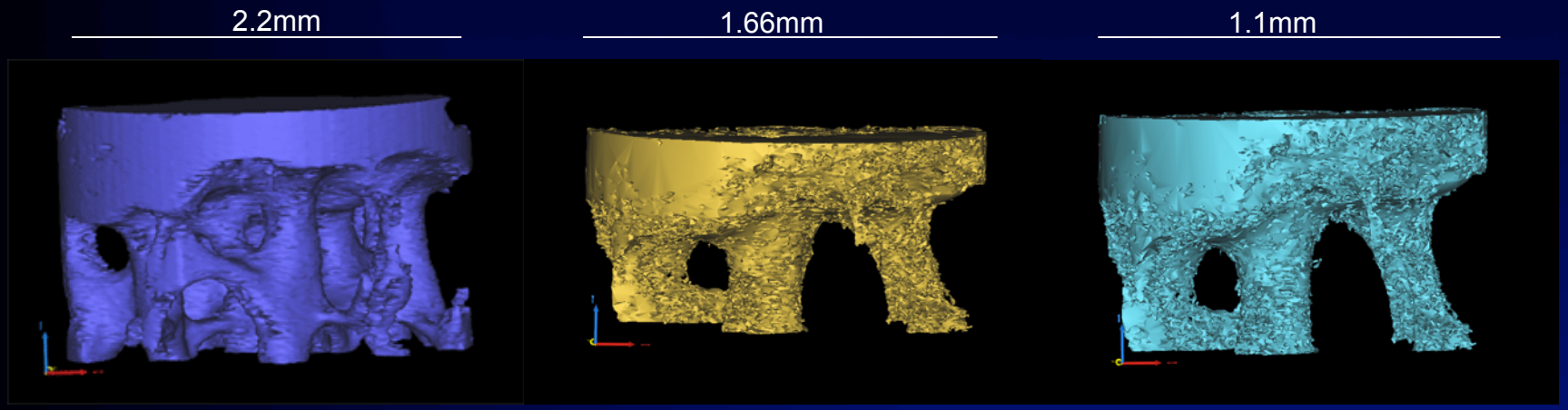


Scan One
Diameter: 2.2mm
4.351 microns

Scan Two
Diameter: 1.66mm
3.264 microns

Scan Three
Diameter: 1.1mm
2.176 microns

MIMICS (3D Reconstruction)

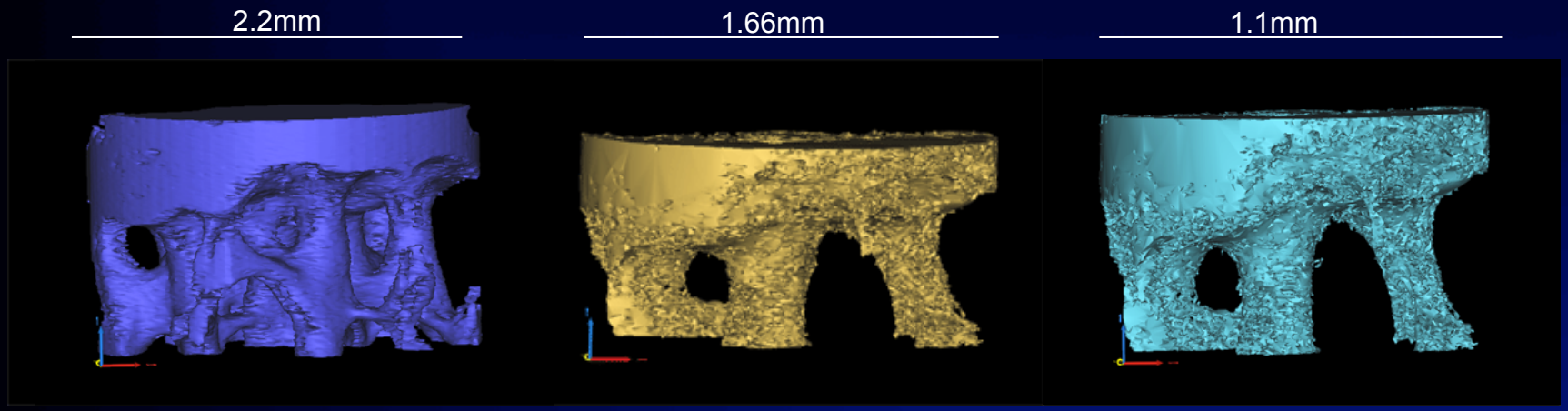


Scan One
Diameter: 2.2mm
4.351 microns

Scan Two
Diameter: 1.66mm
3.264 microns

Scan Three
Diameter: 1.1mm
2.176 microns

MIMICS (3D Reconstruction)



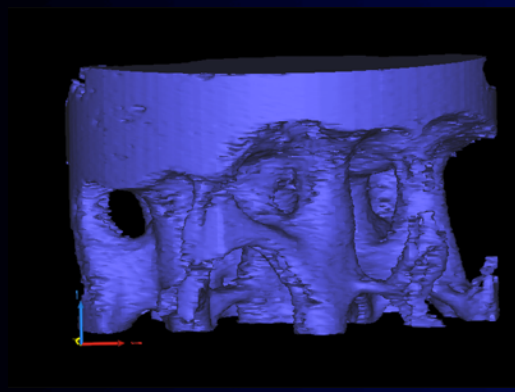
Scan One
Diameter: 2.2mm
4.351 microns

Scan Two
Diameter: 1.66mm
3.264 microns

Scan Three
Diameter: 1.1mm
2.176 microns

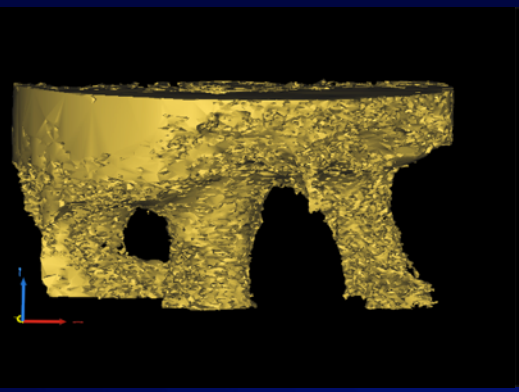
MIMICS (3D Reconstruction)

2.2mm



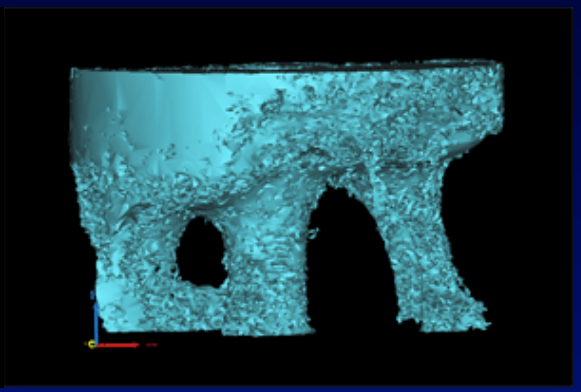
Scan One
Diameter: 2.2mm
4.351 microns

1.66mm



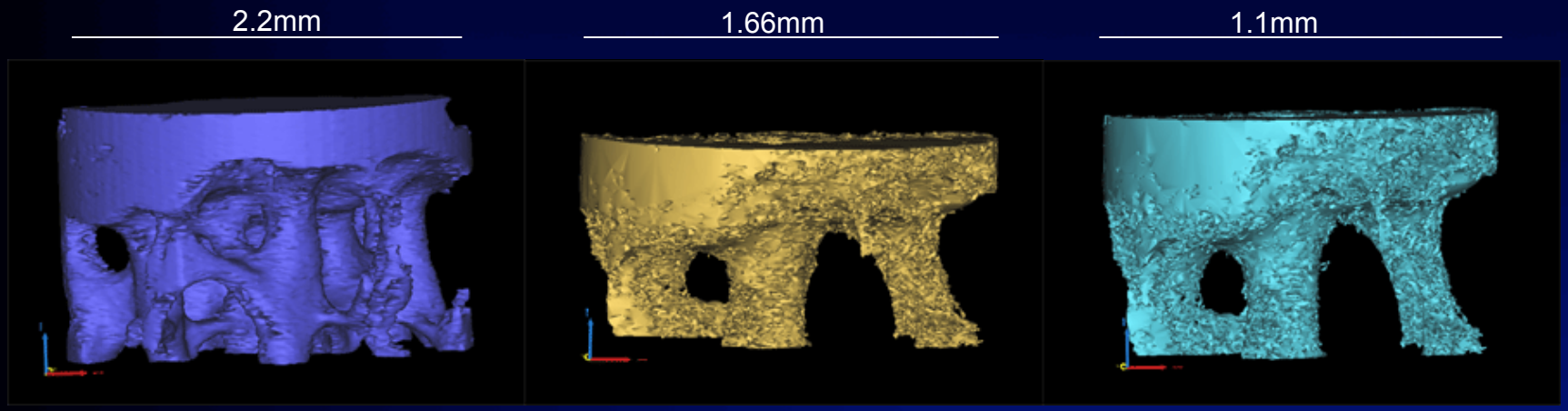
Scan Two
Diameter: 1.66mm
3.264 microns

1.1mm



Scan Three
Diameter: 1.1mm
2.176 microns

MIMICS (3D Reconstruction)



Scan One
Diameter: 2.2mm
4.351 microns

Scan Two
Diameter: 1.66mm
3.264 microns

Scan Three
Diameter: 1.1mm
2.176 microns

Discussion

- Accomplished/Established
  - High resolution scanning of the vertebral endplate
  - Practical resolution needed to visualize the microstructure of the vertebral endplate
  - Simple MIMICS 3D reconstruction
- Future Goals
  - Produce quantifiable data
    - Segment canals in MIMICS
    - Perform surface roughness analysis in MATLAB
    - Correlate to age, location, lumbar level, and disc degeneration

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