Quantifying Stress and Strain in the Canine Sacroiliac Joint using Computed Tomography and Finite Element Analysis

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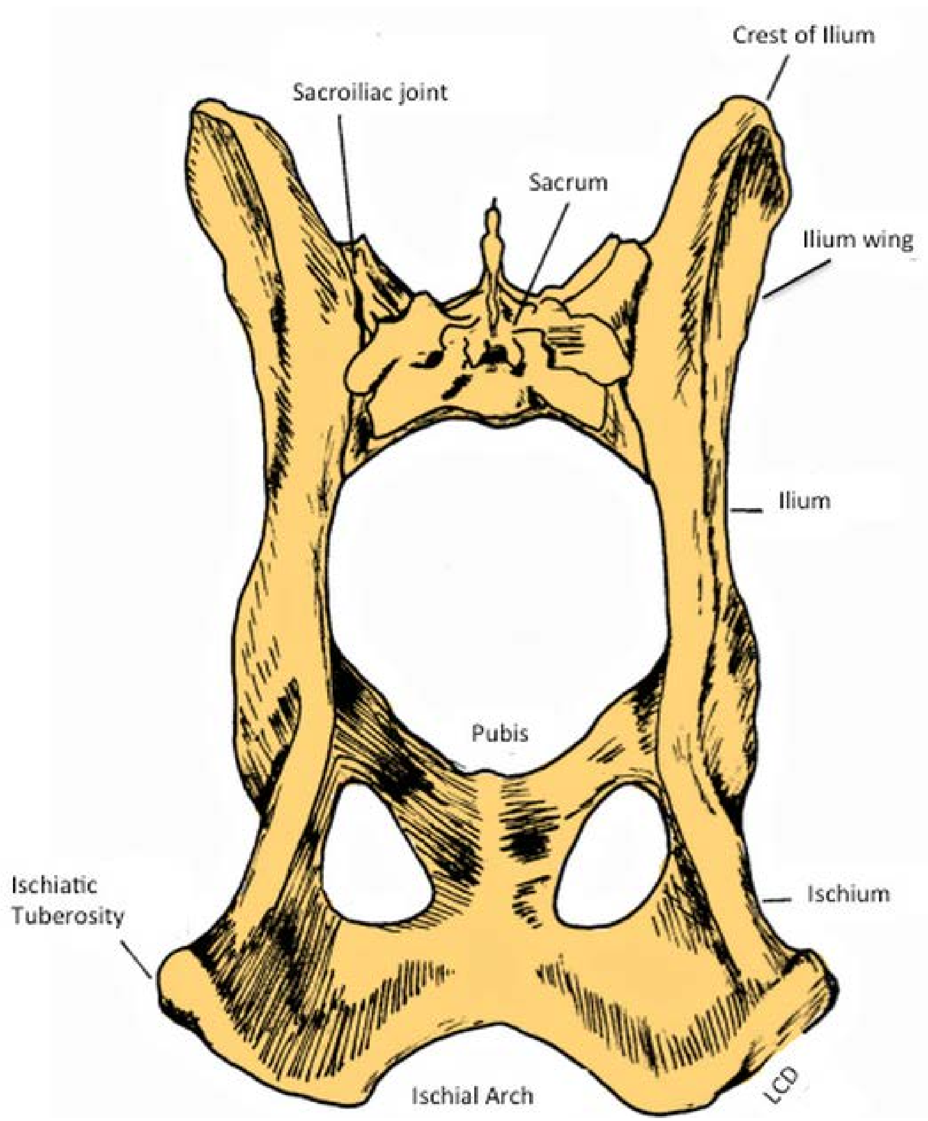
Justification

- Lower back pain can cause performance problems in working dogs (Linn et al., 2013)
- Working dogs undergo repetitive training tasks (Breit and Kunzel, 2001)
  - Assume upright positions
  - Increases weight on sacroiliac joint (SIJ)

https://upload.wikimedia.org/

Justification

- Increased weight on the sacroiliac joint leads to stress and strain in specific areas on the ilium and sacrum (Breit and Kunzel, 2001)
- How can canine SIJ stress and strain be quantified?



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Literature Review

- Finite element analysis (FEA)
  - A complex structure is divided into elements (mesh)
  - Algebraic mathematical calculations are performed on each element
  - Allows for the calculation of change in the structure (example: stress, strain, deformation etc.)

(Engelke et al., 2016)

Literature Review

- FEA of human pelvis using CT scans
  - Different loads were applied on the model and ligament stiffness was measured
  - Comparison of this study to a cadaveric study presented comparable results (Miller et al., 1987)
  - As stiffness in the ligaments increased, the stress at the sacroiliac joint decreased
  - Pelvic ligament laxity could be a significant source of lower back pain

(Eichenseer et al., 2011)

Hypothesis and Objectives

- Hypothesis

  Finite element analysis (FEA) is a feasible technique for quantifying stress and strain in sacroiliac ligaments in the static canine pelvis

- Objective

  Develop a method for conducting FEA in the canine pelvis using computed tomography (CT)

Methods: Subject Selection

- AVS Image Analysis Laboratory data archives
  - A clinically healthy, purebred, large breed dog
  - Multi-slice CT scan DICOM files
    - 0.625 mm slice thickness
    - Reconstructed using bone filter
    - Included entire SIJ and both ischiatic tuberosities
    - Minimal or no degenerative SIJ lesions

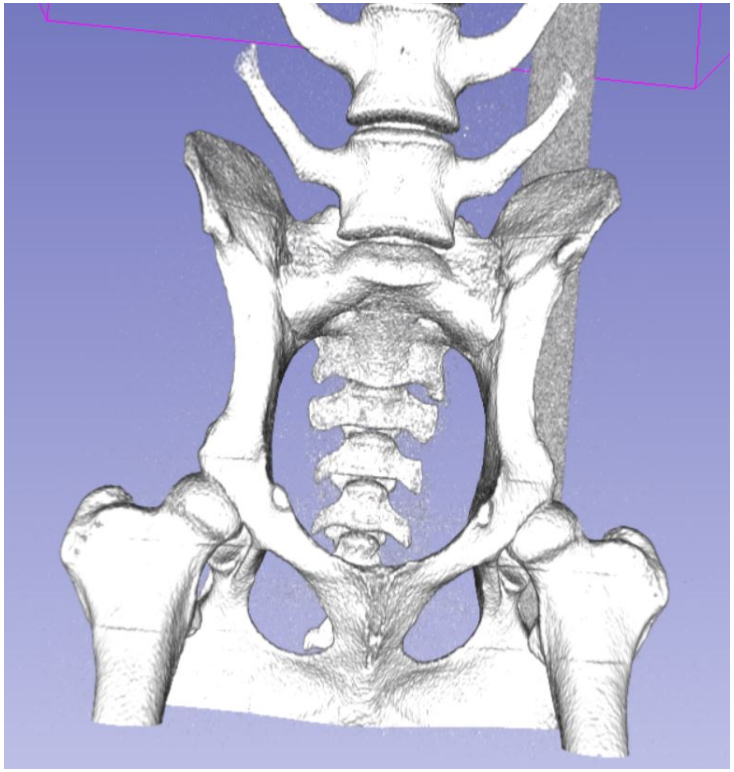
Methods: FEA Technique

- Previously described techniques were adapted using the following software programs (Eichenseer et al., 2011)
  - 3D Slicer
  - ICEM CFD 15.0
  - SolidWorks 2016
  - ANSYS Workbench 15.0

Logos: slicer.org, datakit.com, engineering.com

Results: Subject

- Signalment
  - Labrador retriever*
  - 20 months
  - Female
  - 25 kg



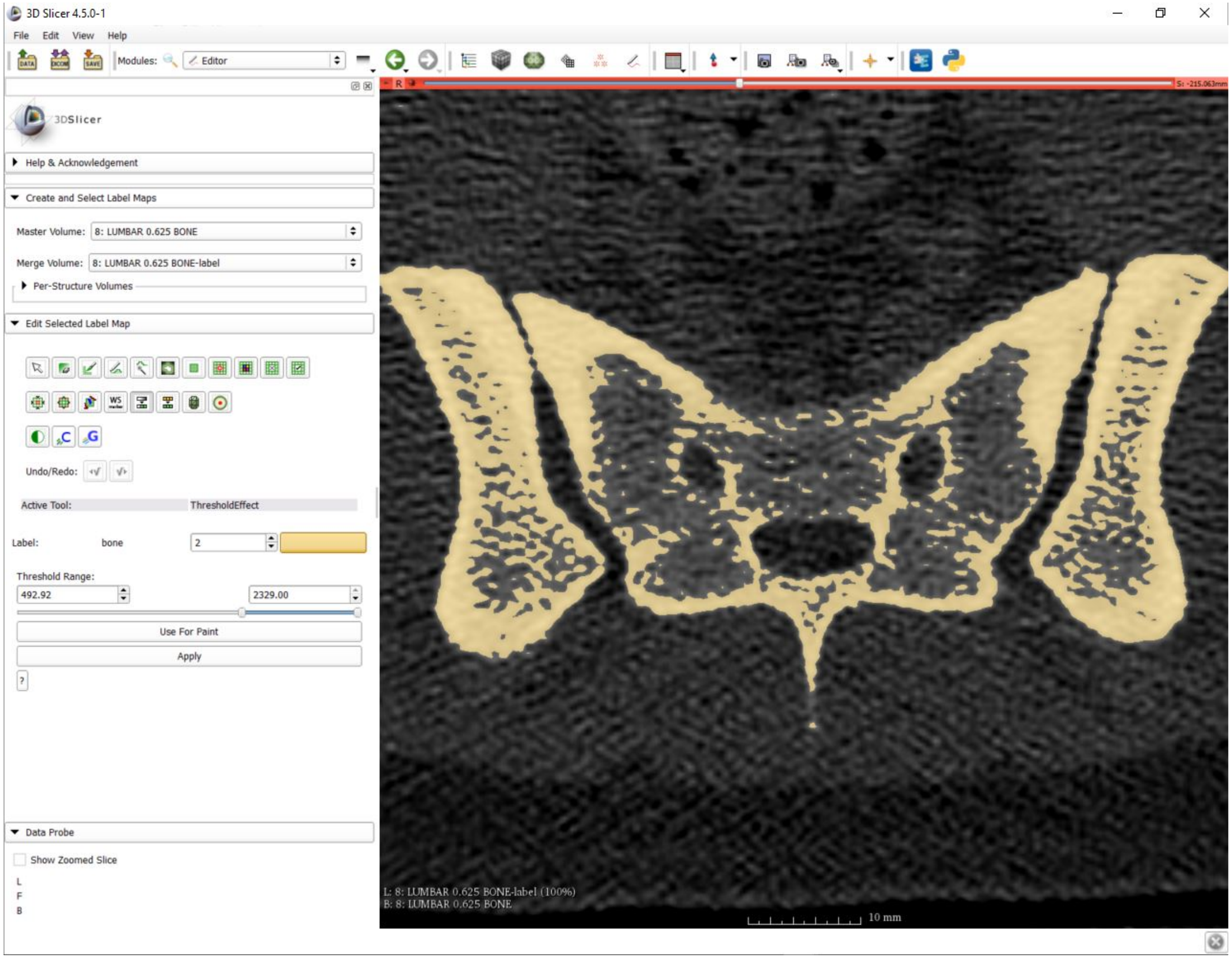
*Mukherjee M, Yao J, Welsh A, Jones J, Holaskova I. Genetic factors associated with lumbosacral stenosis in Labrador retrievers. Poster session of the XXIII International Plant and Animal Genome Conference, Jan. 10-14, 2015. San Diego California.

Results: Subject

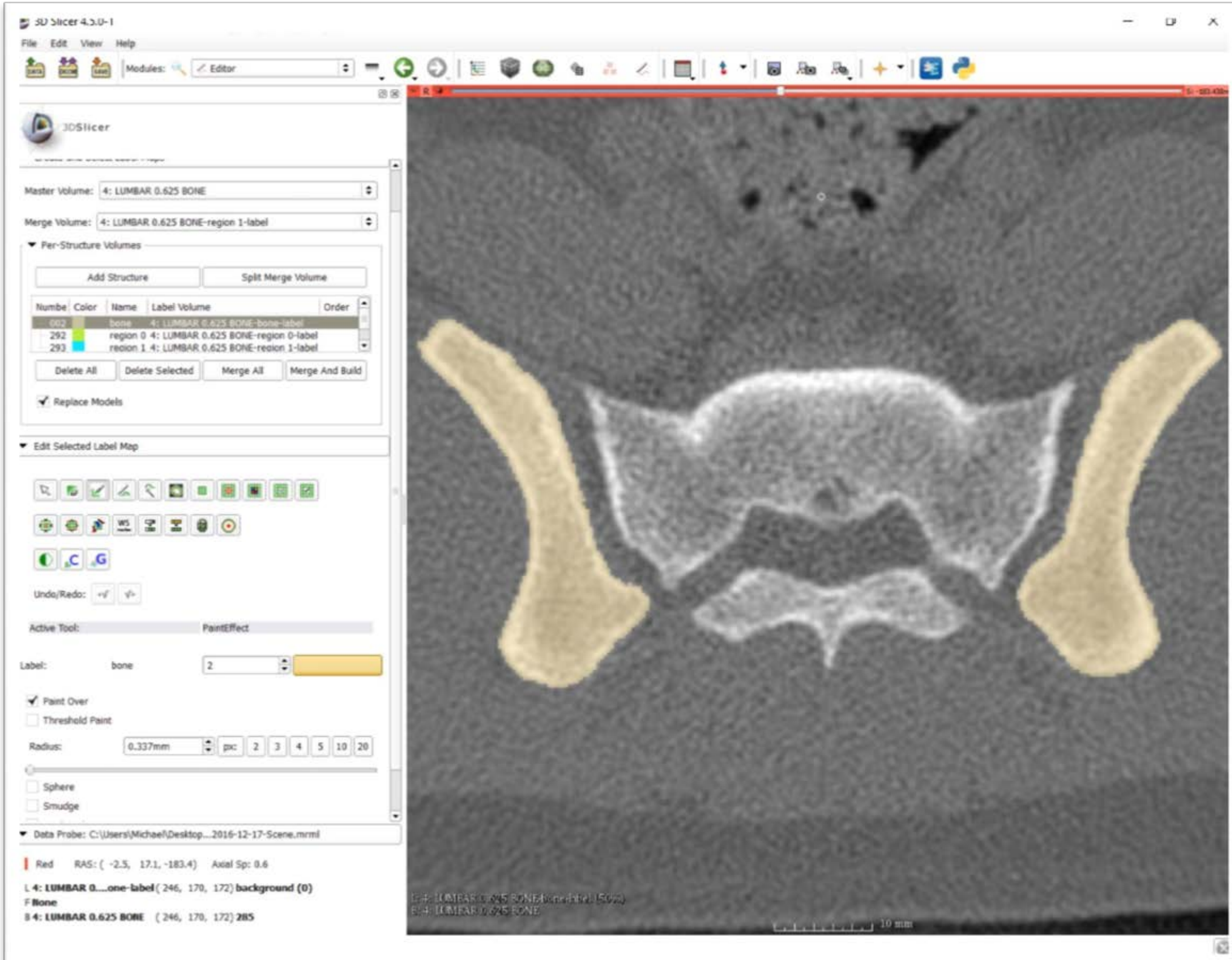
- ❖ CT technical parameters
  - ❖ Scanner = Lightspeed VCT, 32-slice, GE Medical Systems
  - ❖ Positioning = maximally extended hindlimbs, supine, head first
  - ❖ Slice thickness and spacing = 0.625 mm
  - ❖ Scan mode = axial
  - ❖ Matrix = 512 X 512
  - ❖ kVp = 120
  - ❖ Filter type = body
  - ❖ Convolution kernel = bone

Results: FEA Technique

- Segmentation of CT scans using 3D Slicer
  - Ilium
  - Sacrum
  - Cd 1 vertebrae
- Segmentation was completed using threshold effect and manual hand tracing



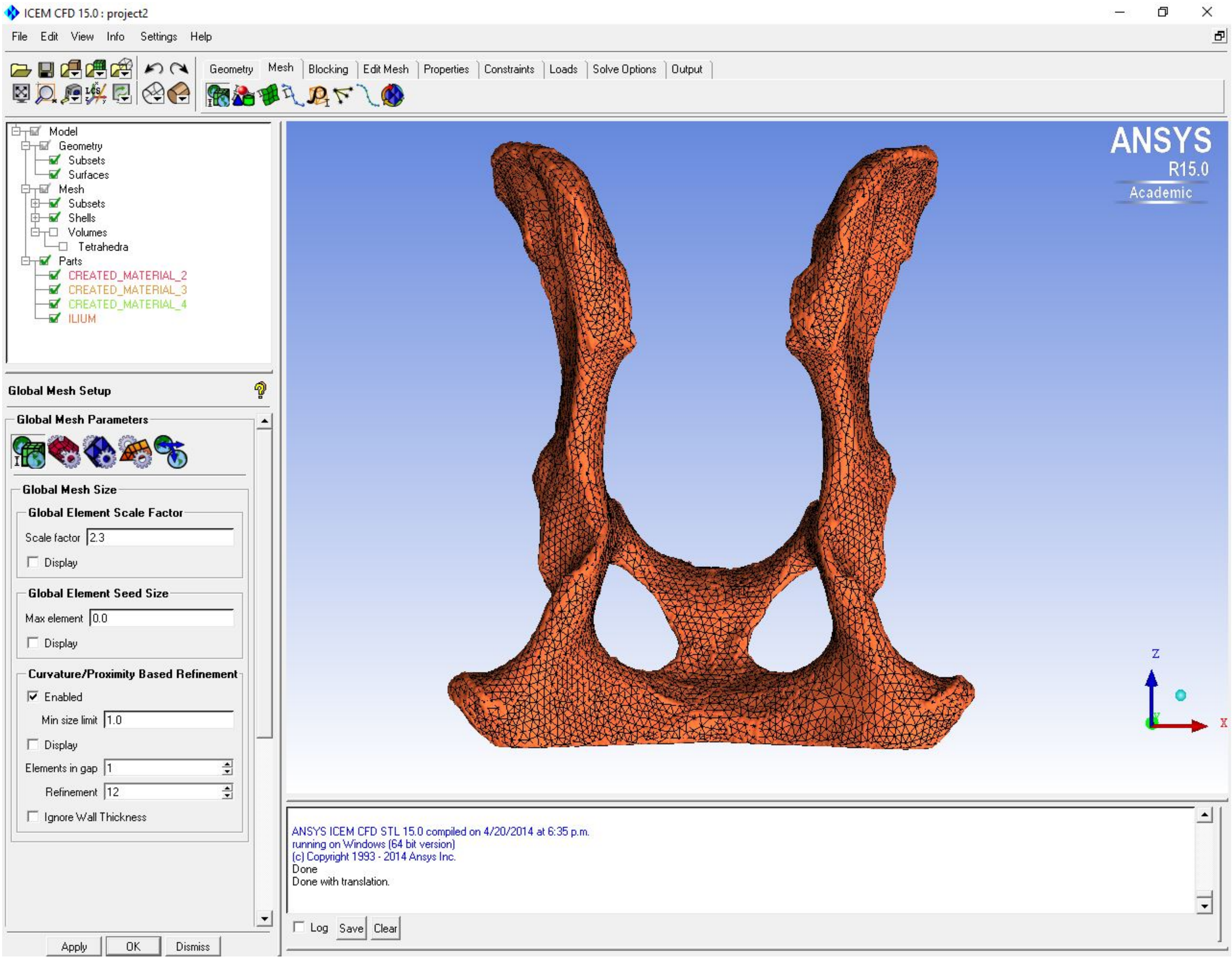
Segmentation, Threshold Effect



Segmentation, Paint Effect

Results: FEA Technique

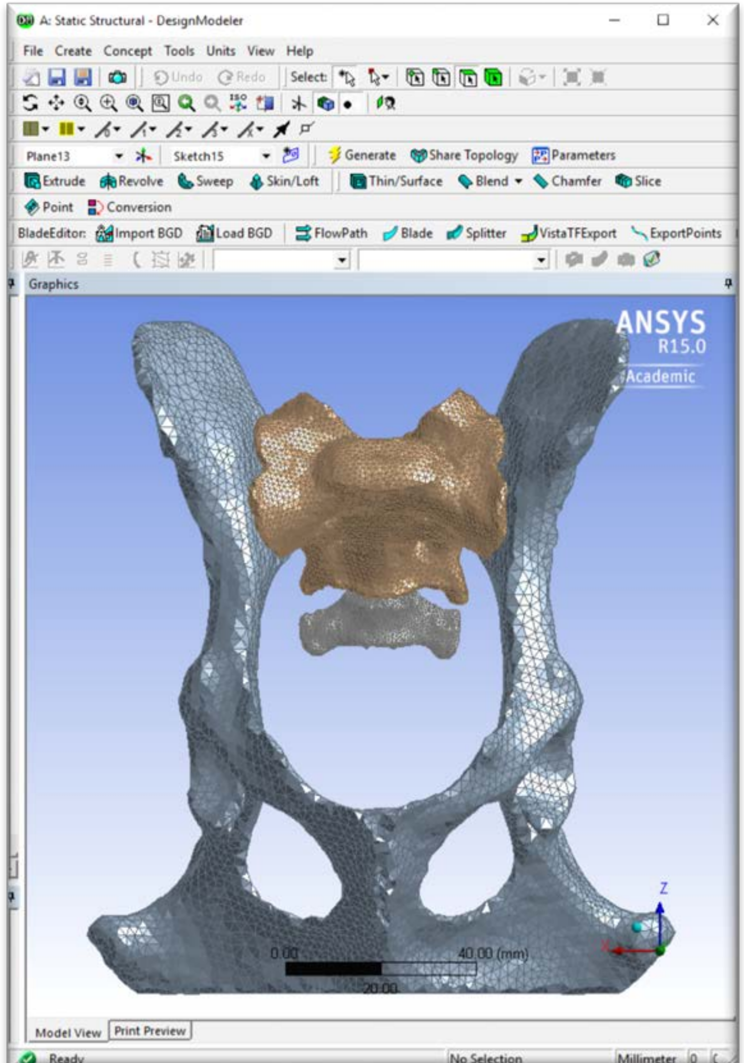
- Individual bone segments were exported as .STL files and saved in folders
- Each .STL file was opened separately in ICEM CFD 15.0 to create a mesh
  - Mesh settings were dependent on size



Mesh of Ilium

Results: FEA Technique

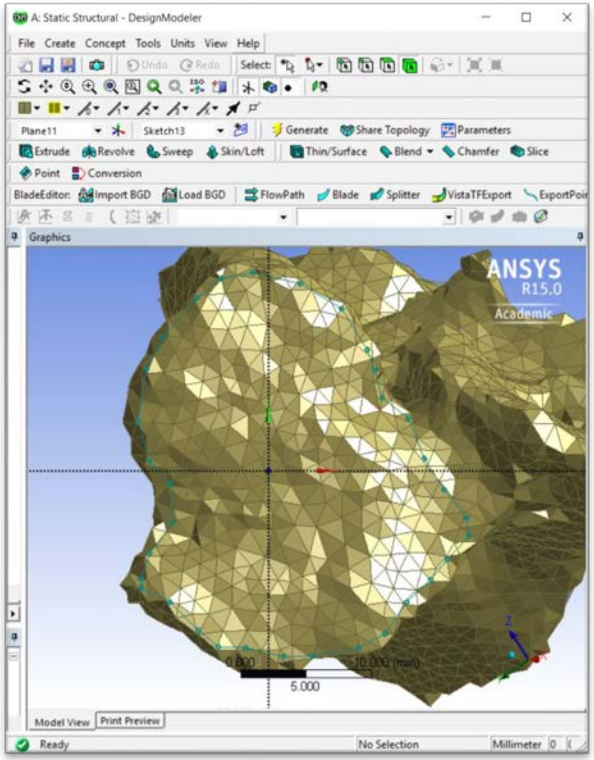
- Mesh was exported to .STL file
- SolidWorks 2016 was opened and .STL was imported and saved as a IGES (.IGS) file
- ANSYS Workbench 15.0 was opened
    - Static Structural Toolbox was dragged into the Project Schematic
- IGES files of each mesh were uploaded into the “Geometry” category

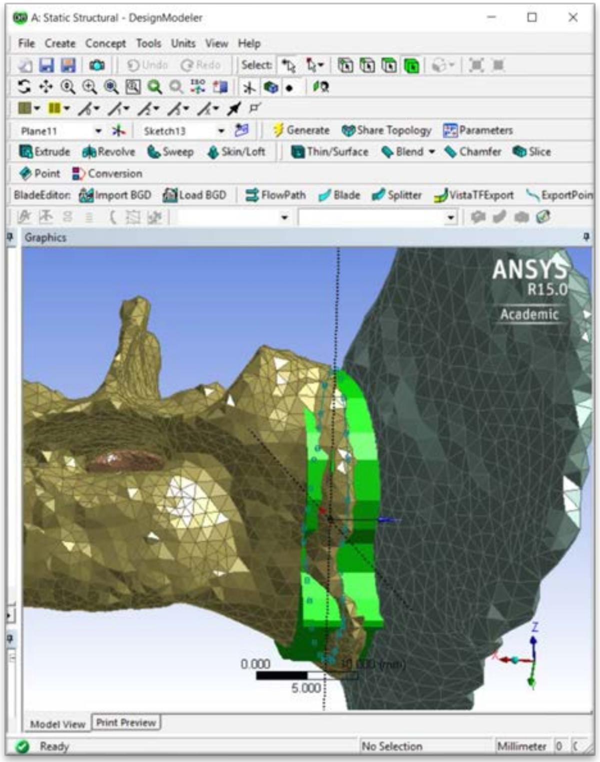


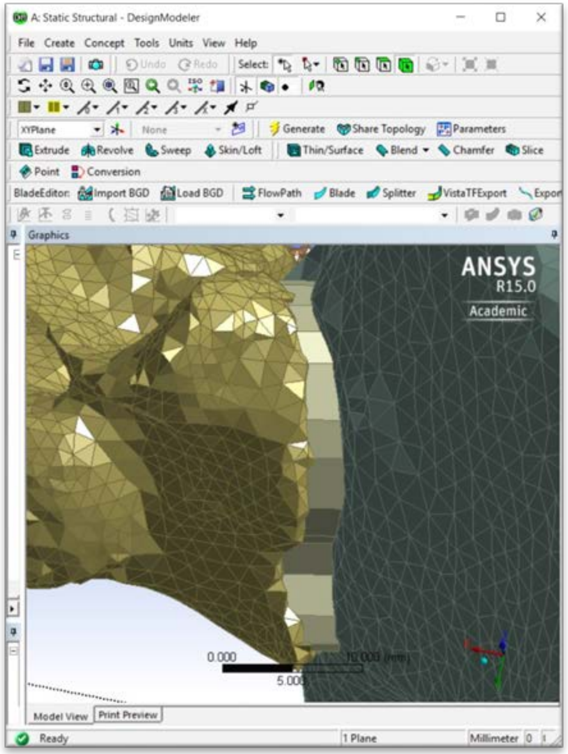
.STL files imported into ANSYS

Results: FEA Technique

- Joint spaces were added to the model

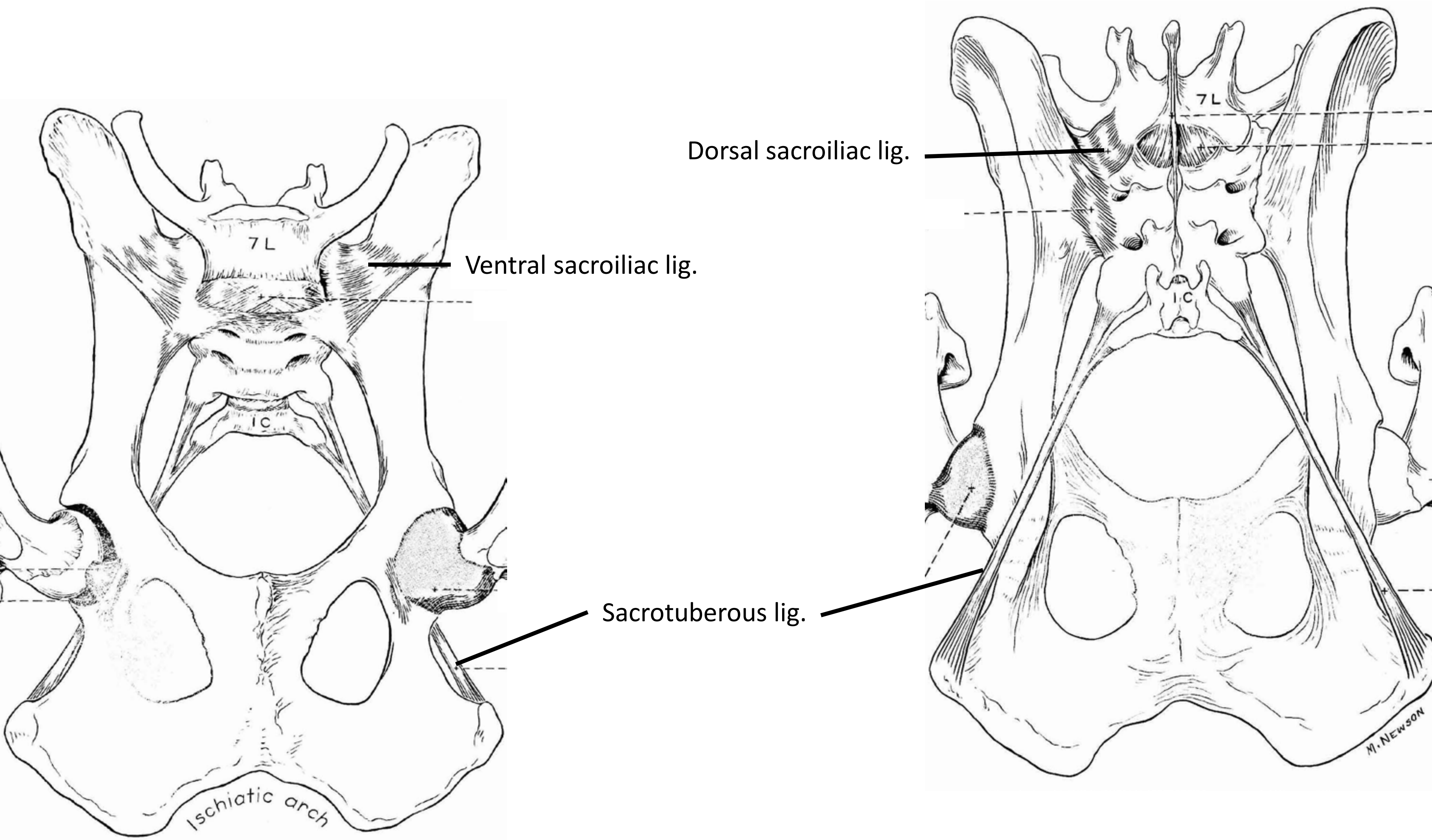




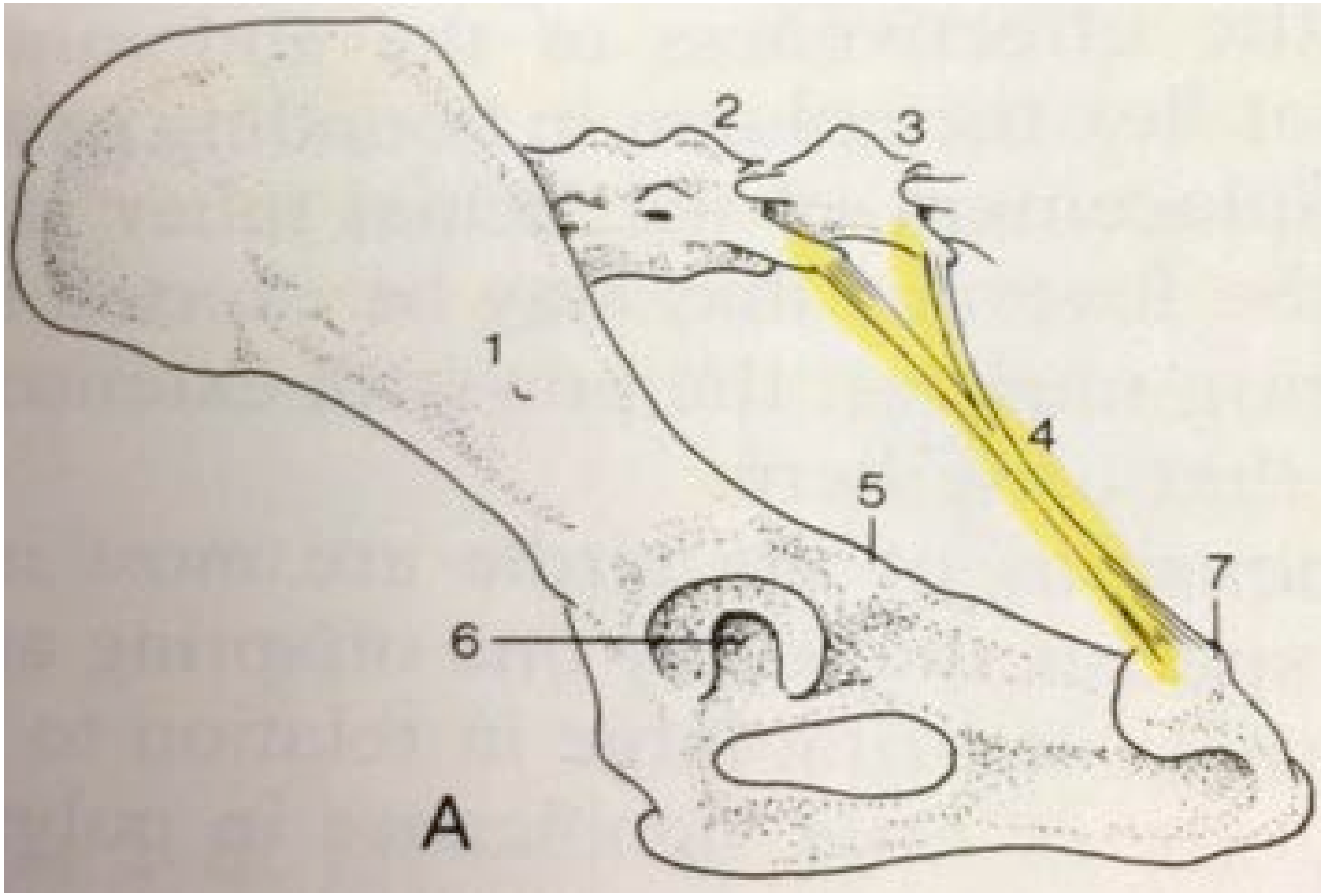


Results: FEA Technique

- Ligaments were manually placed based off figures showing ligament attachment sites (Evans and de Lahunta, 2012)
  - Dorsal sacroiliac ligament
  - Ventral sacroiliac ligament
  - Sacrotuberous ligament
- Ligaments were modeled as non-linear springs

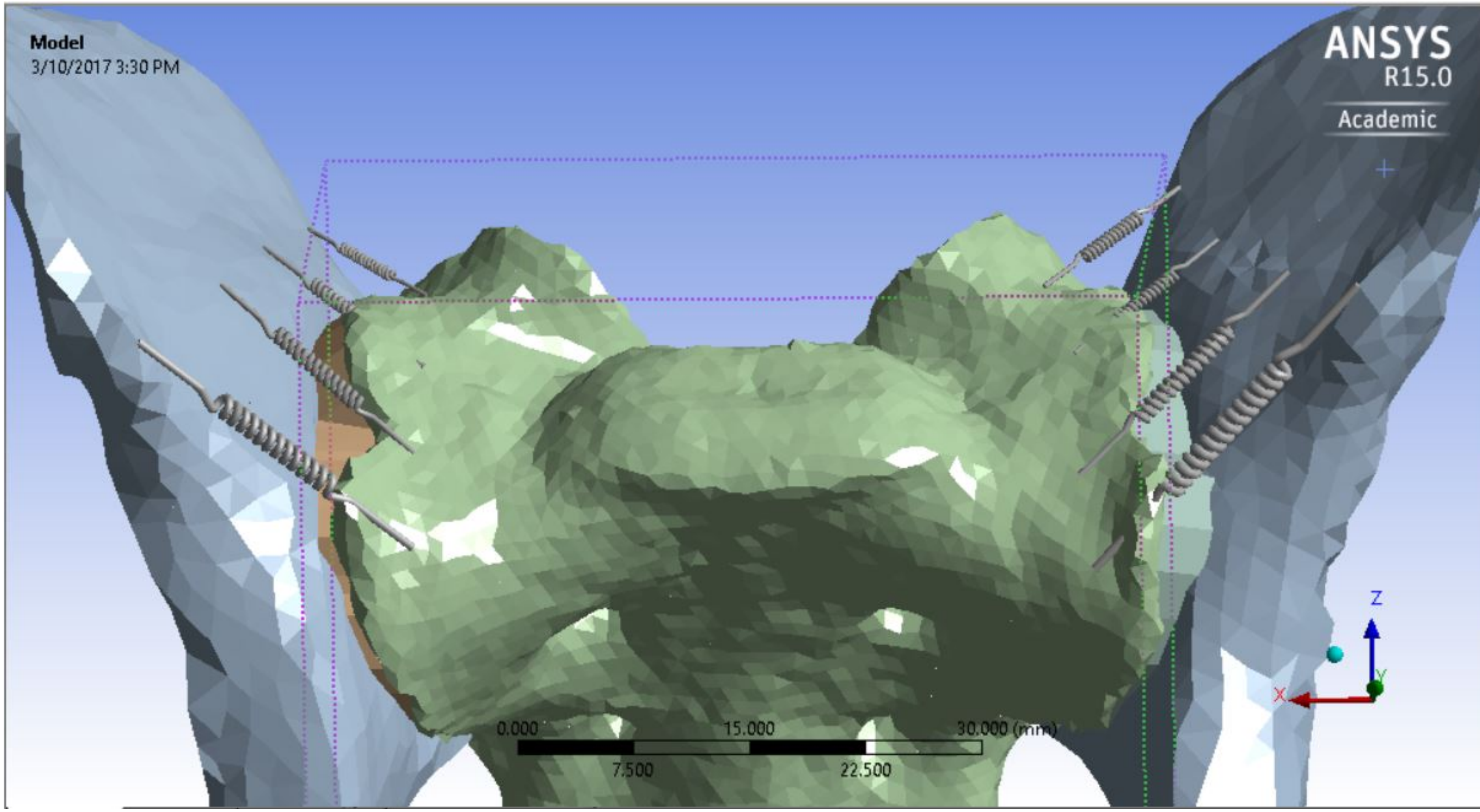


(Evans and de Lahunta, 2012)

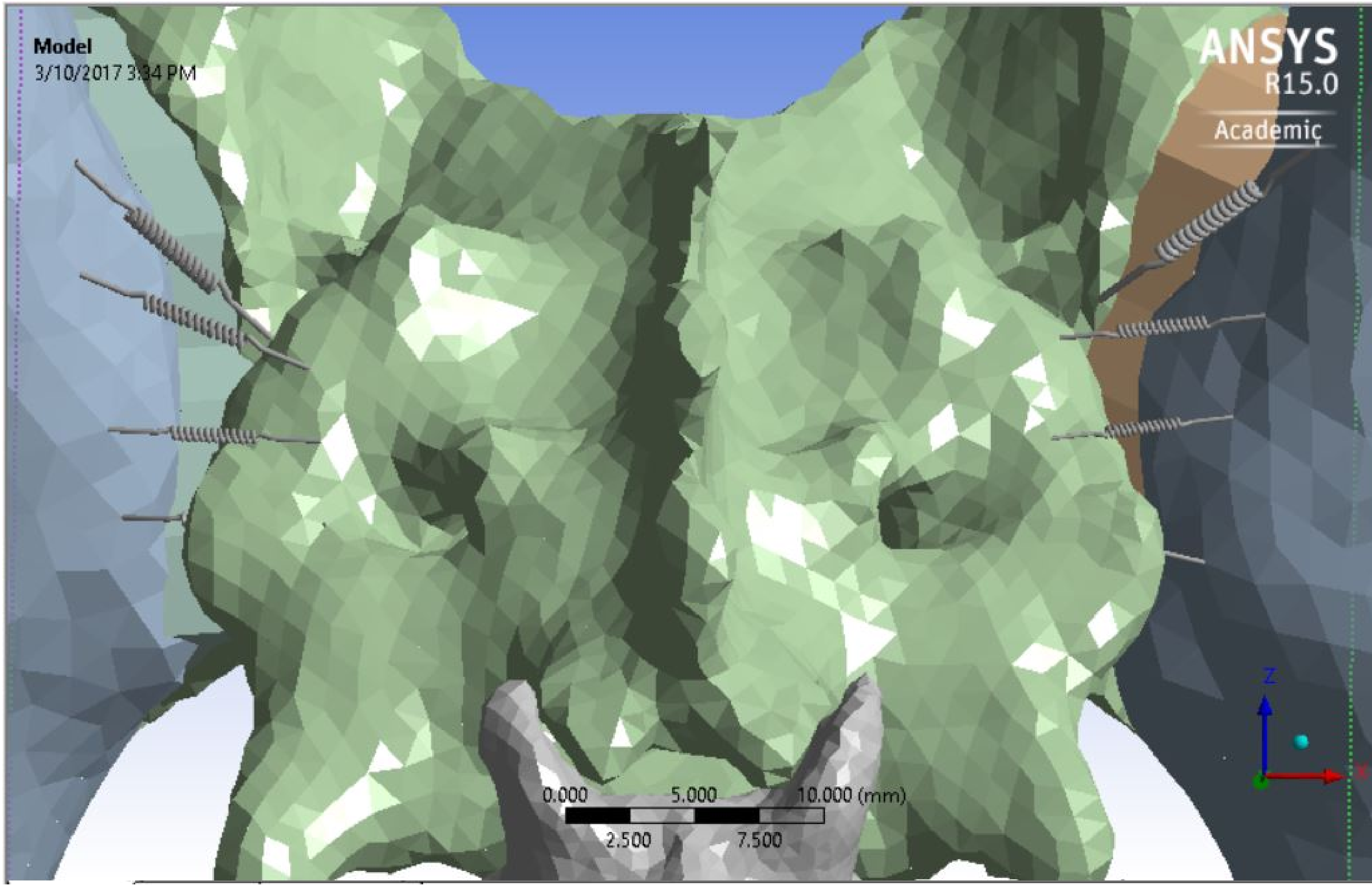


Sacrotuberous ligament

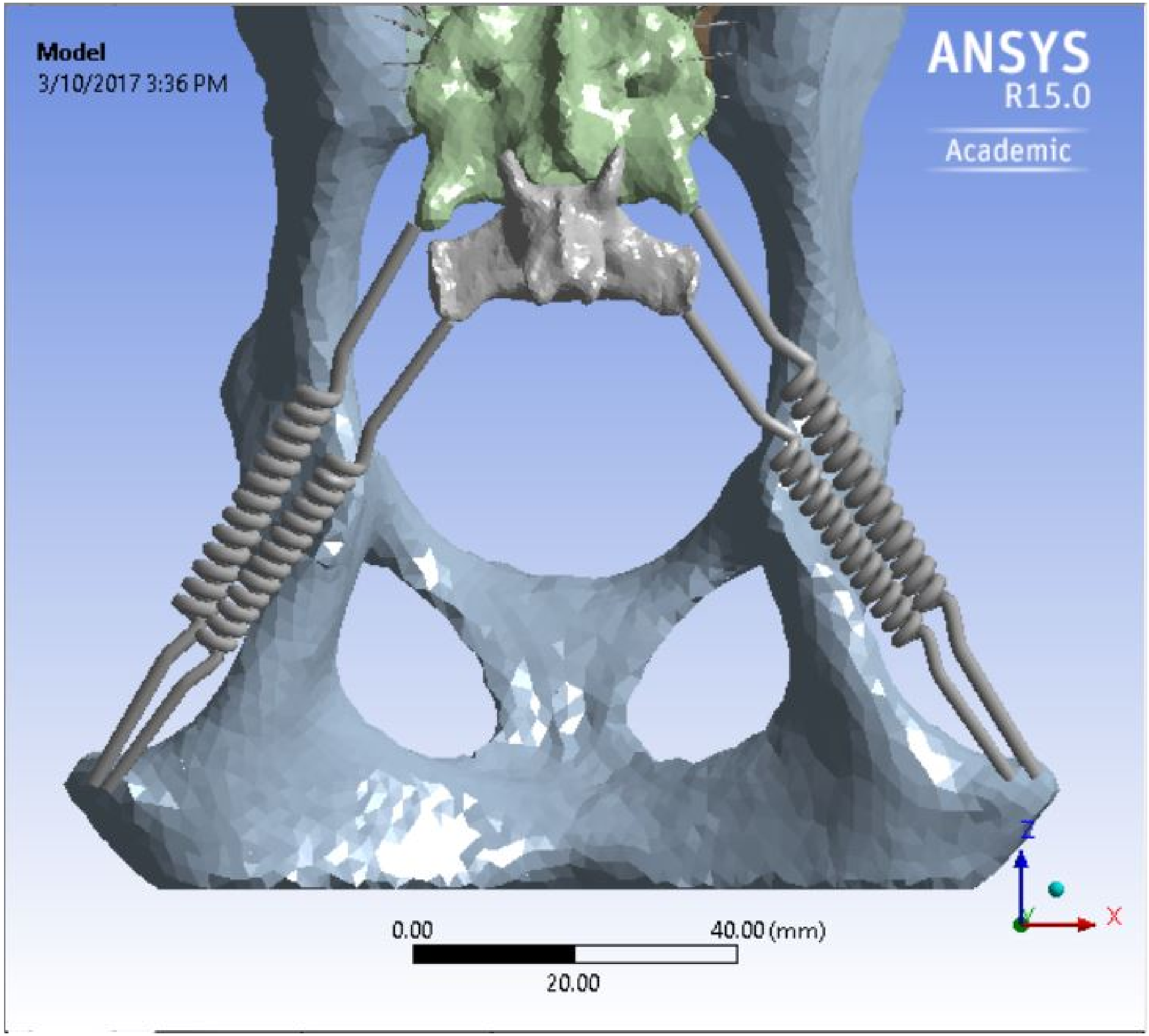
(Evans and de Lahunta, 2012)



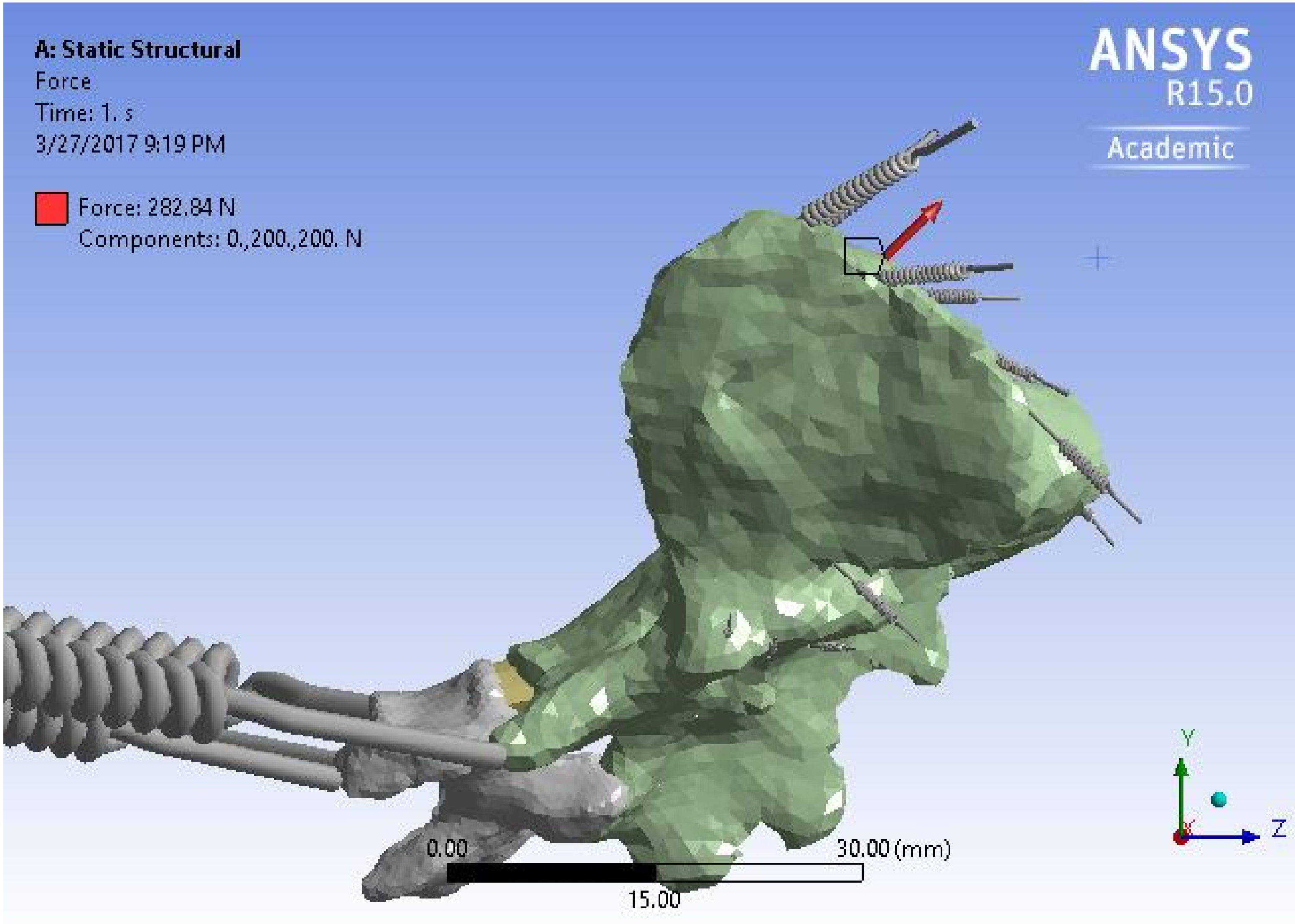
Ventral Ligament Attachment Sites



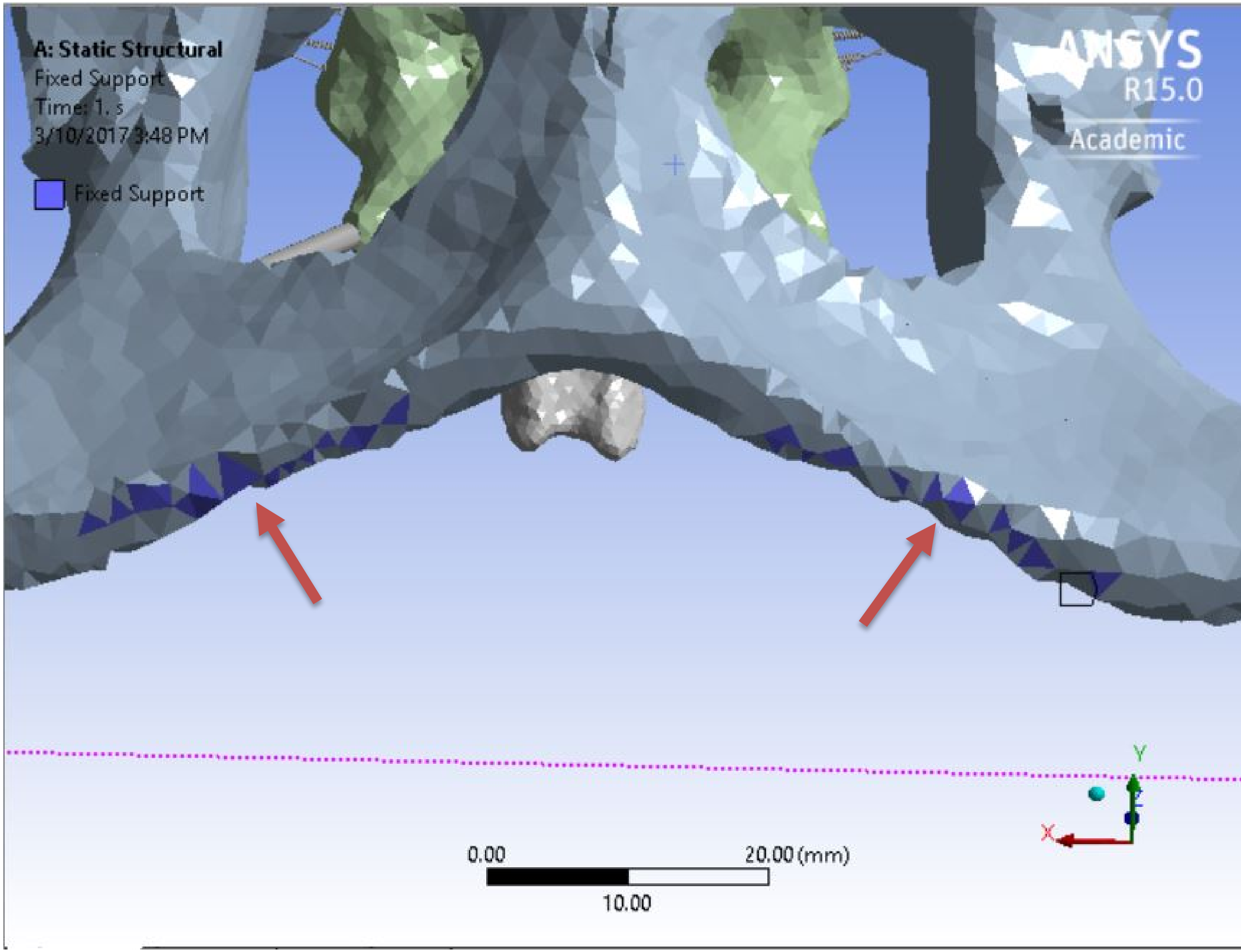
Dorsal Ligament Attachment Sites



Sacrotuberous Ligament Attachment Sites



Force Applied



Fixed Support

Total Deformation

Results: FEA Values

Ligament	Right Side	Strain (%)	Elastic Force (N)
Dorsal SIJ*	Lig. 1	4.72	27.47
	Lig. 2	12.44	80.99
	Lig. 3	7.50	35.31
	Lig. 4	0.56	1.798
Ventral SIJ*	Lig. 1	-4.24	0
	Lig. 2	-7.17	0
	Lig. 3	-10.63	0
	Lig. 4	-8.89	0
Sacrotuberous*	Lig. 1	0.96	30.77
	Lig. 2	0.0095	0.265

*Ligament numbers are from cranial to caudal

Conclusions

- Complete details of methodologies were not available in previous study (Eichenseer et al., 2011)
- There were problems when repeating methodology in ANSYS
- Pilot Study – New method for ANSYS needed to be developed
- FEA can be used to calculate stress and strain values of ligaments in the canine pelvis
- Future studies are needed to validate current study methodology

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