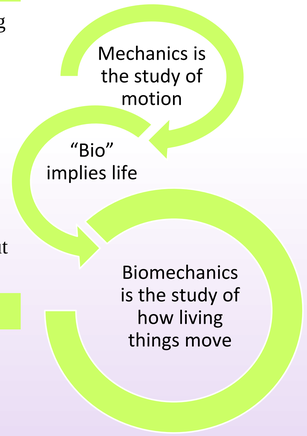
Using Rapid Prototyping to Create an Accurate Model of the Lumbar Spine

Jolene Poulin[1], Nathanial Maeda[2], Jason Carey[2]
1. Vista Virtual School 2. Department of Mechanical Engineering, University of Alberta

Introduction

- Treatments for spine injuries or maladies exist with varying degrees of success
- A model of the human lumbar spine was created to better understand its mechanics
- This model will be used to improve upon the following treatment processes:
  - Bracing for scoliosis
  - Spinal manipulation therapy
  - Spine related surgery
- Models similar to this one have been created in the past, but none were used for this purpose



Objective

Create the intervertebral (IV) disc for a lumbar spine model using 3D printed materials that have been tested for model accuracy.

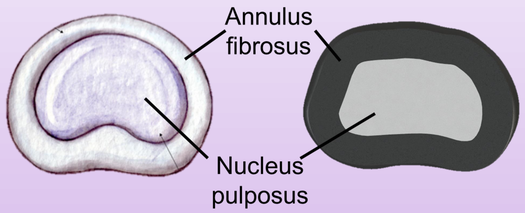


Figure 1 – Comparison of a model of an intervertebral disc (left) next to the model created using computer software (right). Refer to source 1.

Methods – Spine Model

1. The IV disc was modeled in SolidWorks 2014 based on vertebrae previously created in SimpleWare. See Figure 2 for an image of the software model.
2. Individual pieces of the model were printed using MakerBot Replicator 2 Desktop 3D printers. See Figure 3.
3. The model was assembled using rubber cement. See Figure 4 for an image of the completed model.

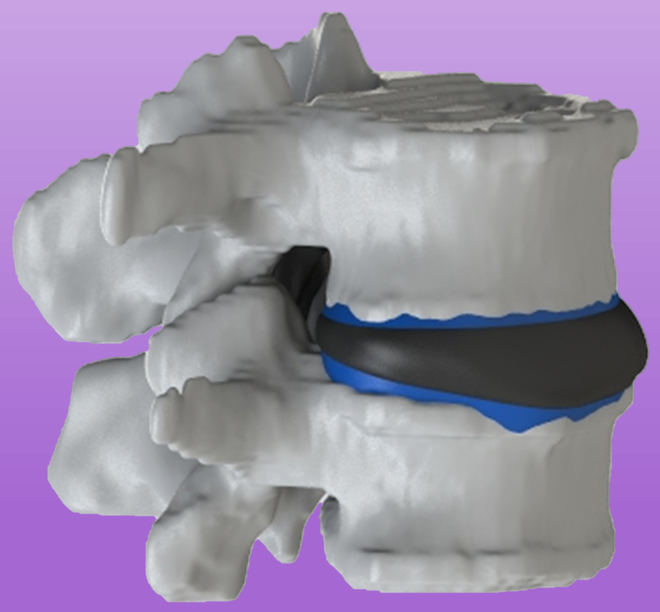
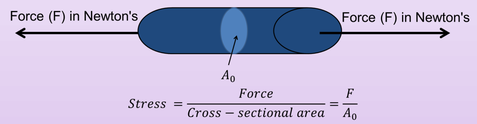


Figure 2 – The software model of lumbar vertebrae L4 and L5 with the completed intervertebral disc.

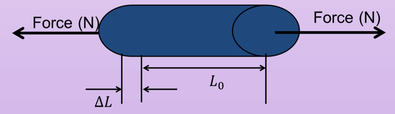
Methods - Testing

- Three materials were available to use when printing the model:
  - *NinjaFlex* brand thermoplastic elastomer
  - *SemiFlex* brand thermoplastic elastomer
  - Polylactic acid (PLA)
- Tensile tests were run on these three materials using the MTS Synergie 400 machine. All samples were printed using the MakerBot printers.
- Each material was loaded until it failed. Failure was noted as one of the following points:
  - When the sample broke
  - When the sample slipped from the machine's grips
- The machine recorded values for the following:
  - Force applied to the sample, measured in Newtons (N)
  - Extension, in millimeters (mm), of the middle section of the samples
  - Time, in seconds (s), measuring the duration of the test
- Values for stress (MPa) (Figure 5-a) and strain (mm/mm) (Figure 5-b) were calculated using Microsoft Excel 2010



$$Stress = \frac{Force}{Cross-sectional\ area} = \frac{F}{A_0}$$

Figure 5-a – The equation for the stress of an object



$$Strain = \frac{Extension}{Original\ length} = \frac{\Delta L}{L_0}$$

Figure 5-b – The equation for the strain applied to an object

Results - Testing

Material	Maximum Extension (mm)	Maximum force applied (N)
NinjaFlex	132	121
SemiFlex	180	247
PLA	1.30	428

Table 1 - A summary of the results from the tensile tests

- NinjaFlex was most flexible. It best ressembled the nucleus pulposus.
- Semiflex was elastic while being strong. It most ressembled the annulus fibrosus.
- PLA had the most plastic properties. It best ressembled the vertebrae and the cartilage endplates

Figure 3 – The individual pieces of the lumbar model. In blue: the cartilage endplates. In black: the annulus fibrosus. In white: the two vertebrae and the nucleus pulposus. Individual parts not to scale.

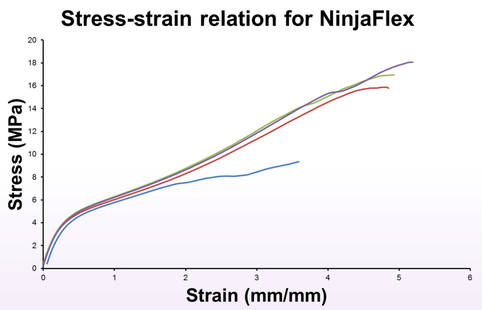


Figure 6-a – Stress-strain relation for NinjaFlex samples

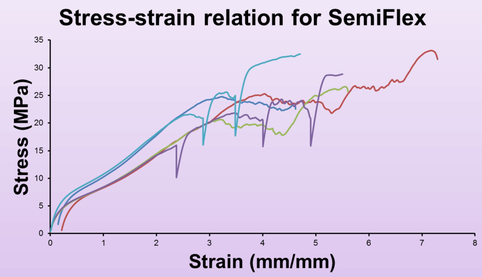


Figure 6-b – Stress-strain relation for SemiFlex samples

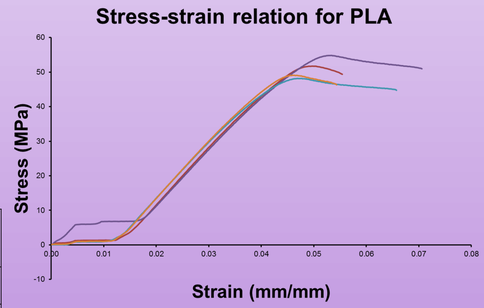


Figure 6-c – Stress-strain relation for PLA samples. Outlying samples were excluded from analysis.

Conclusion

- The pieces of the model were printed after confirming the tensile properties of the different materials. See Table 2 for the composition of the model.
- A model of the lumbar spine was created using rapid prototyping (3D printing)

Item	Material used in model
Vertebrae	PLA
Cartilage endplates	PLA
Annulus fibrosus	SemiFlex
Nucleus pulposus	NinjaFlex

Table 2 - Composition of the spine model.

Literature cited
1. *Spinal Anatomy: Intervertebral Discs.* University of Virginia Health Center - Spine Center. Online. http://www.uvaspine.com/intervertebral-discs.php . Viewed Aug. 6 2015.

Acknowledgements

This research project was made possible with the help of:
- WISEST Summer Research Program
- University of Alberta
- Alberta Innovates Health Solutions
- Jason Carey, Nathanial Maeda, Jonathan Schofield, Benjamin Cheung, Alexander Hunt

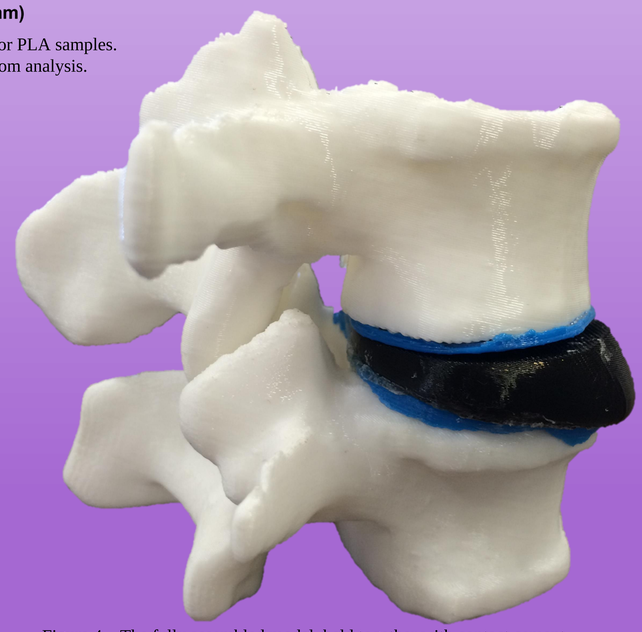


Figure 4 – The fully assembled model, held together with contact cement.