Design of a System to Study Human Disc Strains in Torsion and Compression Measured Noninvasively

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Agenda

• Intervertebral Disc
  – Functions
  – Anatomy
  – Disc Degeneration

• Previous Studies

• Objectives

• Design Process

• Protocols
Intervertebral Disc

- Spine is made of repeating segments
  - Vertebrae
  - Intervertebral discs (IVDs)
- IVDs purpose:
  - Shock absorber
  - Pivot point
  - Distribute stress

http://www.zimmerindia.com/z/ctl/op/global/action/1/id/7753/template/PC/navid/7590
Disc Anatomy

- **Annulus Fibrosus (AF)**
  - Composed of layers of collagen fibers known as lamellae

- **Nucleus Pulposus (NP)**
  - Gelatinous
  - Enclosed by the annulus fibrosus
Disc Degeneration

- **Structural changes**
  - NP loses fluid
  - Becomes semi-gelatinous
  - Tears in the AF
- **Advanced signs of aging**
- **Pain**
Previous Studies

- **Farfan et al 1970**
  - Failure of joints
    - Non-degenerative discs: 8.81 Nm, 22.6°
    - Degenerative discs: 5.38 Nm, 14.3°

- **McGlashen et al 1987**
  - Average angle displacements at 15.7 Nm
    - Non-degenerated, intact: 3.38°, (1.03°)
    - Non-degenerated, isolated: 9.27°, (3.23°)

- **Haughton et al 1999**
  - Non-degenerated discs stiffness was twice that of degenerated discs
Limitations of Previous Studies

- Physical Markers
  - Move separately from the tissue
  - Disrupt the structural integrity
  - Alter the deformation of the disc
- Non-weight bearing studies
  - No compressive force
- Strain was not quantified
Objective

• Entire Project:
  - To quantify strain in normal and degenerated human lumbar IVD due to torsion and compression, measured noninvasively using a combination of MRI and ANTS (advanced normalization tools).

• Summer Project:
  - To design a device that is MRI compatible and will load the specimen in torsion and compression, simultaneously.
Criteria

- MRI compatible torque & compression load cell
  - Cooper Instruments: LXT-900
- MRI compatible hydraulic cylinder (linear motion)
  - Clippard Minimatic: URR-17-1/2
- MRI compatible rotary actuator
  - BIMBA
- No metal components within ~8” of the specimen
Preliminary Design

- Delrin and PVC plastic
- T-slot grips
- Minimize bending moments
  - Bearing supports
Preliminary Design

- Mimics current compressive device

- Issue:
  - Delrin rod would be loaded in tension
Design

• Current Design
• Issues:
  – Exact dimensions are unknown
    – Will be determined by MRI testing
Design Grips
Protocol

- **Constant compressive load, 750 N**
  - Average disc area: 1560 mm$^2$
  - Desired Stress: 0.48 MPa

- **Displacement control will be used for the torsion**
  - $2^\circ$, $4^\circ$, and $6^\circ$
    - Common displacements *in vivo*
Preliminary Tests

- Stress Relaxation
  - Bovine tail specimen
  - 365 N compressive force
  - Incremental rotations: 2º, 4º, and 6º
Conclusions

• The Design
  - Exact dimensions are unknown

• Testing Protocol
  - Late-stage development
Thank You

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Thank You

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NIAMS
National Institute of Arthritis and Musculoskeletal and Skin Diseases