Orthopedic Device to Prevent Lumbosacral Stenosis in Military Working Dogs

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WPI Project Presentation Day
Significance: Military Background

- United States military currently trains over **500** dogs per year\(^1\)
- Cost to maintain each dog is about **$11,000** per year\(^1\)
- Nearly **70** dogs are retired per year due to injury in the spine\(^2\)
- **Lumbosacral Stenosis** accounts for most of the injury based retirement because of actions during work

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Lumbosacral Stenosis\textsuperscript{3,4}

- **Causes**
  - spinal canal stenosis or vertebral malformations, disc protrusion, ligament hypertrophy, and lumbosacral instability

- **Symptoms**
  - difficulty rising, reluctance to jump or climb stairs, limb lameness, lumbosacral pain, urinary dysfunction

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Background: Lumbosacral Stenosis

• Current Surgical Treatments
  – L7 – S1 Fusion
  – Pedicle Screw-Rod Fixation

• All reduce mobility

Design, develop, and validate an orthopedic device to alleviate canine back pain.
Project Approach: Key Objectives

- **Canine Orthopedic Device**
  - **Safe**
    - Biocompatible materials
    - Sterile
    - Minimal wear
  - **Easily Implantable**
    - Minimal pieces
    - Minimal spinal alteration
    - Use current surgical techniques
  - **Effective**
    - Withstand desired loads
    - Preserve Mobility
  - **Easily Manufactured**
    - Common materials
    - Minimal cost
  - **Constraints**
    - Budget
    - Manufacturing Capabilities

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Objective: Safe

- Biocompatible materials
  - Ti-6Al-4V
  - Nitinol
  - Type 316L Stainless Steel
- Sterile
- Minimal wear
  - Minimal pieces/rubbing
Objective: Easy Implantation

- Minimal pieces
- Minimal spinal alteration
- Use current surgical techniques
  - Cadaver dissection observed by Dr. Julien Cabassu
  - Demonstrated the ventral and dorsal surgical approaches to the lumbosacral joint
  - Use current spinal fixation screw locations for mounting
Objective: Effective

- Capable of withstanding desired loads
  - Studies have shown forces up to 185N in lumbosacral facet joint of standing dogs.
  - 200N was used to evaluate our devices
- Preserve mobility
  - 2mm displacement was observed during the cadaver dissection
Our more-defined goal was to design an *easily implanted* and *safe* orthopedic device for use in canines. The device must be effective at *carrying spinal loads*, alleviate pain in the spine, and retain the dog’s range of motion. The device must be able to displace a minimum of *2mm* and withstand *loads of 200 N*. The condition lumbosacral stenosis is caused by a compression of nerves in the spinal canal, so our device must remove any impinging material while leaving as much of the *original spine intact* as possible. Following the procedure, the patient must have *decreased stress on the lumbosacral disc*, retain mobility, and able to return to *normal military activities*. The instrumentation must be *easy to manufacture* at a *low cost* to the client, be biocompatible and durable. The surgical procedure must be *integrated into existing technology* to therefore simplify the compatibility of this device.
Design Specifications

• Sacral plate hole spacing
  – 8.26mm
• Lumbar plate hole spacing
  – 9.59mm
• Lumbar-sacral hole spacing
  – 20.73mm
• Minimum force applied
  – 200N (Yield Strength 316L Stainless = 170 Mpa)
• Minimum displacement
  – 2mm
Zig-Zag Alternative Design

Displacement
  • 0.034mm

Stress
  • 647 MPa

Did not meet displacement or loading design specifications
Mesh Preliminary Design

Displacement
- 0.005mm

Stress
- 120 Mpa

Did not meet the displacement design specifications
Final Design

- Two vertebral plates
  - 316L Stainless Steel
- Spring
  - Spring Steel
- Holes sized for 2mm screws
  - Space available for 4mm head countersinks
Spring Testing

- Four springs
- Compression testing
- Force-Displacement data

- Coil interactions begin at 5mm
- Max load applied: 625N
- No failures
Assembly Testing

- Three finished devices
- Compression testing
- Force-Displacement data

- Coil interactions began before 5mm
  - Spring Bending
- 225 N applied to each spring
  - No failures

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Assembly Testing Setup
Manufacturing

- Plates manufactured at WPI
- Spring welded to plates by local microwelding company
- Costs
  - Springs: 35 springs for $30
  - Stainless Steel: 12.6 in$^3$ for $33$
  - Welding: four assemblies for $100$
  - Cost per device: about $28$
Conclusions

• Final spring design maintains range of motion in the lumbosacral joint

• Final spring design withstands desired loading

• Device is manufactured for minimal cost

• Final design meets the design specifications
Acknowledgements

• Glenn Gaudette – Project Advisor
• Harry Wotton – Securos, Inc.
• Dr. Julien Cabassu

• Micro Arc Welding Service Co.
• Century Spring Corp.
• WPI Machine Shop
### Spring Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring Rate (R)</td>
<td>179 lb/in</td>
<td>31 N/mm</td>
</tr>
<tr>
<td>Spring Length</td>
<td>0.81 in</td>
<td>20.6mm</td>
</tr>
<tr>
<td>Spring OD (OD)</td>
<td>0.188 in</td>
<td>4.78mm</td>
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<tr>
<td>Spring ID (ID)</td>
<td>0.98 in</td>
<td>2.5mm</td>
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<tr>
<td>Spring Mean Diameter (D)</td>
<td>0.188-0.045=0.143 in</td>
<td>3.6322mm</td>
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<tr>
<td>Spring Shear Modulus (G)</td>
<td>11500000 psi</td>
<td>79.3 GPa</td>
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<tr>
<td>Wire Diameter (d)</td>
<td>0.045 in</td>
<td>1.1mm</td>
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<tr>
<td>Total Coils (N)</td>
<td>13.5</td>
<td></td>
</tr>
<tr>
<td>Active Coils (n)</td>
<td>13.5-2= 11.5</td>
<td></td>
</tr>
</tbody>
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