Dynamization Potential of Circular External Fixation Frames with Divergent Struts
Disclosures

- Stephen Plachta, MD
  - None

- J. Tracy Watson, MD
  - Intellectual property rights and patent with Smith & Nephew

- Schanz Pins donated to Department of Orthopaedic Surgery by Smith & Nephew
Background

• **Circular External Fixation**
  – Mechanical Advantages over standard monolateral ex-fix

• **Combination of stability and utility**
  – Allow for micromotion at site of pathology
  – Aid in production of fracture callus, distraction regenerate, fracture remodeling
Standard Ilizarov Frame

- Timeframe of Healing
  - Early: More Rigid Fixation
  - Late: Less Rigid Fixation
- Axial Micromotion
  - Stimulates Callus Formation
Hexapod (TSF) Frame

- Ease of Application
- Reduced Pin/Wire fixation points
- Simplified deformity correction
- Improved patient compliance
- Decreased pin infections
- Decreased surgeon angst

UNANSWERED QUESTION:
- Can spatial frames dynamize?
Dynamization Potential

- Constructs may end up non-orthogonal
- Does this affect the ability of the telescoping struts to perform axial dynamization \textit{without} binding or inducing cantilever load.
Dynamization Potential

- Since 2000 there have been > 100 articles
  - published on the clinical and biomechanical abilities of the TSF to correct deformities

- Currently NO data available on the dynamization potential of the strut mechanism
Dynamization Potential

- Clinicians perform cumbersome and time consuming “strut exchanges”:
  - In an effort to reproduce similar dynamization potential as a longitudinal threaded rod frame.
Hypothesis

Hexapod External Fixation Frames with divergent struts are capable of allowing unhindered / unlimited safe dynamization potential equal to the gold standard.
Questions

I. How does the obliquity of the ring affect dynamization potential?

II. To what degree does ring obliquity affect strut mechanics / function?

III. Can Complex Strut Exchange be avoided?
Methods
Methods
Methods
Methods
Measurement

- Standardized Mounting
  - Constrained **only** axial motion
- 70 kg Load to Mimic Gait
- Cyclic Loading on MTS Machine
  - ~100 Cycles
- Biplanar Video Analysis – Image J
  - Fracture Displacement
  - Axial, Sagittal Planes
- Data Compiled into SPSS
Gold Standard

- Longitudinally Threaded Rods
## Methods: Study Groups

<table>
<thead>
<tr>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>5°</td>
<td>10°</td>
<td>15°</td>
<td>20°</td>
</tr>
<tr>
<td>Ring Divergence</td>
<td>Ring Divergence</td>
<td>Ring Divergence</td>
<td>Ring Divergence</td>
<td>Ring Divergence</td>
</tr>
</tbody>
</table>

![Images of devices and sketches showing divergence angles](image-url)
## Axial and Shear Results

<table>
<thead>
<tr>
<th>Degree of Ring Divergence</th>
<th>Axial (in mm)</th>
<th>STDV</th>
<th>Shear (in mm)</th>
<th>STDV</th>
</tr>
</thead>
<tbody>
<tr>
<td>0º</td>
<td>0.614</td>
<td>0.133</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5º</td>
<td>0.529</td>
<td>0.109</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10º</td>
<td>0.517</td>
<td>0.105</td>
<td>0.082</td>
<td>0.077</td>
</tr>
<tr>
<td>15º</td>
<td>0.357</td>
<td>0.093</td>
<td>0.066</td>
<td>0.088</td>
</tr>
<tr>
<td>20º</td>
<td>0.344</td>
<td>0.081</td>
<td>0.14</td>
<td>0.051</td>
</tr>
</tbody>
</table>

As Ring Divergence Increases ➩ Increased Dynamization inhibition
Axial Dynamization

<table>
<thead>
<tr>
<th>Degree of Ring Divergence</th>
<th>5°</th>
<th>10°</th>
<th>15°</th>
<th>20°</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>p=&lt;0.253</td>
<td>p=&lt;0.19</td>
<td>** p=&lt;0.003 **</td>
<td>** p=&lt;0.015 **</td>
</tr>
<tr>
<td>5°</td>
<td>-</td>
<td>p=&lt;0.85</td>
<td>** p=&lt;0.015 **</td>
<td>** p=&lt;0.011 **</td>
</tr>
<tr>
<td>10°</td>
<td>-</td>
<td>-</td>
<td>** p=&lt;0.019 **</td>
<td>** p=&lt;0.014 **</td>
</tr>
<tr>
<td>15°</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>p= &lt;0.557</td>
</tr>
<tr>
<td>20°</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

As Ring Divergence Increases ➤ ➔ Statistically significant ⇣ in Axial Displacement
# Shear Displacement

<table>
<thead>
<tr>
<th>Degree of Ring Divergence</th>
<th>5°</th>
<th>10°</th>
<th>15°</th>
<th>20°</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>p= No Diff</td>
<td>** p=&lt;0.031 **</td>
<td>** p=&lt;0.001 **</td>
<td>** p=&lt;0.001 **</td>
</tr>
<tr>
<td>5°</td>
<td>-</td>
<td>** p=&lt;0.024 **</td>
<td>** p=&lt;0.031 **</td>
<td>** p=&lt;0.001 **</td>
</tr>
<tr>
<td>10°</td>
<td>-</td>
<td>-</td>
<td>p= &lt;0.650</td>
<td>p= &lt;0.263</td>
</tr>
<tr>
<td>15°</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>p= &lt;0.117</td>
</tr>
<tr>
<td>20°</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

As Ring Divergence Increases ↑ → Statistically significant ↑ in Shear Vector Generation
Discussion

• Hexapod (TSF) Circular External Fixation has revolutionized complex 3D limb reconstruction

• Traditional Ilizarov Circular Frames do require orthogonal ring orientation in order to achieve their dynamization function

• *Axial Dynamization*- offers mechanical stimulation to improve fracture healing
Discussion

• **Shear Forces**- responsible for delayed callus and fibrous tissue formation → nonunion

• At conclusion of deformity correction, Hexapod Fixators may have non-orthogonal ring orientation.

• With Non-Orthogonal Rings using standard struts, Axial Dynamization in Hexapod Fixators may be problematic and induce shear forces
Conclusion

• There is a *limit* to unencumbered dynamization with standard struts
  – when rings are not parallel at the end of treatment
• Up to 10 degrees of Ring Divergence
  – Can safely dynamize without fear of adverse biomechanical consequences
Conclusion

- Greater than 10 degrees of Ring Divergence:
  - Shear Vector Generation
  - Dynamization Inhibition when using the standard oblique struts
Conclusion

• Based on our results, our guidelines for strut exchange are as follows:
  
  – **Intra-op** ⇒ Attempt to align rings orthogonally in each limb segment such that at the end of treatment, the rings are relatively parallel
  
  – **At conclusion of deformity correction** ⇒ If construct demonstrates >10 degrees of ring divergence, complex strut exchanges are indicated
Thank You!

LLRS 2016
CHARLESTON, SC