Introduction

Increasing interest in the treatment of non-arthritic hip pathology, facilitated by the advent of hip arthroscopy and advancements in diagnostic imaging, has led to an improved understanding of hip joint pathoanatomy and disease progression. Acetabular labral tears are a known biomechanical source of hip-centric joint pain and are the leading indication for hip arthroscopy. Defining the role of the labrum in normal hip joint biomechanics is critical for understanding the pathology of labral tear. Cadaveric and simulation studies have shown that the labrum: (1) creates a seal that maintains negative intra-articular pressure, providing stability by resisting distraction of the femoral head; (2) resists synovial fluid egress from the central compartment during joint loading; (3) imparts mechanical resistance to femoral head subluxation and dislocation. The objective of the present study was to assess the contribution of the entire acetabular labrum to mechanical joint stability. We developed a novel “dislocation potential test” that utilizes a dynamic, cadaveric, robotic model that functions in real-time under load-control parameters to map the joint space for low-displacement determination of stability, and expressed this quantitatively using a stability index (SI).

Methods

- 5 fresh-frozen human cadaveric hips (all male, ages 58-79 years) without labral tears tested
- Hip mounted to a 6-degree-of-freedom (DOF) robotic manipulator (Robopod R2000; Parallel Robotics Systems, Hampton, NH, USA)
- 6-DOF force-torque sensor (SI-2500-400, ATI Industrial Automation, Apex, NC, USA) used to evaluate force vectors required for dislocation
- Custom rotary stage used to recreate flexion and extension
- Joint coordinate system (JCS) defined according to International Society of Biomechanics standards
- MicroScribe G2L coordinate measuring machine (Immersion Corporation, San Jose, CA, USA) used to determine spatial orientation
- Coordinate transformations (JCS, robot motion, force sensor coordinate system) computed in real-time using LabVIEW (National Instruments, Austin, TX, USA)
- Hip positioned in 2 most provocative positions for dislocation
  - Full extension (0° flexion) with external rotation until impingement (i.e., anterior provocative position)
  - 90° flexion and 10° adduction with internal rotation until impingement (posterior provocative position)
- Dislocation potential tests were run in 15° intervals (new transverse or sweep plane), about the face of the acetabulum
- For each interval, a 100 N force vector was applied medially and swept laterally until dislocation occurred
- 3-D kinematic data with and without labrum were quantified using the SI (percentage of all possible directions a constant force can be applied while maintaining a stable joint, evaluated globally (all 360°) and regionally (posterior provocative position))
- Protocol performed 5 times each to precondition and reduce creep, with 5th run used for statistical analysis

Statistics

- For each sweep angle, curve of displacement with respect to increasing vector angle of the 3-D force was plotted and 1st-order derivatives were calculated to identify point of dislocation at threshold of 0.05 mm/degree (Figure 3)
- SI calculated as the percentage of all possible directions a constant force can be applied while maintaining a stable joint, evaluated globally (all 360°) and regionally (posterior provocative position) from 30° superior of posterior axis to 15° anterior of the inferior axis, anterior provocative position from directly anterior to 30° posterior of superior axis) (Figure 4)
- Differences in SI analyzed using repeated measures mixed models with pairwise comparisons on LS means with statistical significance set at p≤0.05

Results

<table>
<thead>
<tr>
<th>Position</th>
<th>SI With Labrum</th>
<th>SI Without Labrum</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Anterior Provocative</td>
<td>40% ± 15%</td>
<td>46% ± 13%</td>
<td>0.02</td>
</tr>
<tr>
<td>Regional Anterior Provocative</td>
<td>56% ± 7%</td>
<td>49% ± 7%</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Conclusions

This study was funded in part by the Orthopaedic Research and Education Foundation.