TORSIONAL STRENGTH OF THE FEMORAL CAPITAL EPiphySEAL PLATE

*Chuinard C R; **Williams J L; ***Schmidt T L
+Department of Orthopaedic Surgery, University of Missouri–Kansas City, Kansas City, MO

INTRODUCTION:

It has been postulated that torsion may play a role in the etiology of slipped capital femoral epiphysis (SCFE) [1]. The argument for this is partly based on the symptom of rotational deformity (involving external femoral rotation) at presentation of SCFE and on the use of internal femoral rotation in the reduction of SCFE. The torsional properties of the femoral capital physis are, however, unknown and information on the torsional behavior of other intact epiphyseal plates is scarce. The only physiologic torsion study, that we are aware of, reported the torsional strength of the proximal tibial epiphyseal plate in rabbits [2]. Furthermore, the relative contribution of the perichondrium in resisting torsion has never been evaluated. The aim of our study was to determine the torsional behavior of the femoral capital physis in the pig and to measure the relative contribution of the perichondrial ring in resisting torsional loads.

METHODS:

We chose the one-year old pig as a model because the pig and human adolescent capital femoral physis are similar in size and shear strength [3]. Eight pairs of pig femurs were obtained from a slaughterhouse and kept frozen in sealed plastic bags until needed. Prior to testing, each femur was thawed overnight in a refrigerator and then placed (still in plastic bags) in a bath of warm water for 90 minutes. All soft tissue was removed except for perichondrium and periosteum. The femoral head of each femur was secured in specially designed torque holder consisting of an aluminum cylinder with two rows of set screws machined to have cup points, somewhat analogous to a halo ring with halo pins. Eight of the screws were mounted in one row at 60 degrees, and the other eight in another row at 90 degrees to the cylinder axis. The torque holder was mounted as close to the capital femoral physis as possible, without having any of the screws enter or cross the growth cartilage, and in an orientation so that the cylinder axis was perpendicular to the plane of the physis. The distal end of the femur was secured with four long screws in a box mounted to the base of an MTS Syntech 5/G machine (MTS Systems Corporation, Eden Prairie, MN). A pulley (radius 44 mm) and cable system converted vertical motion of the MTS crosshead to angular motion of the femoral head. After applying a pre-torque of 0.88 Newton-meter, the head of the femur was twisted in internal rotation at 0.002 rad/sec (0.11 degrees/sec) about an axis perpendicular to the growth plate, simulating an external rotation of the femur. Force was measured with a load cell (range + 20,000 Newtons, accuracy of + 2 Newtons, resulting in a torque accuracy of + 0.11 Newton-meter) and rotation with a rotary potentiometer (range: 0 to 353 degrees; accuracy + 0.33 degrees). All test data were digitally acquired at 100 Hertz using MTS TestWorks 4.02 data acquisition software.

The perichondrial ring was sharply excised on all left femurs prior to testing, whereas the right femurs were left intact. When the perichondrium was not excised, the perichondrium was removed prior to testing. The perichondrium was always removed by incising the skin, dissecting the subcutaneous tissue, and incising the anterior leaf of the capsule. The perichondrium was removed until no cartilage was visible. When the perichondrium had been removed, the femoral head was twisted to failure as above. We chose the one femur from each pair that failed to the highest torque.

RESULTS:

Without the perichondrial ring the peak torque of the capital femoral physis was 80% (Table 1) of the value for the intact physis. This is comparable to the relative contribution of the perichondrium in anteroposterior shear, as found in previous studies of both the human adolescent as well as the one-year old pig capital femoral physis [4]. The angle at peak torque was unaffected by the perichondrium, but without the perichondrium the angle at failure (defined as a drop in torque of 30% from the peak value) was 50% of that for the intact physis. Without the perichondrium, the torsional stiffness was 83% of the value for the intact physis; and the energy measured by the area under the torque-rotation curve up to peak torque, was 68% of values for the intact physis (Figure 1). The total energy to failure (as defined above) without the perichondrium was 52% of the value for the intact physis.

<table>
<thead>
<tr>
<th>State of perichondrium</th>
<th>Peak torque (N.m)</th>
<th>Angle at peak torque (deg)</th>
<th>Torsional stiffness (N.m/rad)</th>
<th>Energy at peak torque (Joules/rad)</th>
<th>Energy at failure (Joules/rad)</th>
<th>Angle at failure (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intact</td>
<td>23.4 (3.6)</td>
<td>9.4 (1.4)</td>
<td>176 (35)</td>
<td>2.1 (0.5)</td>
<td>4.5 (0.5)</td>
<td>16.4 (2.6)</td>
</tr>
<tr>
<td>Excised</td>
<td>18.7 (3.0)</td>
<td>8.0 (1.4)</td>
<td>146 (31)</td>
<td>1.5 (0.4)</td>
<td>1.6 (0.5)</td>
<td>8.5 (1.4)</td>
</tr>
<tr>
<td>P-level</td>
<td>0.002</td>
<td>0.20</td>
<td>0.03</td>
<td>0.04</td>
<td>0.0001</td>
<td>0.0002</td>
</tr>
</tbody>
</table>

DISCUSSION:

The perichondrium contributed significantly to the torsional strength of the femoral capital physis. When the perichondrium was not excised, the physis supported larger torques and allowed more energy to be absorbed, both up to peak torque and beyond peak torque values. Our definition of failure as the point where the torque dropped to 70% of its peak value was quite arbitrary. In the present series of experiments, this testing protocol completely disrupted the growth cartilage in all femurs in which the perichondrium was removed prior to testing. When the perichondrium was left intact, this test protocol resulted in major destruction of the growth cartilage. We verified this qualitatively by manually assessing the residual strength after testing and after excising the perichondrium.

REFERENCES:


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**Pediatric Orthopaedic Surgery Associates of Kansas City, P.A., Suite 202, 10730 Nall Avenue, Overland Park, KS 66211

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