TORSIONAL STRENGTH OF SINGLE-VERSUS DOUBLE-SCREW FIXATION IN A MODEL OF UNSTABLE SLIPPED CAPITAL FEMORAL EPIPHYSIS

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INTRODUCTION:
Slipped capital femoral epiphysis (SCFE) is the most common hip disorder of adolescent children [1]. It results in fracture of the growth cartilage, separating the proximal femoral epiphysis from the metaphysis, due to hormonal and mechanical factors [2]. The most widely accepted treatment for stable SCFE (defined by the ability to bear weight on the affected limb) has been a single centrally placed cannulated cancellous bone screw. The treatment of unstable SCFE (defined as the inability to bear weight) is more controversial with some advocating double-screw fixation [3].

A torsional component has been suggested for the mechanical basis of SCFE fractures [4,5]. If this is true then single-screw fixation would be less resistant to torsional loading than double-screw fixation.

The objective of this study was to determine the relative torsional strength of the femoral capital growth plate after single- or double-screw fixation in an in vitro pig model of SCFE.

METHODS:
We chose the one-year old pig as a model because the pig and human adolescent femoral capital physis are similar in size and shear strength [5]. Nine pairs of pig femurs were obtained from a slaughterhouse. All soft tissue was removed except for perichondrium and periosteum. After applying a pre-torque of 0.88 Newton meter, the head of the femur was twisted in internal rotation at 0.11 degrees/sec about an axis perpendicular to the growth plate, simulating an external rotation of the femur. Torque and rotation data were acquired (100 Hertz) to 0.1 Nm and 0.33 degree accuracy, respectively.

After testing to failure, defined as a drop of torque equal to 50% of the peak reading or a rotation of 60 degrees, each femur was fixed with either one or two (by random allocation) Synthes 7.3-mm diameter 316L stainless steel cannulated screws of 70, 75 or 80 mm lengths with 32 mm thread length and then re-tested to failure in the same manner. The proximal cortical was tapped with a 6.6mm OD and 4.5 mm ID tap. For double-screw fixation, an adjustable parallel guide set was used to provide 11.5 mm separation between the two screws. After fixation, the perichondrium was stripped and incised before re-testing. Matched-pair testing was used to compare peak torque and torsional stiffness (defined as the steepest linear regression fit to the torque versus rotation plot) of single- to double-screw fixation.

Changed scores were calculated by subtracting the peak torque or stiffness after fixation from the results before fixation. Paired student t-tests were used to test for differences in the changed scores between single-screw fixation and double-screw fixation (contralateral side).

RESULTS:
The torsional strength (peak torque) was 37% of the intact physis for single-screw fixation and 74% for double-screw fixation (Table 1). Double-screw fixation was twice as strong as single-screw fixation (p = 0.004). The torsional stiffness was 22% of the intact physis for single-screw fixation and 43% for double-screw fixation (Table 2). Double-screw fixation resulted in 1.8 x the torsional stiffness of single-screw fixation (p < 0.0001).

The angle of rotation at the growth plate was 10.3 degrees (SD 2.7) at the peak torque and 24.4 degrees (SD 7.3) at the defined break point for the intact (pre-fixation) femurs.

Example plots (Fig. 1) show the loss of strength and stiffness after fracture fixation and the substantial improvement of double- over single-screw fixation.

Table 1. Mean torsional shear strengths (standard deviation) of the femoral capital growth plate in the pig (Nm).

<table>
<thead>
<tr>
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<th>Pre-fixation</th>
<th>Post-fixation</th>
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<tbody>
<tr>
<td>Single screw fixation</td>
<td>21.6 (3.9)</td>
<td>8.0 (3.2)</td>
</tr>
<tr>
<td>Double screw fixation</td>
<td>22.2 (3.4)</td>
<td>16.4 (3.0)</td>
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The perichondrium was intact before all pre-fixation tests, but was removed after fixation and before post-fixation testing.

DISCUSSION:
Double-screw fixation resulted in twice the torsional strength and stiffness compared to single-screw fixation. Even so, the strength and stiffness of the constructs were much less than the intact physis. Anterior-to-posterior (AP) shear of the femoral head in a cow model of SCFE fixation provided only a 33% increase in stiffness in double-versus single-screw fixation. However, the capital femoral physis of the cow is larger and two-fold stronger in AP shear than either the human adolescent or the 1-year pig [6]. In addition, the perichondrium was not removed in the cow model [7]. The perichondrium contributes to AP shear strength, even after fixation by a single central screw [8].

Clinical observation of continuing external rotation of the affected leg with advancing slip would support the idea of a torsional basis for the slip mechanism. In general, the use of multiple screws in SCFE fixation is a concern for increasing the risk of avascular necrosis (AVN). However, the consequences of complications due to rotational failure of single-screw fixation in unstable SCFE could be worse than the potential complications of AVN due to the use of a second screw. Therefore, double-screw fixation may be a suitable choice for unstable acute slips with mild displacement. Further study is warranted.

REFERENCES:

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