Introduction:
The anterior cruciate ligament (ACL) is an important restraint to anterior posterior translation and torsional stability of the knee joint[1]. After ACL rupture the role of the secondary restraints become of primary importance in ensuring knee joint stability[2][3][4]. The aim of this study was to investigate the effect of chronic ACL deficiency on the secondary restraints by measuring the anterior-posterior drawer and torsional stability of acute and chronically ACL-deficient knees in an experimental sheep model.

Methods:
Animal Model:
Eight Merino Border-Leicester male sheep were used in this study. ACL division was performed on one randomly selected knee joint of each sheep (chronic ACL group), while the contralateral joint underwent a sham operation (sham group). The sham operation comprised of an arthroscopy and reproduction of all the surgical steps with the exception of ACL transection. At 20 weeks all sheep were euthanised, and biomechanical and macroscopic evaluation of each joint performed. After biomechanical testing of the sham operated knees was complete, the ACL was divided and the joint retested to simulate an acute ACL lesion (acute ACL group).

Biomechanical Evaluation:
Each knee was positioned in an Instron 8874 biaxial testing system (Instron Pty. Limited) using specially design jigs (Figure 1). Joints were evaluated under cyclic load control both in anterior-posterior (A-P) translation (+50N) and internal-external (I-E) rotation (+/-5Nm) at a rate of 0.05Hz for 5 cycles. At these subphysiological loads there was no soft tissue damage and creep upon each loading cycle was minimal. Knee joint flexion angles were set at 45 and 90 degrees. Force and displacement data was collected. A-P and I-E laxity was determined by measuring the total displacement or rotation over the final loading cycle. Measuring the maximum force-displacement slope at each end of the motion range gave a measure of the stiffness on anterior, posterior, internal and external loading.

Discussion
In this animal model, instability did not increase with time after ACL division and the secondary restraints did not stretch. In fact there was evidence for a significant 20-30% reduction in anterior-posterior and rotational laxity in sheep knees 20 weeks post ACL division compared with the acute ACL division[5]. To our knowledge this is the first demonstration of a reduction in rotational laxity with time, in animals or humans, following ACL injury. These findings may have implications for the concurrent surgical management of secondary capsuloligamentous restraints in knees undergoing ACL reconstruction for chronic ACL deficiency.

Results:

Macroscopic findings:
No residual of the ACL was found in the chronic ACL transection group and all ACLs were intact in the sham group. No PCL lesions were found in the chronic or sham groups. Gross arthritic changes, including significant cartilage erosion, especially within the patello-femoral joint, and one meniscal tear of the posterior horn of the medial meniscus, were found in the chronic ACL transection group. The sham group only showed mild arthritic change.

Biomechanical findings:
We calculated the percentage change in A-P and I-E laxity and stiffness between the sham, chronic and acute groups at 45 and 90 degrees of flexion. In all cases the chronic and acute ACL groups were significantly more lax and less stiff in A-P and I-E translation than the sham joints at 45 and 90 degrees of flexion. At 45 degrees of flexion, A-P and I-E laxity in the chronic ACL group was 20% and 28% less than the acute ACL group respectively. Anterior and posterior stiffness of chronic ACL group was 28% and 32% greater than the acute ACL group respectively. The chronic ACL was 51% stiffer on internal rotation and 23% stiffer on external rotation than the acute ACL group (Table 1).

No significant differences between the chronic and acute ACL groups in laxity or stiffness were detected at 90 degrees flexion.

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Table 1: Biomechanical properties of ovine knee joint tested in A-P translation and I-E rotation at 45 degrees flexion

<table>
<thead>
<tr>
<th>Assesment</th>
<th>Sham group</th>
<th>Chronic ACL group</th>
<th>Acute ACL group</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-P laxity</td>
<td>mm/p value</td>
<td>2.3 ± 0.5</td>
<td>7.1 ± 2.4</td>
</tr>
<tr>
<td>I-E laxity</td>
<td>deg/p value</td>
<td>63 ± 5</td>
<td>51 ± 7</td>
</tr>
<tr>
<td>Anterior stiff.</td>
<td>N/mm</td>
<td>159 ± 18</td>
<td>97 ± 18</td>
</tr>
<tr>
<td>Posterior stiff.</td>
<td>N/mm</td>
<td>23 ± 8</td>
<td>121 ± 28</td>
</tr>
<tr>
<td>Internal stiff.</td>
<td>Nm/deg</td>
<td>0.40 ± 0.12</td>
<td>0.59 ± 0.13</td>
</tr>
<tr>
<td>External stiff.</td>
<td>Nm/deg</td>
<td>0.66 ± 0.13</td>
<td>0.73 ± 0.04</td>
</tr>
</tbody>
</table>

* (A/B) p<0.0001
(B/C) p<0.0001
(B/C) p=0.082
(B/C) p=0.011
(B/C) p=0.045

Figure 1: Biomechanical testing of the ovine knee joint with Instron 8874 machine; the figure showing a internal-external rotation laxity test at 45\(^\circ\) flexion.