

**ANNOTATION**

Extra-articular techniques in anterior cruciate ligament reconstruction

A LITERATURE REVIEW

In patients with anterior cruciate ligament (ACL) deficiency, reconstructive procedures should correct anterior tibial translation and restore rotatory control. From basic science models, placing an ACL graft that is orientated obliquely provides a greater moment of resistance against the rotatory torque that occurs during the pivot-shift.1,15 Hence, when using the commonly referred-to 'clock-face' analogy to describe femoral tunnel positioning, it is increasingly suggested that ideal positioning should be 'further round the clock-face' in a lower position, such as between the 9.30 and 2.30 positions, rather than the traditional 11 to 1 o'clock positions in right/left knees.3,6,8 Although one *in vitro* study9 has questioned whether further obliquity of the graft does actually reduce the pivot-shift in the ACL-deficient knee, clinical data have shown a correlation between persistent rotatory instability and graft placement towards the 'high noon' position.7,10 Recently, the introduction of double-bundled reconstruction techniques has drawn attention to the potential of a more ‘anatomical’ procedure that counteracts both sagittal plane instability, especially via the anteromedial bundle, and rotatory instability, via the posterolateral bundle.5,11,12 However, some double-bundled as well as single-bundled reconstructions do not restore normal kinematics under simulated pivot-shift loads *in vitro* and *in vivo*, even for a ‘successful’ reconstruction.14 In addition, the clinical benefits of the double-bundle approach have not been clearly established.15

One further way of addressing pivot-shift is to perform a lateral extra-articular tenodesis, which, being peripheral to the centre of rotation, of the knee, has a lever arm for controlling rotation, which is far greater than that provided by an intra-articular reconstruction.11,16 However, little is known about the anatomy, biomechanics and radiological appearances of damaged anterolateral structures. Thus it would be difficult to identify those knees with damage to these structures acutely that might benefit from extra-articularly augmented.

The ‘pivot-shift’ phenomenon; the clinical sign of anterolateral instability

As long ago as 1914 a ‘slipping knee’ was described in a case report.17 In 1920, Hey Groves18 described the ‘jerk’ as the tibia moves acutely that might benefit from extra-articular augmentation.

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The term ‘pivot-shift’ was first used in 1972. This is a complex rotational and translational instability of the tibio-femoral joint, caused by combined ‘coupled’ sagittal plane linear laxity (anterior translation) with an axial rotatory abnormality (internal rotation). In the original description, the knee was flexed from full extension with a valgus and internal rotation moment. The pivot-shift was felt as a sudden reduction of the anteriorly subluxed lateral tibial plateau as the knee moved from full extension through 30° flexion. This resulted from the iliotibial band moving from its position anterior to the centre of rotation of the knee at 0°, to posterior to it at approximately 30°. Several variations of the test have been described. The exact structures that are necessary to be damaged to produce the pivot-shift are unclear. It is usually simply assumed that a positive test equates to ACL deficiency. Most commonly, it is combined damage to the ACL and lateral structures which produces a pivot. Interestingly, whilst some ‘isolated’ ACL injuries can result in a pivot, others do not. Furthermore an isolated injury to the lateral structures can also produce the pivot-shift sign without a torn ACL. Perhaps then not surprisingly it has been shown that the pivot-shift sign can remain positive after intra-articular ACL reconstruction.

The ‘pivot lesion’ comprises characteristic bone bruising on the posterolateral tibial plateau and anterolateral femoral condyle that can be present on MRI scans of patients with acute ACL ruptures. This is due to impaction between the tibia and femur that results from the lateral joint subluxation which accompanies most ACL ruptures: the lateral femoral condyle moves posteriorly off the lateral tibia, which mirrors the pivot-shift phenomenon. A positive pivot-shift sign has been associated with increased scintigraphic activity of the bone.

The instability that occurs as a result of the pivot phenomenon is most commonly encountered as difficulty with sharp changes in direction or cutting movements. It is reasonable to postulate that obliterating the pivot will improve both kinematics and symptoms and physical signs (Figs 1 and 2).

**Anatomy of the rotatory stabilisers of the knee**

The structures that stabilise the lateral aspect of the knee are in a complex arrangement. Understanding the anatomy of this area may be crucial in determining whether any extra-articular reconstruction is likely to be desirable at the time of ACL reconstruction. Merican and Amis described the lateral soft-tissues of the knee as being organised into three layers; the first superficial layer containing the iliotibial tract (ITT) laterally and the biceps femoris posterolaterally, the second layer containing the transverse fibres of the lateral retinaculum anteriorly, joining the deep aspect of the ITT to the patella, and the third layer containing the lateral joint capsule with localised thickenings of the lateral patellofemoral and patellomeniscal ligaments. Terry,
Hughston and Norwood divided the ITT into five layers: aponeurotic, superficial, middle, deep and capsulo-osseous. The latter two layers include bands known as ‘Kaplan’s fibres’, which link the deep aspect of the ITT to the lateral metaphysis (Fig. 3). The capsulo-osseous layer originates from the region of the lateral intermuscular septum and the fascia over the posterior aspects of the lateral gastrocnemius and plantaris muscles. This blends with the short head of the biceps femoris, forming an anterolateral sling over the lateral femoral condyle and acting as an anterolateral ligament of the knee.

Radiological evidence of damage to the lateral stabilising structures: the ‘Ségond’ fracture
The Ségond fracture may provide a vital clue to the sequential failure of the extra articular structures during ACL injury, particularly when a rotatory component has been involved (Fig. 4). There is a high correlation between the presence of a Ségond fracture and an ACL tear, with an association of 75% to 100%. Ségond first described his eponymous avulsion fracture of the proximal tibia whilst carrying out cadaveric experiments and suggested that this cortical tibial avulsion fracture was at the site of insertion of the middle third of the lateral capsular ligament, at a point posterior to the ITT insertion. MRI and cadaveric studies have suggested that the Ségond fragment is at the site of insertion of the ITT or at the site of insertion of the ‘anterolateral oblique band’ of the fibular collateral ligament. However, it is difficult to determine the exact structures described in the literature and further anatomical and biomechanical studies on this area of the knee are required.

The Ségond fracture indicates that the anterolateral capsular structures are under significant load in certain modes of ACL injury. It is possible to speculate that these structures may act as secondary restraints to the pivot-shift phenomenon, supplementing the primary restraint role of the ACL. If this is the case, the current trend towards performing anatomical ACL reconstruction may involve surgical repair or reconstruction of damaged anterolateral structures as well as reconstructing the damaged intra-articular ACL.

Natural history and techniques of anterior cruciate ligament reconstruction
The natural history of the ACL-deficient knee is that it leads to the development of medial compartment osteoarthritis. It is fairly well established that ACL deficiency predisposes to medial meniscal tear and that ACL reconstruction protects against this. A medial meniscal tear has been shown to be one of the most important factors predisposing to the development of osteoarthritis in the ACL deficient knee. It is unclear how extra-articular reconstruction would affect the medial compartment, although there is some evidence to suggest increased degenerative change in the lateral compartment after extra-articular surgery. There is little in the literature related to long term outcome after ACL reconstruction.

Intra-articular reconstructions
Nearly all surgeons use isolated intra-articular ACL reconstruction alone, using hamstrings or bone-patellar tendon-bone grafts. At present, only the Scandinavian countries keep an ACL register, so it is difficult to know the relative popularity of different techniques which are currently being used worldwide. Despite giving relatively consistent results, there is good evidence that the operation does not restore normal kinematics and biomechanics, and does not prevent rotational instability. The introduction of double-bundled reconstruction has raised debate on the value of the posterolateral bundle in resisting the pivot-shift, thus resulting in a more
EXTRA-ARTICULAR TECHNIQUES IN ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

‘anatomical’ restoration of the ACL. However the clinical benefit of this continues to be debated. There are also technical challenges of performing double-bundled reconstruction in less experienced hands, which may prejudice against widespread adoption of this procedure.

Extra-articular reconstruction

Extra-articular reconstruction has been undertaken either as an isolated procedure or to augment an intra-articular reconstruction. Variable results have been reported. However, some shortcomings have been highlighted. Some authors have reported failure of the extra-articular reconstruction and recurrent instability. Secondary degenerative changes in the lateral compartment from overtightening resulting in increased stresses in the lateral compartment have been reported. However, this may be because historically the procedure was performed without concomitant intra-articular ACL reconstruction, which may have allowed the joint to be secured in a subluxed position. One further cause for poor post-operative function may have been the rehabilitation methods employed, which included immobilising the knee in a plaster-cast for up to two months post-operatively (Tables I and II).

An inability to restore normal anterior tibial translation whilst maintaining normal rotational laxity has also been reported; and donor site morbidity and concerns about cosmesis have also been described.

Table I. Results of isolated extra articular anterior cruciate ligament reconstruction

<table>
<thead>
<tr>
<th>Author/s</th>
<th>Operation</th>
<th>Technique</th>
<th>Number of patients</th>
<th>Follow-up period</th>
<th>Post-operative protocol</th>
<th>Scoring system used</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amirault et al</td>
<td>MacIntosh technique</td>
<td>MacIntosh technique</td>
<td>27</td>
<td>Mean 11.3 years (8 to 14.4)</td>
<td>Long-leg plaster for 5 weeks</td>
<td>Based on range of movement, arthritic change, anterior draw and pivot shift</td>
<td>52% good to excellent, 26% fair, 22% poor</td>
</tr>
<tr>
<td>Ireland and Trickey</td>
<td>MacIntosh</td>
<td>MacIntosh</td>
<td>50</td>
<td>Mean 2.25 years</td>
<td>Non-weight-bearing in plaster for 6 weeks, no sport for 6 months</td>
<td>Clinical assessment</td>
<td>Abolished positive anterolateral jerk test in 42 out of 50 knees, 37 (74%) returned to active sport</td>
</tr>
<tr>
<td>Dandy</td>
<td>MacIntosh (as originally described)</td>
<td>MacIntosh</td>
<td>18</td>
<td>Mean 69 months</td>
<td></td>
<td>Lysholm</td>
<td>77 at 6 years, pivot shift returned in 38% of patients</td>
</tr>
<tr>
<td>Taylor et al</td>
<td>MacIntosh lateral substitution ‘over the top’</td>
<td>MacIntosh</td>
<td>18</td>
<td>Mean 9.3 months</td>
<td>Plaster cylinder at 30° for Cincinatti 4 weeks, passive recovery of extension, return to sports 6 months</td>
<td></td>
<td>Sustained benefit maintained up to 9 years post operation. Radiographs showed degenerative changes in most cases</td>
</tr>
<tr>
<td>Losee et al</td>
<td>‘Sling and reef operation’</td>
<td>See description in main text</td>
<td>50</td>
<td>1 to 6.5 years</td>
<td>Seven weeks in padded cast (knee flexed and tibia in external rotation); long brace worn for further 3 months</td>
<td>Own criteria, based on stability, ability to work and arthrosis</td>
<td>Good in 41, Fair in 6, Poor in 3. 33 patients had anteromedial rotatory instability post-operation.</td>
</tr>
<tr>
<td>Ellison</td>
<td>Distal iliotibial band transfer</td>
<td>ITT released distally from Gerdy’s tubercle, passed beneath fibular collateral ligament</td>
<td>18 (10 had previous surgery)</td>
<td>Mean 31 to 44 months</td>
<td>Long-leg cast for 6 weeks</td>
<td>Kennedy – excellent: no limitations, good: returned to sport with minor problems, poor: any other results</td>
<td>44% excellent results, 39% good results, 17% failures</td>
</tr>
<tr>
<td>Reid et al</td>
<td>Ellison</td>
<td></td>
<td>32</td>
<td>11 years (7 to 15)</td>
<td></td>
<td>Lysholm</td>
<td>56% modified Lysholm less than 84, 75% positive pivot-shift test</td>
</tr>
<tr>
<td>Kennedy et al</td>
<td>Ellison</td>
<td>Modification of MacIntosh/Galway techniques</td>
<td>28 (13 had 6 months anserinis transfer)</td>
<td>Plaster cast at 70° flexion, 15° external rotation for 6 weeks. Resumption of activities when quads/hamstring at full strength</td>
<td></td>
<td></td>
<td>16 (57%) good or excellent results. 24 still had pivot-shift sign remaining. There may be ‘specific indications’ for the operation</td>
</tr>
<tr>
<td>Neyret et al</td>
<td>Lemaire</td>
<td>See description of Lemaire procedure in main text</td>
<td>33 knees</td>
<td>Mean 4.5 years</td>
<td>Arpege score, subjective assessment, clinical assessment</td>
<td></td>
<td>Isolated extra-articular reconstruction not recommended; results better where pivot-shift was abolished</td>
</tr>
<tr>
<td>Lazzarone et al</td>
<td>Lemaire</td>
<td></td>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td>Success rate 80%</td>
</tr>
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</table>
These shortcomings may indicate that previous attempts at extra-articular reconstruction have been ‘non-anatomical’, and that an isolated extra-articular reconstruction may not be the function of the intra-articular ACL.

Methods of extra-articular reconstruction

Isolated extra-articular reconstruction. Several different techniques for extra-articular reconstruction have been described. Most use strips of isolated ITT band to act as a

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**Table II. Results of combined extra- and intra-articular anterior cruciate ligament reconstruction**

<table>
<thead>
<tr>
<th>Author/s</th>
<th>Operation</th>
<th>Technique/Femoral attachment</th>
<th>Number of patients</th>
<th>Follow-up period</th>
<th>Post-operative protocol</th>
<th>Scoring system used Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bertoia et al</td>
<td>MacIntosh lateral substitution over the top</td>
<td>MacIntosh lateral substitution 'over the top', femoral attachment-posterior to proximal attachment of lateral collateral ligament</td>
<td>34</td>
<td>Mean 37 months (24 to 58)</td>
<td>Toe to groin plaster cast with knee in 70° flexion and full external rotation for 5 weeks, 9 to 12 months to full activity</td>
<td>Own results scoring system based on pain/swelling/level of physical activity, conversion to negative pivot-shift post-op.</td>
</tr>
<tr>
<td>Dandy et al</td>
<td>MacIntosh extra-articular with intra-articular patellar tendon or Leeds-Keio MacIntosh</td>
<td>Free graft from medial third of patellar tendon with MacIntosh reinforcement</td>
<td>74/129</td>
<td>Lysholm</td>
<td>Concluded ACL reconstruction with patellar tendon and extra-articular MacIntosh is a reliable technique for return to professional sport.</td>
<td>Results 'unsatisfactory' when compared with patellar tendon and MacIntosh</td>
</tr>
<tr>
<td>Dandy and Gray</td>
<td>Leeds-Keio with Standard MacIntosh</td>
<td>129</td>
<td>71</td>
<td>Lysholm, Tegner</td>
<td>Subjectively: 65% 'very satisfied', 24% satisfied; International Knee Documentation Committee (IKDC): A 22, B 49.</td>
<td>87% returned to sport. MacIntosh: 91% excellent, good, 8% fair.</td>
</tr>
</tbody>
</table>
| Dejour et al    | Patellar tendon with Lemaire                   | 251                                         | Minimum 3 years    | Subjective, IKDC | Movement in brace Lysholm, radiological 20° to 90° for 4 weeks, full weight-bearing after 9 weeks | Lysholm: 17 excellent, 35%
  good, 19 fair, 13 poor. |
| Dejour et al    | Patellar tendon with Lemaire                   | 148                                         | 11.5 years (10 to 15) | Objective, IKDC | Partial weight-bearing after 2 weeks with range of movement to 120°, proprioceptive exercises for 4 weeks, running at 2 months, sports at 4 months | 90.7% of patients good or excellent results at 11 years, ligament arthrometer using KT-2000 demonstrated only 2 patients had > 5 mm side to side difference in laxity. Mean Lysholm 91.3, joint space narrowing only in 20 with meniscal surgery |
| Edwards et al   | Semitendinosus intra-articular, ITT extra-articular | STT passed through femoral condyle at site of insertion of ACL. ITT passed superficial to lateral collateral, attached to femur at isometric point (Krackow)
  
  Strips of fascia lata – MacIntosh | 84 knees | Lysholm, Tegner | Results 'unsatisfactory' when compared with patellar tendon and MacIntosh | 87% returned to sport. MacIntosh: 91% excellent, good, 8% fair. |
| Johnston et al  | MacIntosh lateral substitution over the top    | See description in main text and diagram     | 54                 | IKDC and Lysholm, Tegner | Two different proto-IKDC, Knee Injury and Osteoarthritis Outcome Score (KOOS), physical examination, radiographs |
| Maracci et al   | Standard hamstring tendon with hamstring used extra-articular | 64 patients randomised | 24 months | Tegner, Lysholm, KT-1000 | 77% no pivot-shift, 17% moderate, 6% major. |
| Moyen et al     | Marshall-MacIntosh technique versus same with addi-augment | Kennedy ligament augmentation – a ribbon of polypropylene as an augmentation |
  |                  | of Kennedy ligament augmentation              | 64 patients randomised | Continuous passive motion, initially, partial weight-bearing at 2 weeks, slow running at 6 months | Addition of Kennedy augment provided no benefit |
| Perrin et al    | Bone-patellar bone, Lemaire                    | Bone-tendon-bone graft as intra-articular with modified Lemaire procedure as extra-articular | 148                 | IKDC and Lysholm, Tegner | Two different proto-IKDC, Knee Injury and Osteoarthritis Outcome Score (KOOS), physical examination, radiographs |
| Rackemann et al | Combined                                       | Middle third patella tendon with MacIntosh extra-articular | 74                 | Lysholm, clinical assessment | Satisfaction in 93%, 0 positive pivot-shifts at 3 years, 1 at 6 years |
| Roth et al      | Extensor mechanism with biceps femoris advancement | Advancement of biceps femoris as extra-articular restraint (no control group) | 43 (50 as mean 24 months | Continuous immobilisation in cast for at least 6 weeks | No subjective, clinical objective or radiological improvement between two groups |
| Saragaglia et al | MacIntosh and Kennedy ligament augmentation device | Standard MacIntosh | 171 operations, 107 at medium follow-up | Stability, pain and functional scoring system. | Knees nearly normal in 72.9% |

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restraint to internal rotation of the tibia and to anterior laxity of the lateral compartment. The important literature relating to isolated extra-articular reconstruction is summarised in Table I.

The exact site of femoral attachment and tension of the extra-articular reconstruction is critical in determining the successful restoration of normal biomechanics. It has been suggested that the optimum site of femoral fixation is proximal and posterior to the femoral origin of the lateral collateral ligament.

**MacIntosh procedure.** The MacIntosh procedure used a strip of ITT in a technique called the ‘lateral substitution reconstruction’. A 20 cm long strip 2 cm to 4 cm wide was dissected from the mid-portions of the ITT and turned down to its attachment at Gerdy’s tubercle. A subperiosteal tunnel was made on the lateral femoral condyle posterior to the attachment of the fibular collateral ligament. The strip of ITT was passed deep to the collateral ligament and through the periosteal tunnel. A second subperiosteal tunnel was made to insert the strip of ITT through the distal insertion of the lateral intermuscular septum onto the lateral femoral condyle. The band was looped behind the insertion of the intermuscular septum, and then passed again deep to the collateral ligament. The ITT was then anchored with the knee held at 90° flexion.

**Losee’s ‘sling and reef’ operation.** Losee et al designed an operation called the ‘sling and reef’ operation, which used a strip of ITT to create a sling and then ‘reef’ the posterolateral capsule. An incision was made approximately 15 cm proximal to the joint which followed the lateral intermuscular septum to the joint line, and then continued anteriorly along the lateral joint line, before curving distally along the lateral margin of the tibial tubercle to finish 3 cm distal to the joint line. Parallel incisions 2.5 cm apart were then made in the ITT to obtain a strip of tissue approximately 16 cm long, which remained attached to Gerdy’s tubercle. A tunnel was made through the lateral femoral condyle, anterior and distal to the attachment of the lateral collateral ligament, followed by passage of the graft of the ITT.

**Ellison’s distal ITT transfer.** Ellison’s technique was a modification of earlier work by Galway and MacIntosh, but the ITT was released from its origin at Gerdy’s tubercle, before being passed under the insertion of the lateral collateral ligament to the femoral condyle.

Results for extra-articular repair alone were mixed. While Marston reported good or excellent results in 77% of patients, Kennedy et al using the same Ellison procedure, reported that a positive pivot-shift sign was still present in 24 of 28 patients at a minimum follow-up of six months. Comparison with modern techniques is difficult as many of the studies did not report their results using validated outcome measures.

**Lemaire operation.** The Lemaire repair was first described in 1967. A 16 cm × 1.5 cm strip of fascia lata that was still attached to Gerdy’s tubercle was passed under the lateral collateral ligament, and then through a bone tunnel at the lateral head of gastrocnemius. It was then passed again under the lateral collateral ligament before being attached at another bony tunnel under Gerdy’s tubercle.

Although this procedure was designed to address pivot-shift, it did not control anterior translation of the tibia. For this reason, when performed in isolation it has poor results, with less than 50% success in sportsmen.

**Andrews operation.** The Andrews procedure was a mini-reconstruction designed to prevent anterolateral instability, using isometric bundles in the ITT. It was suggested that the procedure could be used in combination with an ACL repair in patients with anterolateral instability.

### Combined intra- and extra-articular reconstruction

Extra-articular reconstruction has been employed to augment an intra-articular reconstruction because it may protect the intra-articular graft during the healing phase. Another reason previously given is that once the patient returned to activity it provided a secondary restraint to the pivot shift. Engbretsen et al found that an extra-articular reconstruction decreased the forces going through an intra-articular reconstruction by 43% in vitro.

Marcacci’s technique used a hamstrings graft as an intra-articular reconstruction combined with an extra-articular augmentation. (Fig. 5.) The semitendinosus and gracilis tendons were harvested but left attached to the tibia. They were passed through the tibial and femoral tunnels, before being passed laterally and then deep to the ITT to be fixed onto Gerdy’s tubercle. This technique avoided some of the problems associated with using an ITT graft, such as donor site morbidity and cosmesis. Their post-operative regime consisted of proprioceptive exercises, strengthening and an average return to sports at four months. Their ten-year results do not show significant degenerative changes of the lateral compartment. They concluded that a combined extra- and intra-
articul ar repair is a valid surgical option. Similar techniques using extra-articular tenodesis with the same hamstring grafts have been described by others.90

There are few studies with direct comparisons between the different techniques. Roth et al58 compared isolated intra- with combined intra- and extra-articular reconstruction. They concluded that there was no benefit in using an additional extra-articular repair. However, there was no indication as to why some patients had an isolated intra-articular reconstruction and some had a combined procedure. Strum et al59 compared 43 patients who had a combined repair with 84 who had an isolated intra-articular reconstruction, and found no difference in outcome. Other studies have also not shown a benefit of an additional extra-articular reconstruction.57,59

Johnson and Smith66 identified the outcome measures used in publications relating to the ACL and found 54 different scoring methods, many of which were not validated. Thus comparison of different reconstruction techniques remains difficult.

The future
It is our impression that the use of additional extra-articular procedures is increasing, especially in revision cases and sometimes also in challenging primary cases. The anatomy and biomechanics of the structures that contribute to resistance to the pivot shift remain undetermined. Before considering any new procedures using extra-articular reconstruction, a detailed knowledge of the anterolateral structures around the knee is required.

Once the anatomy and biomechanics of this area have been established it may be possible to devise a more ‘anatomical’ ACL reconstruction taking into account the specific structures which have been damaged, and to allow repair of these tissues in acute cases. This may alleviate the previous problems with extra-articular reconstruction both in terms of stability and prevention of long-term degenerative change in the lateral compartment. It would also be possible to develop more appropriate post-operative rehabilitation regimes with this knowledge. When reconsidering the main criticisms of extra-articular procedures outlined above the following should be borne in mind:

First: if more anatomically or biomechanically appropriate extra-articular reconstruction techniques are developed this may reduce failure and recurrence rates when used in conjunction with an intra-articular reconstruction.

Secondly: the previous concept of lateral ‘overtightening’ causing degenerative changes in the lateral compartment is unlikely to be correct, especially with modern rehabilitation avoiding immobilisation and joint contracture. If performed concomitantly to an intra-articular ACL reconstruction, over tensioning of an extra-articular tenodesis is less likely, therefore guarding against fixed subluxation seen in isolated extra-articular reconstructions. The authors believe that isolated extra-articular lateral tenodeses were associated with isolated chondral degeneration because the tenodesis alone cannot restore normal kinematics while the intra-articular ACL deficiency persists.

Thirdly: the inability of an isolated extra-articular reconstruction to restore anterior tibial translation to normal, while also not over-constraining rotational laxity, will be avoided by always using an intra-articular ACL reconstruction.

Fourthly: concerns regarding donor site morbidity and cosmesis58,60 may be overcome by new ‘minimally-invasive’ techniques, which are likely to involve ‘tunnelling’ of grafts deep to the ITT. We now consider a combined reconstruction in patients with hyperlaxity and those requiring revision ACL reconstruction.

Computer-assisted surgery may help to validate the use of extra-articular augmentation in the future.60,88

Conclusion
Intra-articular ACL reconstruction is a popular and effective procedure. However, attempts to improve its results and obtain a more kinematic restoration of function must address the extra-articular structures that contribute to the pivot shift phenomenon. Further anatomical, biomechanical and radiological knowledge of these structures may help inform the development of extra-articular ‘anatomical’ augmentation of ACL reconstruction. This may be a key factor in providing a more biomechanically faithful restoration of the knee.

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