Anterior cruciate ligament reconstruction: a personal perspective

Steve Bollen

Abstract

Anterior cruciate ligament reconstruction has undergone an evolution over the past 30 years. As Winston Churchill said, 'those who do not learn from history are condemned to repeat its mistakes.' and it is cogent to understand something of the history in order to put current 'advances' into perspective. As we have come to understand more about the structure, function and biomechanics of the native ligament, various techniques have been developed to try and mimic the behaviour of the native ACL. It is an unusual procedure in that the operation developed 30 years ago is still the operation that has the best survivorship according to the 'big data' recently coming out from registry studies. Currently the focus is on trying to improve ligamentization and biologic fixation using adjuvant biological techniques.

Keywords anterior cruciate ligament; biologic enhancement; biomechanics; history; repair; surgical technique

When I was a senior registrar in Leeds, expressing an interest in knee ligament surgery was not viewed with much enthusiasm by my trainers. The professor told me the anterior cruciate ligament (ACL) was 'the most overrated piece of fascia in the body' and another consultant I worked for expressed the opinion that all sports injuries were self-inflicted and the answer to all problems was 'better quads'. Indeed, he told me I was wasting my time going to Australia to do a fellowship in arthroscopic surgery (with Leo Pinczewski!) as 'you can't possibly see as much through a hole 5 mm wide as you can through an incision 15 cm long'!

Fortunately for my career, these opinions have proved baseless and the number of ACL reconstructions in the UK has been climbing steadily over the last 20 years. According to PubMed, the amount of annually published literature has seen a similar growth, roughly doubling every 10 years from 148 papers in 1987, to 1522 in 2017.

The first publication in the English literature describing ACL reconstruction was published in 1917 by the great Hey-Groves.[1] Following this, there are scattered references over the next 50 years, but it was not really until the 1970s that interest was revived and our understanding of structure and function started to grow.

In that fallow period, one piece of literature stands out: 'On Injuries to the Knee Joint' by Ivar Palmer.[2] This is a masterpiece of clinical observation and scientific thought, and I would urge anyone interested in this subject to seek it out.

The 70s and 80s saw a proliferation of papers on the biomechanics of the ACL, with an appreciation of the key points: that the ACL is the primary restraint to anterior translation of the tibia on the femur; that it is made up of two main functional bundles (the posterolateral taught in extension and the anteromedial taught in flexion[3]); how important the femoral attachment is in graft placement if you want to retain a full range of motion[4] (Figure 1); and that the pivot shift occurs because the ACL is no longer acting as the centre of rotation in the knee.[5] Ignoring these basic principles during reconstruction always leads to failure!

This period also saw an evolution of surgical techniques designed to restore functional stability. This started with 'the McKintosh' an extra-articular reinforcement[6] and moved on to the 'Jones', where the middle third of the patellar tendon is harvested but left attached at the tibial tubercle (Figure 2). It was Clancy who first described the technique we still use today, where the middle third of the patellar tendon is harvested as a free graft with a bone block at either end; the bone-patellar tendon-bone (BPTB) graft. It was David Dandy who then pointed out that this graft is always as long or longer than the native ACL.[7]

ACL reconstruction is not a difficult operation, but it is very easy to get wrong. As can be seen in Grood's paper, an error of placement of only a couple of millimeters can produce a restriction in range of movement, or a full range of movement can only be obtained if the graft is loose or broken. It is essential to remember that the biomechanical characteristics of the grafts we use are not the same as a native ACL, generally being much stiffer, and so the concept of isometricity is ignored at your peril. Also, our current techniques do not restore the normal proprioceptive feedback from the original ACL, and this may be one of the critical factors in rehabilitation and re-injury.

The tibial tunnel placement is not so critical, and straightforward to place through the old ACL footprint, but if placed too far forward within that footprint, the front of the notch can impinge in extension, leading to a loss of knee extension and attrition and breakage of the graft.

The biomechanical principles were often not understood or ignored, and rehabilitation was rudimentary, and hence the results of reconstruction for many through the 70s and 80s were poor. The graft was often blamed, and this led to the development of many different synthetic grafts; the argument being that there was no donor site morbidity, the graft was often as strong as it was ever going to be on day one, and mobility was resumed very quickly.

This sounded great, and a large number of these synthetic grafts were rapidly put in. Unfortunately, however, the outcomes were less than ideal! Partly because these grafts were very strong and stiff, any marginal error in placement led to rapid failure or over-constraint of the knee. Once they started to fail, there was often a biological reaction both in the synovium and the bone tunnels leading to significant problems in revision reconstruction (Figure 3).

For those of us doing a lot of reconstruction through the 90s, the middle BPTB graft remained the 'gold standard', until the advent of interference screw fixation for hamstring grafts,

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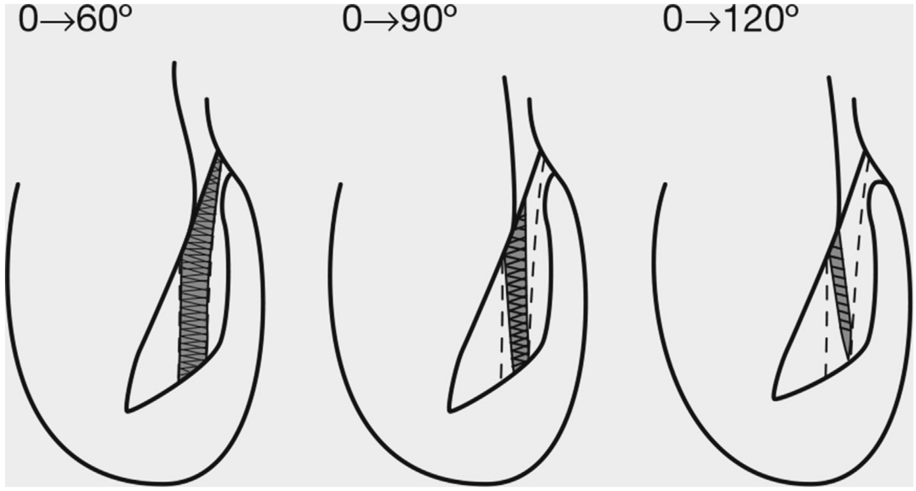

Figure 1 Grood's study, showing if you want a full range of motion you have a 2 mm window in which to place your graft.[4]

promoted by Leo Pinczewski.[8] The use of a hamstring graft is a more forgiving technique, and the popularity of this method of reconstruction rapidly took off.

The other major advance that was running parallel with advances in our reconstruction techniques was the improvement in rehabilitation. In the early 1990s it was not unusual for patients to be put in plaster or a brace for 6 weeks or longer, and on crutches for weeks on end. It was Don Shelbourne[9] who advocated 'accelerated rehabilitation' after critically reviewing his results and realizing that the patients who ignored the conventional rehabilitation protocols and rid themselves of their brace and crutches actually did better than patients who stuck with the standard regime. His new regime emphasized the importance of regaining a normal range of movement (particularly extension) as early as possible. This significantly reduced the morbidity and inconvenience of the procedure for the patient and, as is always the case in surgery, as the morbidity decreases, the relative indications for doing the procedure increase, particularly as successful 5-year outcomes in the region of 80–90% were being reported.

There is a small sub-group of these injuries where advances in treatment ran parallel with the general population, and this is the group who rupture their ACL before epiphyseal closure. The perceived wisdom at the time was that it was best to treat these patients conservatively until growth had stopped, and then reconstruct them with conventional techniques. It was Paul Aicroth[10] who pointed out that managing these patients in this way had a very high morbidity, with a high incidence of meniscal and chondral pathology at the time of their delayed reconstruction; a view subsequently borne out by further studies.[11] It was found that using a soft tissue graft with fixation placed either side of the growth plates actually has a very low incidence of growth plate disturbance, and these patients usually do very well.

One of the fascinating things that we do not yet understand is that the graft seems to grow with the patient and does not 'tether'

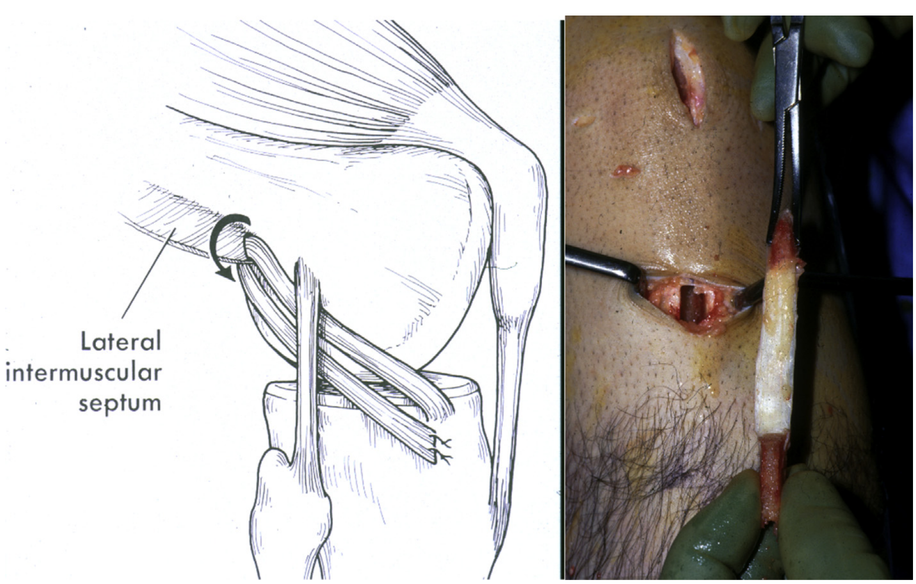

Figure 2 The original McKintosh reconstruction and a middle third patella tendon graft. Reprinted with permission from Wojtys EM (ed): *The ACL Deficient Knee*. Rosemont, IL. American Academy of Orthopaedic Surgeons, 1994.

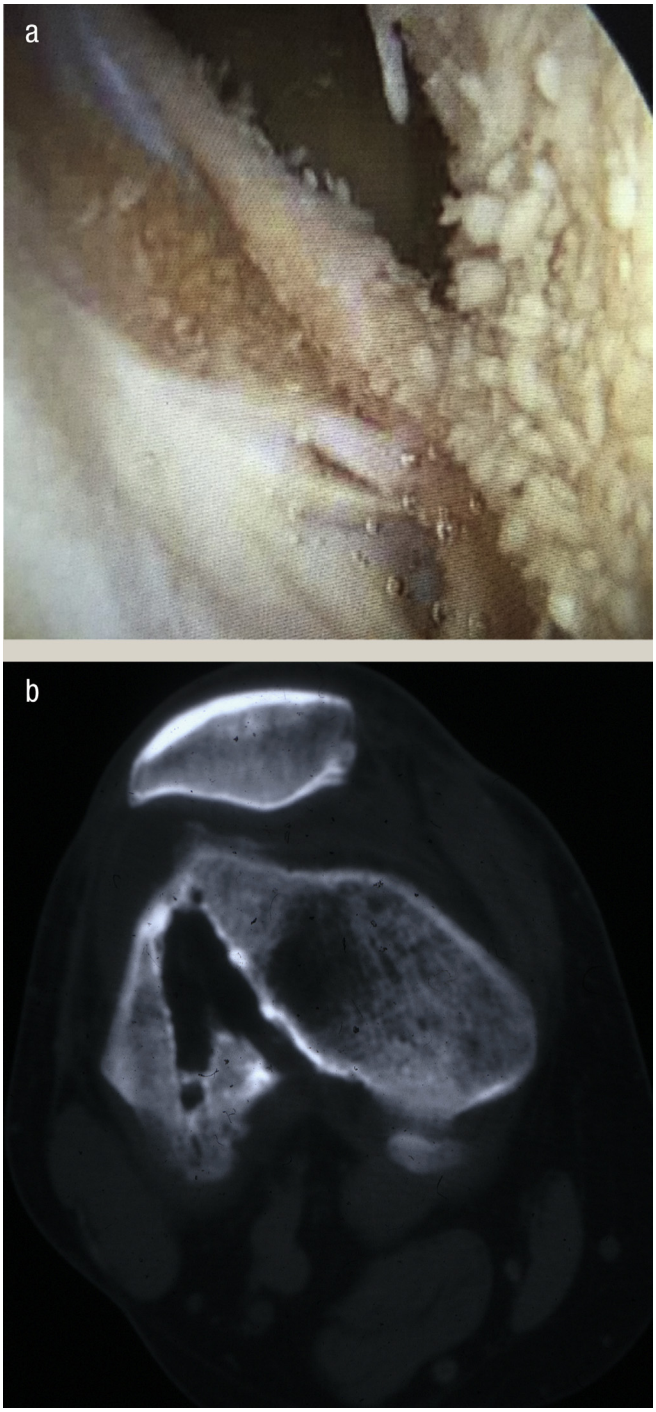

Figure 3 (a) Synovitis following implantation of a LARS ligament, and (b) osteolysis in the distal femur following a Gore-Tex ligament reconstruction.

the joint.[12] In my practice, I have had a patient grow 30 cm without any effect on the anatomy of the joint.

Over the last 20 years the debates have been about which graft is best and which techniques and fixations produce the best outcomes. ACL surgery, like any other type of surgery, has been subject to fad and fashion, many of which have turned out to be blind alleys.

In 2004 Savio Woo,[13] a biomechanical engineer from Pittsburg, demonstrated that dropping the femoral tunnel further down the clock face produced a better resistance to rotation of the tibia on femur, and we dutifully followed this sage advice. Those of us doing a lot of ACL reconstructions started to notice an increase in failure rate, particularly with hamstring grafts, and started to move our tunnels back towards the previous 'optimum' position – 1 o'clock for a left knee and 11 o'clock for a right (my current practice is to aim for 10.30 and 1.30!).[14]

The first major proposed advance was the 'double tunnel' hamstring reconstruction technique pioneered by Phillipe Colmbet in Lyon. The argument went that the functional anatomy of the ACL could be reproduced better by having two tunnels, recreating the anteromedial and posterolateral bundles.[15] This sounded a great idea and was embraced with enthusiasm across the knee reconstruction world. Unfortunately, initial promising results were short-lived and much higher failure rates were reported, particularly of the posterolateral bundle reconstruction, where tension patterns generated on rotation in a stiff graft often produced traumatic rupture.[16] This technique now seems largely to have fallen out of favour.

The next 'improvement' in hamstring technique to be advocated was the 'anatomic reconstruction', where X-ray control or direct measurement is used to place the graft in the centre of the ACL footprint on the femur, promoted by Charlie Brown (Figure 4).[17] Unfortunately, despite theoretical advantages, the initial promise was not fulfilled, with a higher failure rate than standard techniques.

In the UK, the main argument was still whether hamstring grafts or BPTB grafts produce better outcomes. In the USA these competed with allografts (not in the UK, probably because of cost) where in the region of 30% of all primary ACL reconstructions were with allografts. Again, this sounded great, with no donor site morbidity and faster operating times, but in the USA the vast majority of the allografts were sterilized with radiation. This undoubtedly affects the strength of the graft, and failure rates in the region of 30% were being reported.[18] This does not seem to be the case if the grafts are fresh frozen, which we can get in the UK through the blood transfusion service. In the UK these are rarely used for primary reconstruction, however, because of the cost compared with that of an autograft (which is 'free').

There have been one or two recent additions to our understanding, mainly to do with associated pathology. In 2010 a single-surgeon observational study was published describing the association of posteromedial meniscocapsular injury with ACL rupture (Figure 5).[19] Biomechanical studies have subsequently shown this to have a significant effect on the laxity of the knee.[20]

In 2014 the lay press announced, with great excitement, the discovery of a 'new ligament' associated with ACL injury: the 'anterolateral ligament' (ALL).[21] It had of course been described in the 19th century by Segond, but once again the concept was embraced with enthusiasm and its routine reconstruction advocated by many surgeons.

Unfortunately, the practice has not matched the theory. Biomechanical studies have shown that the ALL has little contribution to knee stability[22] and the ALL reconstruction techniques advocated are poor in achieving their aims.[23] A modified Lemaire technique, however, may reduce certain laxities associated with ACL injury,[24] but as yet no long-term clinical studies are available.

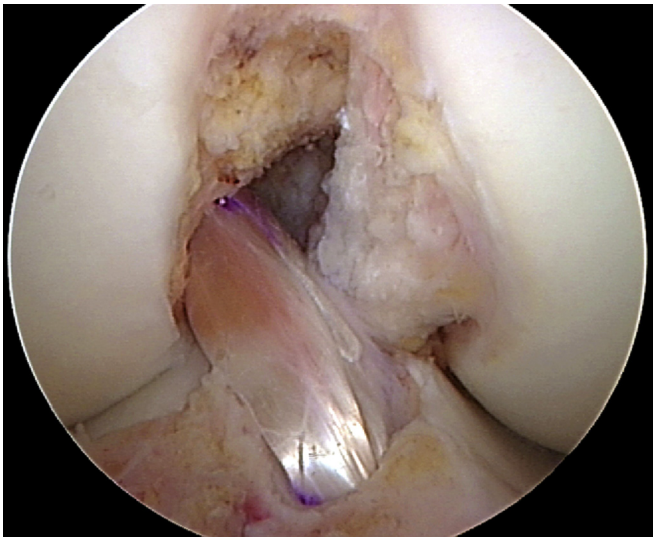

Figure 4 An 'anatomic' anterior cruciate ligament reconstruction.

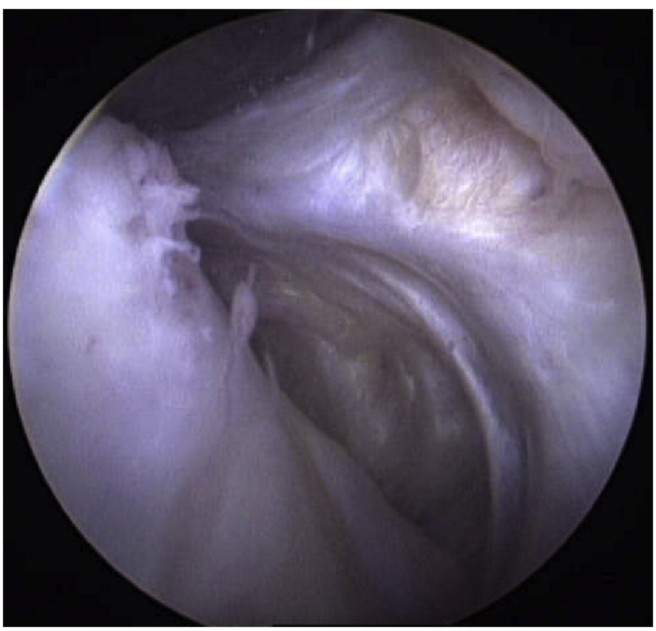

Figure 5 An arthroscopic view looking into the posteromedial recess of the right knee, showing a meniscocapsular tear.

Current debate continues about graft choice and technique, and in particular if some form of lateral reinforcement is needed for particularly lax knees, high-risk individuals and revision procedures. We do not as yet know the answers to this question, although studies from the 1990s showed no real advantage to this approach.[25,26]

The last 10 years or so have seen the development of ligament registries, which may help us to reach some conclusions. Large registry studies seem to show that BPTB grafts have a better survivorship,[27] and recently published 20-year outcomes using these grafts are reasonable.

We do know that a well-placed BPTB graft can restore an ACL-deficient knee to normal laxity patterns,[28] and there is a trend to preserve as much of the torn ACL as possible, which may improve outcomes further.[29,30]

In the last few years we have seen the re-emergence of ACL repair following injury, which is being enthusiastically promoted by some orthopaedic product companies. Once again, we are in danger of ignoring the original basic research on repair, which shows that in ACL injury, whatever its pattern, healed tissue does not return to normal, as resorption occurs very rapidly once the torn synovial sheath exposes the damaged ligament to synovial fluid.[31] Any healing that does occur is scar, which does not remodel, or at best only remodels over a period of years. Protecting the 'healing' ligament with an 'internal brace' merely stress shields the healing ligament, something we learned a long time ago, when the 'ligament aumentation device' went through a short period of widespread use.

When the stiffer 'brace' breaks, two adverse events occur. The 'healed' ligament is biomechanically unprepared for the sudden increase in applied loads, and particulate debris is introduced to the joint, which we have already seen, is not something the joint tolerates well.

A novel technique that recognizes and takes into account the resorption of the torn ligament ends is the 'bridge-enhanced ACL repair' (BEAR) technique.[32] This technique uses a sponge-like scaffold to absorb blood and stabilize clot, rendering it able to conform and fill the irregular contours of the gap between the torn ligament ends. Although good 'mid-term' clinical results have been published, this study only ran out to 6 months post-repair.[33]

There has been much recent work to see if we can biologically augment ACL grafts to enhance osseointegration and intra-articular 'ligamentization'. These have included growth factors, stem cells, gene therapy and a variety of other techniques.[34]

The use of platelet-rich plasma (PRP) has many advocates, particularly on the continent, and its use has been promoted in multiple pathologies including tendonitis, osteoarthritis and ligament reconstruction. It has been suggested that PRP may promote osseointegration and ligamentization of the graft. A large

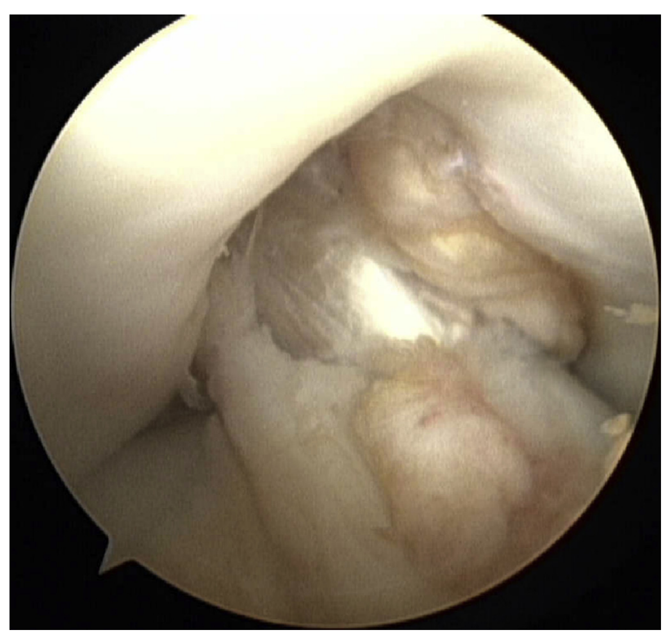

Figure 6 A bone-patellar tendon-bone graft routed through the remains of the old anterior cruciate ligament.

randomized controlled trial, however, failed to demonstrate any improvement in radiological graft healing or laxity on clinical assessment.[35]

There has been much preclinical research in the form of animal studies, which seem to show an advantage to using some of these adjuvant techniques, but to-date no clinical study, other than preserving as much of the old ACL stump as possible (Figure 6), has shown any tangible benefit to their use in patients. There is still a lot of work to do!

Even stem cells and gene therapy, which seem to herald such great advances in many other fields of medicine (and in rabbits), and which have been shown to enhance tendon-bone healing,[36] have not, to date, been shown to offer any great advantages in any clinical trials.[37]

We know that current techniques of ACL reconstruction do not prevent accelerated degenerative change occurring or restore normal knee biomechanics. At the current time we have techniques for restoring functional stability that have high success rates and good medium to long-term outcome; however, all of this may become academic when one day we eventually manage to produce a synthetic collagen graft that truly mimics the normal anatomy and biomechanics of the native ACL. Hand-in-hand with some genetic manipulation, this may enable us to actually restore our patients closer to normality – this is the holy grail of soft tissue knee surgeons! ◆

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