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EDITORIAL

A long journey to be anatomic

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In 1836, Weber and Weber from Göttingen, Germany performed dissection studies and described the anterior cruciate ligament (ACL) as two separate bundles that tension at different knee flexion angles [21, 33]. Many years later in 1912, the first ACL reconstruction was performed by Giertz, the mentor of Palmer, using a single-bundle of tensor fascia lata [5]. In 1917, Hey-Groves used an open ACL reconstruction technique that was "quite" anatomic [9]. He used tunnels to locate the graft, drilling the femoral tunnel inside-out, aiming to place the tunnel aperture on the outer aspect of the notch to produce an oblique graft. In 1938, Palmer proposed the idea of double-bundle reconstruction in his thesis on the ACL [20], though the concept received little attention at the time and his work was not appropriately accredited until many years later.

The first arthroscopically assisted ACL reconstruction was performed in 1980 by Dandy [4]. However, arthroscopic surgery was far more challenging than open reconstruction. Arthroscopic anatomic reconstruction of the ACL has a learning curve, as Snow et al. demonstrate in their paper [26]. Surgeons and industry started focusing on developing standardized techniques to facilitate easier and more efficient graft placement, employing techniques such as the o′clock reference, notchplasty, isometry and drill guides. Some of these terms like the o′clock reference and isometry turned into almost mandatory but often misleading technical descriptions. The resulting surgical techniques were indeed fast and efficient, but as Behrend et al. [2] show in their study on the over-the-top guide, unable to place the tunnels in the ACL insertion site. It was such techniques that lead the field away from the teachings of Weber, Palmer and their colleagues. Anatomic tunnel placement was not a priority, and the two-bundle anatomy of the ACL was never considered.

This had surgeons asking: "Does anatomy matter?" since the general consensus was that these arthroscopic techniques were effective for restoring knee function. However, as longer-term follow-up data and better kinematic analysis techniques emerged, it has become clear that conventional non-anatomic ACL reconstruction techniques do not prevent the development of early osteoarthritis after ACL injury [6, 14, 16] nor do they restore normal dynamic knee function [27]. These results indicate that our reconstruction techniques need to be improved and *restoring anatomy may be the key to success*. Therefore, efforts to make reconstruction techniques more anatomic as well as critically evaluate them, such as by Silva et al. [24, 25] and Serrano-Fernandez et al. [23], should be applauded.

"Anatomic" ACL reconstruction can be defined as the functional restoration of the ACL to its native dimensions, collagen orientation and insertion sites (Fig. 1) [29]. It is a detailed and meticulous procedure that involves visualization of the native ACL insertion site, measuring ACL and knee dimensions, appropriate graft tensioning and evaluation of graft and tunnel position using MRI and 3D CT scan. It encompasses single- and double-bundle reconstruction and can be applied to primary, revision and augmentation surgery. The development of the anatomic technique has made us take a closer look at the ACL anatomy. Just a few years ago, you would not have seen

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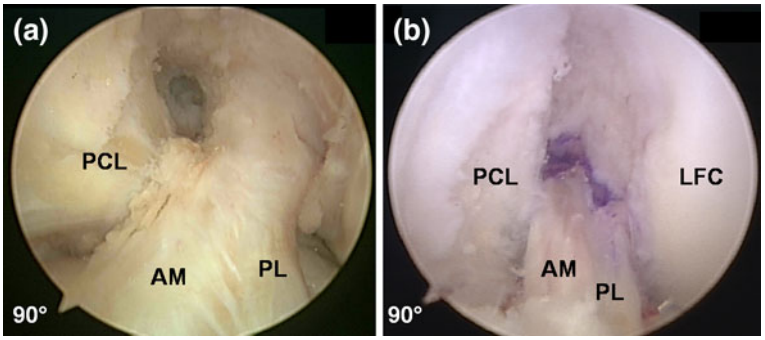

Fig. 1 **a** Arthroscopic view of the native ACL of a left knee through the anteromedial portal (knee in 90° of flexion). The two bundle anatomy of the ACL is clearly visible. **b** Arthroscopic anteromedial portal view of the ACL of a left knee after anatomic double-bundle reconstruction (knee in 90° of flexion). When compared to Fig. 1a, the native ACL anatomy is closely replicated. *AM* anteromedial bundle, *PL* posterolateral bundle, *LFC* lateral femoral condyle, *PCL* posterior cruciate ligament

papers such as by Iriuchishima et al., studying the anatomy of the ACL insertion site in such a detailed fashion [10] and Kasten et al. who evaluated the location of the tibial ACL insertion site using intra-operative fluoroscopy [12].

Anatomic ACL reconstruction also needs to consider concomitant injuries, bony morphology, neuromuscular control and homeostasis of the knee. Bony landmarks include the lateral intercondylar ridge and lateral bifurcate ridge, indicating the superior border of the femoral ACL insertion site and the border between the AM and PL bundle, respectively. These two structures are still visible in chronic ACL injuries, when the remnants of the ACL may be gone, according to a study by Van Eck et al. [32]. In ACL reconstruction, other ligamentous structures of the knee should also be evaluated for injury in case of ACL rupture. As demonstrated by Lertwanich et al. [15] in addition to the posterior cruciate ligament (PCL), the meniscofemoral ligament (MFL) also plays an important role in maintaining posterior stability of the knee. Not only the anatomy of the ACL is important but also that of surrounding structures, like the femoral intercondylar notch. The two papers by Van Eck et al. evaluate different measurement modalities of the notch, such as notch width index (NWI), volume and shape, and how these can aid us in the treatment of ACL injuries [30, 31]. Kendoff et al. [13] showed in their study that even changes in alignment can have an effect on the ACL, with valgisation affecting the length and strain of the PL bundle.

To evaluate our progress, reliable and accurate outcome measures are needed. The appropriate use of these outcomes measures is equally important. If we as surgeons want the best care for our patients, we have to be critical of our own performance. Systematic reviews and meta-analysis comparing different ACL reconstruction techniques all show no difference in outcome [7, 8, 17, 22]. Does this mean that there is no difference, or do we need to reevaluate the ability of our outcome measures to detect subtle differences in kinematics of the knee, that in the long term may be associated with the development or prevention of post-traumatic osteoarthritis? The IKDC Knee Ligament Guidelines suggest that joint laxity, such as for the pivot shift, Lachman and KT-1000 arthrometer tests be reported as normal, nearly normal, abnormal or severely abnormal in comparison with the contra-lateral normal knee. However, when results are reported in the literature, normal and nearly normal outcomes are often combined into a single group, implying that "nearly normal is good enough" [11, 17]. But is "nearly normal" good enough? To answer this question, we may need more precise instruments, such as optical coherence tomography [3] and T2 and T1rho MRI mapping [1] to detect early cartilage changes and dynamic stereo radiographs to precisely quantify in vivo knee kinematics [28]. Our clinical examination can vary largely by observer [19] and as Musahl et al. showed in this issue, it is also significantly influenced by bony morphologic variations [18]. High-quality studies making use of precise outcome measures are needed to make valid conclusions regarding the benefits of anatomic ACL reconstruction. For example, to know if double-bundle reconstruction is superior to single-bundle reconstruction, prospective randomized trials are needed to compare *anatomic* single-bundle reconstruction with *anatomic* double-bundle reconstruction. To avoid bias in assessing outcome, these studies need to be double-blind, implying that both the patient and the individual measuring the outcomes is not aware if single- or double-bundle surgery was performed. Most importantly, we need to continue to modify our technique as more information about structure and function of the ACL becomes available. It is important to learn from the past and not let history repeat itself. It is a long and continuing journey to be anatomic. We have lost sight of the anatomy once; let us not repeat this mistake!

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