Symposia on “ACL Femoral Footprint Revisited: For Accurate/Anatomical Tunnel Creation”

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Anatomic ACL reconstruction

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How I use the ACL footprint in ACL reconstruction

**Ferretti, Mario**
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ACL reconstruction using the native ACL insertion sites

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Anatomic single-bundle reconstruction using the ACL footprint

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Anatomic double-bundle reconstruction using the ACL footprint

Discussion and possible presentation of cases by the entire panel (10 min)
Anatomic ACL Reconstruction
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Anatomic Double Bundle ACL Reconstruction
- Pre-operatively, the ACL insertion site and ACL length can be measured on the sagittal MRI. The ACL inclination angle can also be measured, as can be seen further below.

- The MRI can also be used to measure the size of the certain autografts. Both the patellar tendon and the quadriceps tendon size can be measured on the sagittal MRI sequence. As can be appreciated below, the quadriceps tendon is often much larger than the patellar tendon and can offer more autograft substance.
Anatomic double-bundle ACL reconstruction is an “Insertion Site Surgery”. We utilize three portals: Lateral Portal (LP), Medial Portal (MP), and Accessory Medial Portal (AMP).

We routinely place the arthroscope in the MP and work through the AMP. In doing so, visualization of the femoral insertion of the ACL is greatly enhanced and the need for notchplasty is virtually eliminated.¹

The anatomic insertion sites of each native ACL bundle are marked on the femur and tibia with a thermal device, with care taken to preserve the border of the bundles for later reference. This is a critical step in identifying the correct placement of the tunnels, and is performed prior to resection of any residual ACL tissue. In addition, the length and width of the AM and PL bundle insertion site are measured as references to decide tunnel diameters. The surgery is individualized for each patient.

There is a large area on the lateral wall of the intercondylar notch for potential non-anatomic tunnel placement. Our preliminary data suggested that it may occupy more than 65% of the area on the wall.

A “lateral bifurcate ridge” is often seen on the femoral insertion between the AM and PL bundles, whereas a “lateral intercondylar ridge” is often seen on the upper limit of both the AM and PL bundles. These are useful surgical landmarks in addition to the native insertion fibers.²⁻³

Notchplasty destroys the femoral anatomy of the ACL and is not necessary if medial and accessory medial portals are used.
- The tibial and femur tunnels are placed at their native insertion site, which were previously marked by thermal device.
- The PL femoral tunnel is always drilled through the anteromedial portal. The primary advantage of drilling trans-tibially for the AM femoral tunnel is the creation of a longer tunnel which diverges from the PL femoral tunnel, and we routinely attempt this approach first before using the accessory medial portal. However, sometimes it can’t reach the anatomic insertion site. In that case, the tunnel will be drill through the anteromedial portal.
- Finally, the PL graft is passed first, followed by the AM graft. Femoral fixation is typically performed with an EndoButton.
- Post-operatively, the MRI can be used to compare the pre- and post-op insertion site size to measure how much of the insertion site is restored. In addition, the pre- and post-operative inclination angle can be compared. After anatomic ACL reconstruction, the ACL inclination angle should be similar to the native ACL inclination angle.

3D CT scan can be used to evaluate tunnel position.

**Anatomic Single Bundle ACL Reconstruction**
- Except for the one bundle augmentation (performed when only one of the two native bundles are torn), there are a few other scenarios where we prefer to perform single bundle surgery (30%).⁴
- Small native ACL insertion site (< 14mm)
- Open growth plate
- Severe arthritic changes
- Multiple knee ligament injuries
- Severe bone bruises
- Narrow intercondylar notch

- Our single bundle surgery is performed with careful attention to soft tissue and bony landmarks. We carefully investigate the rupture pattern of the ACL and we identify the native ACL insertion sites -- just as we do in double bundle ACL surgery. Then, the tibial tunnel is placed at between the native insertion sites of the AM bundle and PL bundles, or at the center of the entire tibial insertion site.

- The distance from anterior margin of ACL footprint to center of tibial tunnel should be measured, and the femoral tunnel should be placed at the same distance from the posterior margin (knee in 90° flexion) of the femoral ACL footprint.

**One Bundle Augmentation**
- In cases only the AM or the PL bundle was torn, we save the intact bundle and “augment” the ACL with a single bundle reconstruction – either the AM or PL, whichever one is torn.

**Biological Enhancement**
- Typically the graft heals to the bone through bleeding created by drilling the tunnels.
- We have begun using a “fibrin clot” to try to enhance the healing of the two bundles together and to the bone.
- A fibrin clot is created from the patient’s own blood by gently stirring it in a glass beaker for 5 – 10 minutes and contains many of the same growth factors advertised as being present in commercially available blood preparation products, such as platelet rich plasma (PRP).
References:
Use of the resident's ridge as an arthroscopic landmark of the anterior border of the ACL femoral attachment

K. Shino, MD
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The resident’s ridge is a nearly-longitudinal ridge, 3 quarters of the way back on the roof to lateral border of the notch. The idea to use this ridge as a landmark of the anterior border for femoral tunnel placement is not new but was already described by Clancy et al some years ago. However, the technique to arthroscopically identify the resident’s ridge without bony notchplasty in patients with chronic ACL insufficiency had not been established.

We developed a technique to find out a linear ridge running proximo-distal in a posterior one-third of the lateral notch wall by removal of superficial soft tissue with radiofrequency energy. We created a socket with a rectangular aperture of 5 × 10 mm just behind the ridge. Postoperatively, three-dimensional computed tomography (3-D CT) was taken to geographically identify the location of the
ridge using the socket as a reference.

Arthroscopically, a linear ridge running from superior-anterior to inferior-posterior on the lateral notch wall was consistently observed 7-10 mm anterior to the posterior articular cartilage margin of the lateral femoral condyle. The 3-D CT pictures proved the arthroscopically identified ridge to be the resident’s ridge. As the resident’s ridge is arthroscopically identifiable after non-mechanical removal of the soft tissues without bony notchplasty, it could be used as a useful landmark for anatomical femoral tunnel drilling in arthroscopic ACL reconstruction.
Anatomic single-bundle reconstruction using the ACL footprint:

The Ruler technique

Tim Spalding

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Introduction

Identification of the lateral intercondylar and bifurcate ridges which act as osseous landmarks has been shown to be an accurate and reliable method to locate the native ACL femoral insertion site [1] and the true entry point for the femoral tunnel. The presence of these ridges is however variable and they may not be seen [2]. Reports describe identifying and lateral intercondylar ridge in 100% of 60 knees at arthroscopy and the bifurcate ridge in 82% in one series [1] and then 88% and 48% respectively in another [3].

In the absence of consistent intra-operative visualisation, knee surgeons have used a variety of methods such as preoperative and intra-operative radiographic images, computer navigation and arthroscopic measuring devices with triangulation to locate the native ACL femoral insertion site [4-7]. Radiological techniques utilise the Bernard-Hertel radiographic quadrant method on a true lateral image to define the insertion point of the ACL [8]. This requires an intra-operative true lateral view on an image intensifier which although accurate, adds to the complexity and cost of the procedure making it potentially unpopular. Use of 3D CT has been used to validate femoral tunnel position post operatively [9 - 11].

Kaseta et al. noted that the center of the ACL was within 2mm of an arthroscopic reference point located at the junction of a line drawn distally from the most proximal corner of the articular margin on the lateral wall of the notch and a perpendicular line drawn to the most posterior point of the condyle [12]. This study along with observations of the anatomy of the femoral attachment of the ACL by Freddie Fu and Charlie Brown led to the development of the Ruler Technique for localizing the start point of the femoral tunnel guidewire. We have validated this technique using post-operative 3D CT scans comparing the tunnel position to published radiographic measurements and to our previous antero-medial portal surgical technique using an offset guide.

The Ruler Technique: operative procedure

Ipsilateral semi-tendinosis and gracilis tendons are harvested and prepared into a four-strand graft using a whip-stitch.

Three arthroscopic portals are then made in the knee to allow optimal vision and instrumentation. A high anterolateral (AL) portal is made at the level of the inferior pole of the patella, adjacent to the lateral border of the patellar tendon. A high anteromedial (AM) visualization portal is inserted at the level of the inferior pole of the patella, adjacent to the medial border of the patellar tendon. Finally an accessory anteromedial portal (AAM) is located inferior and medial to the anteromedial portal just above the level of the medial meniscus [13]. This portal is made under direct vision to avoid damage to the medial meniscus.

The notch is then prepared by using an arthroscopic shaver device to remove scar tissue and the remaining ACL stump with care taken to preserve the bony anatomy (Figure 2a). A radiofrequency probe is then used to remove the residual ACL stump and to identify the proximal margin of the articular cartilage as a specific reference point.
A 6mm wide arthroscopic ruler (Smith and Nephew, Andover, MA) curved to shape is then inserted through the AL portal and placed against the lateral wall of the notch and viewed through the high AM portal. Ensuring the knee is flexed to 90 degrees, the tip of the ruler is positioned deep in the notch at the identified and prepared junction of the proximal articular margin and the femur (Figure 2b). This is slightly lower on the arthroscopic view or more posterior anatomically than the “over the top” point. The length of the femoral condyle from deep in the notch to shallow (anatomically proximal to distal) is then measured on the “high” side of the ruler and the mid point is then marked with a microfracture awl inserted through the AAM portal (Figure 2c).

The height of the entry point is determined by the diameter of the tunnel. We aim to leave a 2mm bridge of bone between the tunnel wall and the articular margin on the low (anatomically posterior) aspect of the notch. This usually corresponds to the top edge of the arthroscopic ruler. A drill tip guide wire with an eye in the opposite end is inserted through the AAM portal and tapped 2-3mm into the mark (Figure 2d) and the knee is then flexed to 120 degrees and the guide wire is drilled out through the lateral condyle and skin.

The wire is over drilled with the 4.5mm endobutton drill and the length measured by hooking the drill part of the endobutton drill on the lateral cortex and deducting 10mm from the measurement viewed with the arthroscope (Figure 2e). An appropriately sized drill is then used to create the femoral tunnel taking care not to scuff the articular surface of the medial femoral condyle (Figure 2f). The resulting femoral tunnel can then be visualized at the mid-bundle position with the knee repositioned at 90 degrees of knee flexion. A lead suture is passed in to the mouth of the tunnel (Figure 2g).

The exit point of the tibial tunnel into the knee is referenced from just anterior to the posterior rim of the anterior horn of the lateral meniscus, within the midpoint of the tibial footprint. The graft is attached to an endobutton (usually 15mm), passed through the knee and fixed in the tibia with the knee in extension using an interference screw (Figure 2h).

Results of 3D CT Scan Analysis:
Final femoral tunnel position in 50 patients

Between 6 and 12 weeks following surgery, a 3D CT scan was obtained in 50 patients following surgery, using a slice acquisition thickness of 1.25mm – the Anatomic group. The scan was then orientated into a true lateral position so that both condyles were superimposed and the medial femoral condyle removed.

CT analysis was performed in an additional sixteen patients in whom the femoral tunnel had been located by using a 5mm offset jig referenced from the posterior wall of the notch – the Traditional group.
The centre of the femoral tunnel was then determined using the grid system described by Bernard and Hertel [8]. The grid was positioned so that the superior arm was positioned against the roof of the notch corresponding to Blumensaat’s line and the posterior section against the posterior aspect of the lateral femoral condyle. The location of each tunnel on this grid was recorded expressed as co-ordinates along Blumensaat’s line from proximal to distal and along the opposite axis for anterior to posterior (Figure 3).

The mean positions for the ‘anatomic’ group and the ‘traditional’ group were then calculated and related to the optimal position. We determined this optimal position by the mean co-ordinates reported by previous authors (Table 1) [7, 8, 11, 14, 15, 16].

**This put the mean mid bundle position at point 28% on the proximal to distal axis and 35% on the perpendicular axis.**

Table 1) The co-ordinates of the ideal position of the ACL insertion on Bernard and Hertel’s grid as reported in the literature.

<table>
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Statistical analysis of the distance from the centre of the tunnel to the ideal literature point was performed using the Mann-Whitney U test for the independent, continuous data and analysed using Statistical Package for Social Sciences (SPSS, Chicago, Il).

The positions of the 50 femoral tunnels in the Anatomic group are shown in Figure 4 compared to the positions of 16 in the Traditional group in Figure 5. The average position of the femoral tunnel in each group is shown in Figure 6.

The distance between the Anatomical tunnels (5.95 units) were significantly closer to the ideal literature point than the Traditional group (16.17 units) P<0.001.

**Figure 4) The distribution of the mid tunnel points of the femoral tunnels using the anatomic technique.**

**Figure 5) The distribution of the mid tunnel points of the femoral tunnels using the traditional method.**

**Figure 6) The average positions of the femoral tunnels using both the anatomic (Green 30,35) and traditional (Yellow 30,17) methods compared to the optimal average position from the literature (Blue 27.34).**

Though we have not measured this for each patient, the distance of the mean spot of the ‘anatomic’ group to the “optimal position” (Table 1) was 0.9mm compared to 5mm in the ‘traditional’ group in a male with an average sized femur.

**Discussion**

We have described a new technique to reliably position the femoral tunnel in the mid bundle position of the ACL insertion on the lateral wall of the intercondylar notch. An arthroscopic ruler is used to measure the depth of the lateral wall and the tunnel is drilled at the midpoint of this line. Quantification of the centre of the resulting tunnel on specific 3D CT scan reconstructions has shown that the technique reproducibly places the tunnel close to the anatomic centre of the insertion as defined radiographically [9-11] using the grid method popularized by Bernard and Hertel [8]. When we compared this anatomic position to the position determined by using a 5mm offset guide inserted through the anteromedial portal and into...
the “over the top position”, there was a substantial difference in tunnel location.

The advantage of this current reported technique is that it produces an accurate mid footprint placement of the femoral tunnel. The technique is readily teachable and reproducible with a close grouping of the measured points on the overall grid placed on the cutaway 3D reconstruction scan image.

Conclusions

The use of the ruler technique produced femoral tunnels comparable to published radiographic criteria used for tunnel placement and is reproducible and accurate. Our study has demonstrated that the ruler method is a safe, simple, quick and cost effective method for the establishment of an anatomical single-bundle ACL femoral tunnel.

Acknowledgments

Charlie Brown, Abu Dhabi, UAE
Jonathan Bird, Knee Fellow UHCW England
Simon Spencer, Knee Fellow UHCW England
Pete Thompson, Knee Surgeon UHCW

References


Anatomic double-bundle reconstruction using the ACL footprint.

The Concept of Complete Footprint Restoration with

Guidelines for Single - and Double Bundle ACL Reconstruction

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The “classical” SB procedure is performed by drilling the bone tunnels according to the diameter of the graft without considering the relationship between the size of the natural insertion site area (ISA) and the reconstructed area. This results in a randomized reconstruction of the original ACL footprint.

However, several biomechanical studies showed that different ACL fibres add different to knee function. Consequently – by placing bone tunnels in a defined position of the ACL footprint the surgeon defines the biomechanical envelope of the ACL reconstruction.

To restore a maximum amount of stability and function we developed the concept of “complete footprint restoration”. It is based on the hypothesis, that the restored biomechanical envelope of the knee is a function of reconstructed ISA. The presentation introduces the new concept and defines indications for SB and DB ACL reconstruction based on the individual size of the ACL insertion sites. An “insertion site table” with guidelines for graft sizes and drill angles was designed to match the surgical technique to the individual ACL insertion sites of the patient.

Guidelines for Single Bundle and Double Bundle ACL Reconstruction

The surgically restored ISA of the ACL is defined by the width and the length of the oval bone tunnel outlet(s), which is a function of the drill (graft) diameter and drill angle. The average width of the native tibial and femoral insertion sites is between 9 - 11 mm. As this
range is rather small it may sufficiently reconstructed by the width of the tunnel diameters during SB or DB ACL reconstruction in the majority of patients. However, big individual variations do exist for the long axis of the tibial ACL insertion site in anterior-posterior direction and for the long axis of the femoral insertion site in superior-inferior direction. The surgically relevant range is reported to be between 9 - 21 mm on the tibia and between 11 - 21 mm on the femur.

**Insertion site table**

The “insertion site table” (Table 1) presents guidelines for SB and DB ACL reconstruction based on the concept of “complete footprint restoration”. The length of the individual tibial insertion sites (first column) is matched to an individual drill (graft) diameter and drill angle (second column). Different grafts (third column) may be favourable depending on the size of the recommended drill diameters and individual patient requirements, e.g. kneeling profession, etc. The oval length of each articular bone tunnel outlet was calculated according to the formula: \( \text{drill size divided by } \sin \alpha \) based on a parallel alignment of the long axis to the sagittal plane from anterior to posterior (Table 1). Oblique drilling directions to the sagittal plane were not considered, as this complex the calculation significantly and may not play a significant role. The surgically restored insertion site length (last column Table 1) is displayed in milimeters and percentage of the native insertion site length (Table 1). To clarify the concept and to avoid overdrilling of the insertion site length the calculated numbers are given in millimeters with decimals. This accuracy cannot be achieved during drilling.

In contrast to the “classical” order of surgical steps during ACL reconstruction the concept makes it necessary to **first measure the length of the tibial ACL insertion site with a ruler** from anterior to posterior. The drill diameter and -angle as well as the surgical technique (SB/DB) are assessed from the “insertion site table”. Then the diameter of the graft is prepared according to the defined drill diameter and the ACL reconstruction is completed respectively (Table 1).
According to our calculations a short tibial ACL insertion site between 8 - 13 mm may be restored to more than 95% by an individually matched SB technique (Table 1). However, an intermediate insertion site length of 14 - 15 mm is more critical to be reconstructed, as this length needs large SB bone tunnels of 10 - 11 mm (Table 1). To increase the reconstructed insertion site length even more, smaller drill angles as low as 45° may be used to create a longer oval of the bone tunnel outlet. However, a long insertion site of 16 mm or more cannot be completely reconstructed by one SB bone tunnel (Table 1) and consequently the deficit of non-reconstructed ISA increase significantly with larger insertion sites. These are the patients, which may have the highest biomechanical and clinical benefit from a DB procedure as the reconstructed area is significantly larger than with a SB procedure.

**Conclusion**

The new concept of complete footprint restoration aims to maximize the reconstructed ACL insertion site areas to achieve an optimized functional outcome. An “insertion site table” was calculated for the surgeon, which defines drill diameters and drill angles as well as indications for SB and DB reconstruction depending on the length of the tibial insertion site. In this concept the DB technique is only considered as a surgical tool for large footprints and may not be indicated for smaller insertion sites.

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**Fig. 1: Insertion Site Table** (see page 4)

Recommendations for anatomical ACL footprint reconstruction to maximize the restored insertion site area. ST semitendinosus 2x doubled, 3x trippled, 4x quadrupled, GT: gracilis tendon, BPTB: bone patella bone tendon, QTB: quadriceps tendon., BB: bone bridge between AM and PL.
# INSERTION SITE TABLE

for complete ACL Footprint Restoration

PD Dr. Rainer Siebold – ATOS Klinik Heidelberg

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</table>