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VALIDATION OF THE 65° HOWELL GUIDE FOR ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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Abstract

Purpose: to study in cadaver knees the position of the tibial tunnel in anterior cruciate ligament (ACL) reconstruction using the 65° Howell guide.

Type of study: controlled laboratory study in vitro

Methods: 21 fresh-frozen cadaver knees were employed. The ACL was resected and its tibial attachment was demarcated. To drill the guide wire we employed the Howell 65 degrees tibial guide which references off of the intercondylar roof in extension to avoid impingement. The intraarticular position of the wire was digitised with a digital camera and referred to a transverse axis passing through the 'over the back' position and a sagittal axis passing through the lateral aspect of the medial spine. The percentage position of the wire within the ACL attachment was also calculated, taking the posterior and medial limits as the 0% positions.

Results: all the wires were within the ACL attachment: 17 were in the ACL posterolateral bundle attachment and the other 4 in the anteromedial. The average distance of the wire from the transverse and sagittal axes was 12 mm (SD 3 mm) anterior and 1 mm (SD 1 mm) lateral, respectively. The wire was positioned at 38% (SD 16%) of the length of the ACL attachment and at 40% (SD 17%) of the width. Eighty percent of the wires were positioned at between 35% and 48% of the attachment length.

Conclusions: the 65° Howell guide, which positions the tibial tunnel in extension to avoid roof impingement, ensures anatomical positioning of the graft on the tibial side and reproducibility can be expected.

Clinical relevance: this study proves that a commonly used drill guide succeeds in placing the ACL graft in the tibial anatomical attachment.

Key words: ACL reconstruction; tibial tunnel; tibial guide; howell guide; ligament attachment, graft impingement.

Introduction

Anterior cruciate ligament (ACL) reconstruction is a common orthopaedic procedure and satisfactory results are achieved in the majority of cases^{1,2,3,4,5}. Despite the range of grafts and fixation devices employed, correct tunnel placement remains the main determinant of the final outcome^{6,7} and a malpositioned tunnel is likely to result in instability or in lack of recovery of the range of motion^{8,9,10,11}. An anatomic position of the graft is desirable but identifying the correct tunnel exit point within the whole attachment area of the ACL may be a challenge. Furthermore, usually at arthroscopy and especially in chronic lesions, no ACL remnants may be identified. Many authors have studied the correct intraarticular position of the tunnels and several methods to achieve it have been developed^{7,8,10,12,13}. Most of the existing methods either need intraoperative X-rays to confirm the location or rely on “point and shoot” guides aiming at intraarticular landmarks. The result is that tunnel positioning is mostly surgeon dependent and so reproducibility may be lacking.

The aim of this investigation was to verify in cadaver knees the ability of the Howell tibial drill guide system (Arthrotek) to place the tibial tunnel in the correct position. This system locates the tibial guidewire path by referencing from the roof of the femoral intercondylar notch of the fully extended knee. The guide includes an offset between the probe that locates against the roof of the notch, and the path of the guidewire, that is larger than the radius of the graft tunnel, thus it should prevent graft impingement. As the wire is drilled in maximum extension the system should prevent roof impingement even in knees that hyperextend. Because the natural ACL fits against the roof of the notch in the extended knee, we hypothesised that this type of drill guide would result in the tibial tunnel guidewire exiting the tibia within the anatomical ACL attachment. On

the other hand, Buzzi et al¹⁴ found that the intersection of the extended line of the roof of the femoral intercondylar notch was extremely variable, from 22 to 41% of the anterior-posterior width of the tibial plateau, suggesting that the tunnel may not always be within the anatomic ACL attachment.

Although the originators have published data to support an anatomical placement¹⁵, the design of the guide has been modified recently and it has been implemented with a larger intrarticular probe to ensure a more lateral tunnel placement. Furthermore the coronal angulation has been reduced from seventy to sixty-five degrees to allow the femoral tunnel to be drilled in a more lateral (i.e. anatomical) position in the notch.

Material and Method

Twenty-one fresh-frozen knee specimens were used. They had been obtained with informed consent from relatives in accordance with a local research ethics committee permission. In all the knees the extensor mechanism had previously been completely removed. None of the knees showed advanced signs of osteoarthritis. The ACL and the posterior cruciate ligament (PCL) were intact and competent in all the specimens, and all none of the knees had abnormal laxity in extension. The femoral and tibial shafts were potted in bone cement and at least 10 cm of bone were left available from the joint line in each knee.

With the knee flexed at 90 degrees an anterior tibial load was applied, which tightened the anteromedial bundle (AM). This was separated with blunt dissection from the posterolateral (PL) that was slack in the flexed knee¹⁶. The ACL was then cut in its midsubstance and the tibial attachments of the two bundles were identified and their periphery marked with red ink after the remnants of the bundles had been cut from the bone. The "over the back" position (defined as the ridge at the initiation of the posterior slope of the tibial plateau that sits just anterior to the PCL¹⁷) and the lateral aspect of the medial spine were marked with red ink as well. The femoral shaft was then clamped in a table vice which allowed knee flexion and extension in a vertical plane. A 40 cm intramedullary rod was inserted into the tibia in order to extend the knee, resembling the intraoperative situation in which the knee is held in maximum extension from the heel. A two kilograms weight was hung on the proximal part of the rod to resemble the weight of the leg in normal conditions, resulting in a posterior drawer stress to the knee when the tibia was horizontal. To drill the tibial tunnel the Howell 65° tibial guide (Arthrotek Inc.) was employed according to the manufacturer's instructions (Fig. 1). This controls the

path of the the tibial guidewire in the extended knee, that is offset away from the roof of the intercondylar notch. It includes a probe which is inserted into the flexed joint through the anteromedial arthroscopic portal and is placed into the notch. When the knee is in full extension the probe is trapped between the femur and the tibia and its correct position must be checked arthroscopically (Fig. 2). The probe is then pulled anteriorly until its anterior aspect is in contact with the roof of the notch. The probe is part of a C-arm which allows the guide wire to be drilled through a telescopic guide barrel on the anteromedial aspect of the proximal tibia. The guide has a reference pin which crosses the C-arm at 65° and this helps to align the tunnel with a 65 degrees coronal angle. The guide barrel has three parallel bores, allowing the tunnel to be moved to a central position or a more lateral one if the first K-wire seems to be too medial. When the guide wire is drilled into the joint, it knocks into the probe, leaving 6 mm between the roof and the wire in order to prevent roof impingement.

With the knee in full extension, the tibia reduced posteriorly and the Howell 65° tibial guide in place, a 2.4 millimetres guidewire was drilled through the central hole of the guide. After removing the guide, the wire position in the joint was first inspected visually and then the joint was disarticulated and the wire was hammered back so that its tip was flush with the tibial plateau. The tibial plateau was then photographed with a Nikon Coolpix 2.1 megapixel digital camera with a ruler positioned on the tibial plateau as a scale factor. A Steinmann pin was held in contact with the posterior aspect of the tibia and was assumed to be the posterior axis of the tibial plateau.

The pictures were downloaded to a personal computer and analysed with Microsoft Powerpoint 2002 software (Microsoft Corp). The pictures were normalised to a common scale and images of left knees reflected in order to all appear right-sided.

The distances of the ACL footprint and of the guidewire anteriorly from the over the back position were calculated. Their mediolateral positions were computed with respect to the lateral aspect of the medial tibial spine. Positions lateral to this axis were assumed to be positive, medial ones to be negative. The position of the border between the AM and PL bundle attachments along the medial and lateral aspects of the footprint was calculated.

The percentage position of the wire with respect to the attachment length and width was computed taking the posterior and medial borders to be the 0% positions in the sagittal and coronal planes respectively. A scatter plot of the wire position with respect to the footprint was obtained.

Because the ACL attachment was not aligned in an AP direction, the position of the wire within the attachment was recalculated in terms of an axis system aligned with the longest dimension of the attachment. A statistical analysis was performed with Windows Statistics 5.1 (StatSoft Inc., Tulsa, OK, USA) and Student's paired t-test was employed to compare the data obtained from the two axis systems.

Results

The anterior and posterior limits of the ACL attachment were at 22 mm mean $\pm$ 3 mm SD, range 16-27 mm and 6 ± 2 (2-8) mm respectively from the 'over the back' position. The medial and lateral limits of the attachment were at -3 ± 1 [-5-(-2)] mm and $+6\pm 2$ (3-9) mm respectively lateral to the medial tibial spine. The tibial attachment was on average 17 ± 2 (12-19) mm long and 9 ± 2 (7-16) mm wide. The border between the PL and AM attachments was at 11 ± 2 (8-14) mm on the medial side and at 17 ± 4 (11-24) mm on the lateral side from the 'over the back' position. In percentage terms the medial border between the bundle attachments was at 33 ± 12 (12-58)% of the footprint length while the lateral was at 68 ± 14 (47-94)%.

The tip of the K-wire drilled through the 65° Howell tibial guide was in the PL bundle attachment in 17 knees and in the AM bundle attachment in 4 knees (Fig. 3). It was 12 ± 3 (5-16) mm anterior to the over the back and $+1\pm 1$ (-3-2) mm lateral to the medial tibial spine. In one knee (Fig. 3) the wire was in a posterior position in the attachment; this could be explained by the relatively anterior position of the attachment itself, its posterior limit being 8 mm from the over the back. In percentage terms the tip of the wire was at 38 ± 16 (11-69)% of the length and at 40 ± 17 (14-75)% of the width of the ACL attachment. A scatter plot of the percentage positions of the 21 wires in the 21 knees is shown in Fig. 4. When considering the long axis of the attachment, the wire was at 37 ± 14 (13-66)% of the length and 48 ± 17 (10-70)% of the width. The differences between the two axis systems were not significant: $p= 0.5$ and 0.1 for length and width measurements, respectively.

Discussion

The main finding of this study was that a guidewire drilled through the tibia with a 6 mm offset from the roof of the femoral intercondylar notch exited the tibial plateau within the anatomical ACL attachment in all twenty-one knees tested, thus confirming the hypothesis. It was within the attachment of the posterolateral bundle in seventeen of the twenty-one knees, the mean position being 38% (6.5 mm) from the posterior edge of the 17 mm long ACL attachment.

Anatomic placement of the tibial tunnel requires the tunnel to exit in the attachment area of the native ACL: the task of the surgeon is then to decide where to put an 8 to 10 mm tunnel in an area 17 mm long and 9 mm wide which may be difficult to identify arthroscopically. Many authors have tried to describe the ideal tibial tunnel position. In the early 1980s the intraarticular exit of the tibial tunnel tended to be positioned slightly anterior to the centre of the natural ACL attachment, following the recommendation of Clancy et al¹⁸ supporting anteromedial positioning to ensure graft isometry. This was not done with reference to the individual notch roof anatomy, and so the need for notchplasties was great.

Like the normal ligament, the anterior aspect of the graft should be parallel to the slope of the intercondylar roof with the knee in maximum extension. Placing the tibial tunnel in the anterior half of the ACL attachment may expose the anterior fibres of the graft to roof impingement⁸, because they go straight from the femur to the tibia, which is not anatomical. In contrast, the fibre architecture of the natural ACL leads to its anterior profile being concave. This means that fibres may reach areas in the anterior part of the tibial attachment that are not accessible by a straight graft without impingement.

MRI studies¹⁹ have shown that an anterior tunnel resulted in graft-roof impingement with subsequent graft failure. The pathognomonic findings of this phenomenon included a signal increase in the distal two-thirds of the intraarticular portion of the graft and posterior bowing caused by contact with the intercondylar roof. Supporting this concept, Marzo et al¹²⁰ reported that anterior graft placement resulted in a fibrous nodule (cyclops) formation from partial graft rupture caused by graft impingement, leading to clinical mechanical symptoms like pain and loss of extension.

The evidence above suggests that it is acceptable to place the tibial tunnel for ACL reconstruction in the middle third of the original ACL attachment in the sagittal plane. A very posterior position on the tibia should be avoided because it is the least isometric, causing too much “elongation” toward extension.²¹⁻²³ Furthermore, a posteriorly-placed tibial tunnel moves the graft towards a more vertically oriented proximal-distal orientation, and that is not efficient for withstanding anterior draw forces.

Khalfayan et al¹⁰ reported that the optimal placement of the tibial tunnel is within 20% to 40% of the sagittal width of the tibia. Failure to achieve these radiographic parameters was correlated to considerably compromised clinical results. However, it is difficult to define the ideal anteroposterior position radiographically, and it would need intraoperative X-rays to confirm the absence of impingement. Furthermore, the intercondylar roof has an interindividual variability and impingement may still occur in the above-mentioned 20-40% safe area¹⁴.

Jackson and Gasser¹² introduced anatomic landmarks in selecting the correct tunnel position. It was described as the mid-point of a line linking the inner or posterior edge of

the anterior horn of the lateral meniscus and the medial spine and was consistently located 6 to 7 mm anterior to the anterior border of the PCL. In 1995 Morgan et al¹³ introduced a new tibial guide (Arthrex Inc, Naples, FL) using the PCL as a reference. The centre of the tunnel is 7 mm from the PCL with the knee at 90 degrees flexion.

Given that the normal ACL lies against the intercondylar notch roof with the knee in maximum extension²⁴, it was thought that the intercondylar roof could be used as a rigid landmark to position a guide instead of relying on mutable, soft-tissue structures. Based on these observations Howell⁹ designed a guide (One-Step, Impingement-Free Tibial guide, Arthrotek, Inc., Ontario, CA) that customizes the tibial tunnel in relation to the intercondylar roof. The efficacy of this guide in preventing roof impingement was validated with MRI and lateral radiographs of the extended knee²⁵. The coronal angle was preset at 70 degrees. In 2003 a new version of the guide was introduced: the 65° Howell Tibial Guide (Arthrotek, Inc., Ontario, CA). The latest edition is different from the first one in the 65 degrees coronal angle and in a larger intra-articular probe. The 5 degrees reduction in coronal plane angle was based on studies indicating that this would lead to better knee flexion^{15,26}. To our knowledge this is the first study to validate in a cadaver knee the 65° Howell tibial guide.

Our results show reproducibility in tibial tunnel placement. On average the tibial tunnel was at 38% of the anteroposterior length of the attachment and 80% of the wires were between 35% and 48% of the footprint. All the wires but four were in the posterolateral bundle attachment and the most anterior of these was at 69% of the posteroanterior length of the footprint. We were not worried by the four wires exiting in the anterior half of the native ACL because the tibial wire was drilled with the knee in full extension relying on a roof referencing guide. Although the intrarticular position should be safe,

the authors recommend that the absence of graft impingement is always checked in extension after graft fixation. Some roof or lateral notchplasty may still be required because of the residual tibial mobility which may be present after reconstruction.

The importance of the medio-lateral position of the tibial tunnel has also been emphasised. Romano et al¹¹ measured the medio-lateral placement in a radiographic study: tibial tunnel placement was significantly more medial in the patients who had flexion deficits. In our study, using the Howell tibial guide, the guide wire was at 40% of the mediolateral width of the ACL footprint, 1 mm lateral to the lateral aspect of the medial tibial spine. The new version of the guide has a larger probe which positions the wire centrally. Because the tibial guidewire is placed with the knee fully extended, which limits tibial rotation, the system reduces the possibility of medial-lateral errors.

In conclusion: our experience demonstrates the efficacy of a roof-referencing drill guide in positioning the ACL graft reproducibly in an anatomical position. The risk of graft impingement should be avoided because the guide refers off of the intercondylar notch roof when the knee is fully extended.

References

1. Aglietti P, Buzzi R, Giron F, et al: Arthroscopic-assisted anterior cruciate ligament reconstruction with the central third patellar tendon:. A 5- to 8-year follow-up. *Knee Surg Sports Traumatol Arthrosc* 5(3): 138, 1997.
2. Anderson AF, Snyder RB, Lipscomb Jr AB. Anterior cruciate ligament reconstruction. A prospective randomized study of three surgical methods. *Am J Sports Med* 2001;29:272–9.
3. Aune AK, Holm I, Risberg MA, Jensen HK, Steean H. Fourstrand hamstring tendon autograft compared with patellar tendon–bone autograft for anterior cruciate ligament reconstruction. A randomized study with two-year follow-up. *Am J Sports Med* 2001;29:722–8.
4. Bach Jr BR, Tradonsky S, Bojchuk J, Levy ME, Bush-Joseph CA, Khan NH. Arthroscopically assisted anterior cruciate ligament reconstruction using patellar tendon autograft. Five to nine-year follow-up evaluation. *Am J Sports Med* 1998;26:20–9.
5. Shelbourne KD, Gray T. Anterior cruciate ligament reconstruction with autogenous patellar tendon graft followed by accelerated rehabilitation. A two-to nine-year followup. *Am J Sports Med* 1997;25:786–95.
6. Amis AA, Jakob RP: Anterior cruciate ligament graft positioning, tensioning and twisting. *Knee Surg Sports Traumatol Arthrosc.* 1998;6 Suppl 1:S2-12
7. Giron F, Buzzi R, Aglietti P. Femoral tunnel position in anterior cruciate ligament reconstruction using three techniques. A cadaver study. *Arthroscopy* 1999;15:750–6.

8. Howell SM: Principles for placing the tibial tunnel and avoiding roof impingement during reconstruction of a torn anterior cruciate ligament. *Knee Surg Sports Traumatol Arthrosc* 6(Suppl 1): S49, 1998.
9. Howell SM, Taylor MA: Failure of reconstruction of the anterior cruciate ligament due to impingement by the intercondylar roof. *J. Bone Joint Surg Am* 75: 1044, 1993.
10. Khalfayan EE, Sharkey PF, Alexander AH et al: The relationship between tunnel placement and clinical results after anterior cruciate ligament reconstruction. *Am J Sports Med* 24(3): 335, 1996.
11. Romano VM, Graf BK, Keene JS, et al: Anterior cruciate ligament reconstruction. The effect of tibial tunnel placement on range of motion. *Am J Sports Med* 21(3): 415, 1993.
12. Jackson DW, Gasser SI: Tibial tunnel placement in ACL reconstruction. *Arthroscopy* 10(2): 124, 1994.
13. Morgan CD, Kalmann VR, Grawl DM: Definitive landmarks for reproducible tibial tunnel placement in anterior cruciate ligament reconstruction. *Arthroscopy* 11(3): 275, 1995.
14. Buzzi R, Zaccherotti G, Giron F, Aglietti P. The relationship between the intercondylar roof and the tibial plateau with the knee in extension: relevance for tibial tunnel placement in anterior cruciate ligament reconstruction. *Arthroscopy*. 1999 Sep;15(6):625-31
15. Simmons R, Howell SM, Hull ML. Effect of the angle of the femoral and tibial tunnels in the coronal plane and incremental excision of the posterior cruciate ligament on tension of an anterior cruciate ligament graft: an in vitro study. *J Bone Joint Surg Am*. 2003 Jun;85-A(6):1018-29

16. Amis AA, Dawkins GP (1991). Functional anatomy of the anterior cruciate ligament. Fibre bundle actions related to ligament replacements and injuries. *J Bone Joint Surg Br* 73(2): 260-267.
17. Hutchinson MR, Bae TS. Reproducibility of anatomic tibial landmarks for anterior cruciate ligament reconstructions. *Am J Sports Med* 2001, 29(6): 777-780
18. Clancy WG, Nelson DA, Reider B, et al: Anterior cruciate ligament reconstruction using one-third patellar ligament, augmented by extra-articular tendon transfers. *J Bone Joint Surg Am* 64: 352, 1982.
19. Howell SM, Clark JA, Blasier RD: Serial magnetic resonance study assessing the effects of impingement on the MRI image of patellar tendon graft. *Arthroscopy* 8: 350, 1992.
20. Marzo JM, Bowen MK, Warren RF, et al: Intra-articular fibrous nodule as a cause of loss of extension following anterior cruciate ligament reconstruction. *Arthroscopy* 8(1): 10, 1992.
21. Penner DA, Daniel DM, Wood P, et al: An in vitro study of anterior cruciate ligament graft placement and isometry. *Am J Sports Med* 6(3): 238, 1988.
22. Sapega AA, Moyer RA, Scheneck C, et al: Testing for isometry during reconstruction of the anterior cruciate ligament: Anatomical and biomechanical considerations. *J Bone Joint Surg Am* 72: 259, 1990.
23. Sidles JA, Larson RV, Garbini JL, et al: Ligament length relationship in the moving knee. *J Orthop Res* 6(4): 593, 1988.
24. Stäubli H-U, Rausching W: Tibial attachment area of the anterior cruciate ligament in extended knee position: Anatomy and cryosections in vitro complemented by magnetic resonance arthrography in vivo. *Knee Surg Sports Traumatol Arthrosc* 2(3): 138, 1994.
25. Howell SM, Barad SJ: Knee extension and its relationship to the slope of the intercondylar roof. *Am J Sports Med* 23(3): 288, 1995.

26. Howell SM, Gittins ME, Gottlieb JE, Traina SM, Zoellner TM: The relationship between the angle of the tibial tunnel in the coronal plane and loss of flexion and anterior laxity after anterior cruciate ligament reconstruction. *Am J Sports Med* 2001 Sep-Oct;29(5):567-74

Figures

Fig 1: Radiograph of the 65° Howell guide in-situ.

Fig. 2: the probe of the 65° Howell guide in the intercondylar notch

Fig. 3: Normalised ACL attachments with the tip of the K-wire. The circles indicate approximate tunnel openings with 9 mm drill. All diagrams represent the right knee, with lateral to the left and anterior to the bottom of the diagrams.

Fig. 4: Scatter plot of the wire percentage position within the ACL footprint. Mean position: 38% of the length (SD 16%) and 40% of the width (SD 17%)

Figure 1

Figure 2

Figure 3

Figure 4