Anatomical variations in the tibial insertion of the Anterior Cruciate Ligament: An MRI study

Henry Magill1*, Branavan Rudran2, Clare Cullen3 and Neil Jain3

1Orthopedic Registrar, Chelsea and Westminster Hospital, London, UK
2Orthopedic Clinical Fellow, Chelsea and Westminster Hospital, London, UK
3Consultant Orthopedic Surgeon, North Manchester General Hospital, UK

Introduction

Anterior Cruciate Ligament (ACL) reconstructive surgery provides good to excellent (75% to 97%) outcomes overall in terms of joint stability, symptom improvement and return to pre-injury activity [1]. Between 0.7 and 20% of patients, however, undergoing surgery will experience persistent instability symptoms due to ACL graft failure [2]. Femoral and tibial tunnel malposition may cause flexion and extension deficits and ultimately lead to graft failure [3]. Excessively anterior placement of the ACL graft may result in tightness in flexion and graft impingement with the inter-condylar groove of the femur when in extension [4]. In addition, undue posterior placement may cause joint laxity and PCL impingement and stiffness in extension [4]. Murawski, et al. have suggest that anatomic ACL graft placement may lead to improved long-term outcomes and reduced risk of osteoarthritic changes [Murawski]. Furthermore, the MARS cohort reported that tibial tunnel malposition was the cause of 37% of ACL graft failures [5,6].

Precise anatomy of ACL placement of the tibial footprint is therefore required to perform successful anatomical reconstruction. Increasing interest has emerged in the literature regarding the anatomy of ACL tunnel insertion, where large cohorts of studies have investigated the femoral ACL placement and neglected the tibial footprint of the ACL as a whole [7,8]. Few studies have looked at the tibial tunnel placement of the individual bundles alone [9,10]. The ideal positioning of the tibial tunnel on the tibial plateau remains largely unanswered.

Purpose

The aim of the study is to determine precise measurements of normal tibial footprint anatomy. We will also aim to determine if the normal anatomical footprint of the ACL has any consistent dimensions in relation to the surrounding bony anatomy and tibial plateau. Hence, the purpose of the study is to reliably characterise the anatomic centrum of the ACL footprint in order to aid surgeons to perform anatomical ACL reconstruction.

Methods

One hundred (n=100) adult knee MRI Scans were included in the study. A power calculation was performed demonstrating adequate sample sizing in order to prevent excessive type 1 and type 2 errors. Any scans with intra-articular pathology, bony morphology, osteophytes, excessive artefact or ligamentous damage were excluded. The age and sex of each patient was recorded.

Each of the T2-weighted MRI scans was analysed using PACS imaging system to take accurate measurements of the ACL in the mid-sagittal plane. The anterior-posterior (AP) length was determined from the anterior tibia to anterior border of the meniscal root [Figure 1(a)]. Measurements were taken from the anterior tibial border to both the anterior and posterior aspect of the ACL [Figure 1(a)&(b)]. Thus, by simple calculation it was possible to determine the AP length of the tibial footprint and the mid-point of the ACL as both a measurement and a proportion of the entire AP tibia.

Results

Of the 100 patients included in the study, 47 were male...
and 53 were female with a mean age of 48 years (±14.5). The mean AP tibial length was 36.6mm (SD 3.3mm) with a difference between male (38.6mm) and female (34.9mm) mean distances. The mean distances from the anterior tibial boarder to the anterior and posterior aspect of the ACL were 15.0mm (SD 1.97mm) and 29.7mm (SD 2.70mm) respectively. By calculation, the distance from the anterior tibia to the mid-point of the ACL was 22.3mm (SD 2.15mm) and the mean ACL AP footprint length was 14.6mm (SD 1.97mm) [Table 1].

The means of all absolute measurements were larger in males than females, where the difference observed proved significant on unpaired T-Test analysis [Table 1]. However, the mid-point of the ACL as a percentage of the entire AP tibia remained consistent between males and females with an overall mean value of 61% (SD 4.4%) [Table 1].

The use of MRI as a determinantal for AP dimensions remains a limitation, where the individual sagittal image used may not represent the exact centre of the ACL and projection variability may occur. Further studies correlating the reliability of pre-op MRI imaging in relation to the intra-operative measurements would be beneficial.

We conclude that the findings are therefore not clinically relevant in standard ACL reconstructive surgery where a more accurate means of anatomical reconstruction involved tibial tunnel placement through the ACL remnant stump. The results from this study provide a useful guide in revision ACL reconstructive surgery or in chronic pathology of the ligament where residual stump may not be present, where an arthroscopic ruler would provide accurate intra-operative measurements.

**References**

1. Engelman GH, Carry PM, Hitt KG, Polousky JD, Vidal AF (2014) Comparison of allograft versus autograft anterior cruciate ligament reconstruction graft survival in an active adolescent cohort. Am J Sports Med 42: 2311-2318. Link: http://bit.ly/3oJuN7

2. Bach BR, Provencher MT (2010) ACL surgery: how to get it right the first time and what to do if it fails. J Sports Sci Med 9: 527. Link: http://bit.ly/2Ksg9T

3. Johnson DL, Fu FH (1995) Anterior cruciate ligament reconstruction: why do failures occur? Instr Course Lect 44: 391-406. Link: http://bit.ly/2HL5P7f

4. Saranitis G, Marcano AI, Alentorn-Geli E, Cugat R, Farmer KW, et al. (2015) Failure of Anterior Cruciate Ligament Reconstruction. Arch Bone Jt Surg 3: 220-240. Link: http://bit.ly/3nnAeoL

5. Morgan JA, Dahm D, Levy B, Stuart MJ (2012) MARS Study Group. Femoral tunnel malposition in ACL revision reconstruction. J Knee Surg 25: 361-368. Link: http://bit.ly/3nnYvuZ

6. Wright RW, Huston LJ, Spindler KP, Dunn WR, Haas AK, et al. (2010) Descriptive epidemiology of the multicenter ACL revision study (MARS) cohort. Am J Sports Med 38: 1979-1986. Link: http://bit.ly/3qXJ9Qa

7. Zantop T, Diermann N, Schumacher T, Schanz S, Fu FH, et al. (2008) Anatomical and Nonanatomical Double-Bundle Anterior Cruciate Ligament Reconstruction: Importance of Femoral Tunnel Location on Knee Kinematics. Am J Sports Med 36: 678-685. Link: http://bit.ly/3oWMeQm

8. Musahi V, Pliskovskih A, VanScyoc A, Sasaki T, Debski RE, et al. (2005) Varying Femoral Tunnels between the Anatomical Footprint and Isometric Positions: Effect on Kinematics of the Anterior Cruciate Ligament-Reconstructed Knee. Am J Sports Med 33: 712-718. Link: http://bit.ly/2LxKywp

9. Hwang MD, Piefer JW, Lubowitz JH (2012) Anterior Cruciate Ligament Tibial Footprint Anatomy: Systematic Review of the 21st Century Literature. Arthroscopy 28: 728-734. Link: http://bit.ly/2ITmbsg

10. Tsukada H, Ishibashi Y, Tsuda E, Fukuda A, Toh S (2008) Anatomical analysis of the anterior cruciate ligament femoral and tibial footprints. J Orthop Sci 13: 122-129. Link: http://bit.ly/3nxFT

**Discussion**

Our findings show significant variability in the measureable distances from the anterior border of the tibia to the ACL and the overall AP length of the tibia. Variability exists through absolute measurements between males and females. However, we have demonstrated that the proportion of these distances remains fairly constant across both sexes when expressed as a percentage of the entire sagittal length of the tibia. Such findings may be of use in the pre-operative planning of ACL reconstruction.

Our findings show significant variability in the measureable distances from the anterior border of the tibia to the ACL and the overall AP length of the tibia. Variability exists through absolute measurements between males and females. However, we have demonstrated that the proportion of these distances remains fairly constant across both sexes when expressed as a percentage of the entire sagittal length of the tibia. Such