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Research Article

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

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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 boarder 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].



Figure 1: Mid-sagittal measurements: (a) AP Tibia (b) Anterior tibia to anterior ACL (c) Anterior tibia to posterior ACL.

Table 1: All measureable parameters including male-female differences.

	Males	Females	Male-Female Difference (T-Test)	Overall
AP Tibia	36.6mm (± 3.32)	34.9mm (± 2.76)	<0.05	36.6mm (± 3.32)
Anterior Tibia to Anterior ACL	15.9mm (± 1.62)	14.2mm (± 1.91)	<0.05	15.0mm (± 1.97)
Anterior Tibia to Posterior ACL	31.5mm (± 2.17)	28.1mm (± 2.05)	<0.05	29.7mm (± 2.70)
ACL AP Tibial Footprint Length	15.5mm (± 1.96)	13.8mm (± 1.63)	<0.05	14.6mm (± 1.97)
Anterior Tibia to Mid-point ACL	23.7mm (± 1.65)	21.1mm (± 1.81)	<0.05	22.3mm (± 2.15)
Mid-point ACL as % of AP Tibia	61.5% (± 4.28)	60.8% (± 4.51)	0.43	61.1% (4.39)

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.

The use of MRI as a determinant for AP dimensions remains a limitation, where the individual sagittal image used may not represent the exact centre of the ACL and projectional 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.

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