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Anterior cruciate ligament reconstruction and determination of tunnel size and graft obliquity

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Abstract. – OBJECTIVE: Increase in ACL (anterior cruciate ligament) reconstructions has led to a higher prevalence of patients with postoperative symptoms which require investigation. We aimed to investigate the utility of magnetic resonance imaging (MRI) and computer tomography (CT) in determining tunnel size and graft obliquity after single bundle ACL reconstruction.

PATIENTS AND METHODS: A retrospective comparison was made on 29 symptomatic knees after anatomic single bundle (trans AM) and transtibial ACL reconstructions which had both MRI and CT scans at an average of 1.3 years postoperatively (2 months-5.7 years). We compared CT and MRI (T2 sequence) tunnel size and graft obliquity estimates using Pearson correlation and *t*-test. We also compared MRI's of ACL reconstructed knees with hamstrings or patellar autografts, which were confirmed by operative protocol as either antero-medial (AM) technique (n=21) or trans-tibial (TT) technique (n=19). The surgeries were performed for an average of 6.29 (4-10) years for the TT group and 1.3 (0-3) years for the AM group, respectively. The graft inclination was measured relative to the tibial plateau using DICOM software. Statistical analysis used the mean value for each case and the data were processed using the non-parametric Kruskal-Wallis test to determine the difference in graft obliquity and tunnel placement.

RESULTS: Tunnel size estimates correlate well between CT and MRI on axial scans: R2=0.795 and 0.630 for femur and tibia respectively. The position of the tunnels and graft obliquity were found to differ on MRI images in both coronal and sagittal planes. Coronal graft obliquity averaged 72.38° (ranging from 69° to 76°) using the AM technique and 75.47° (ranging from 72° to 78°) with TT technique. Sagittal graft inclination angle was 54.5 (51-58.5) and 63.68 (59-69.5) respectively. MRI proves to be the most useful imaging method in determining outcome after ACL reconstruction. However, for a better revision of the ACL reconstructions, CT can offer a clearer image of tunnels and bone stock. A more anatomical graft positioning increases obliquity in coronal and sagittal planes and, thus, becomes difficult to assess both tunnels in a single slice.

CONCLUSIONS: The anatomic single bundle reconstruction technique has been found to more accurately reproduce the femoral footprint and the orientation of the graft compared to the TT technique where the appropriate tibial tunnel placement resulted in a more vertical graft.

Key Words:
ACL, MRI, CT tunnel size, Graft obliquity.

Introduction

The introduction of the anatomic ACL (anterior cruciate ligament of the knee) reconstruction technique changed the way surgeons drill the femoral tunnel, by using an antero-medial (AM) portal drilling technique instead of the traditional trans-tibial (TT) technique. Subsequently it was changed the positioning of the tunnels and the resulting obliquity of the graft, positioning it in a more anatomical fashion. One of the first materials evaluating the neoligament obliquity, in ACL reconstructed patients, found a continuous and homogeneous graft similar to the native ACL, but with a more vertical position that does not recreate the normal sagittal obliquity. Nevertheless, these more vertical grafts were found to still control anterior posterior knee displacement[1]. Ahn et al[2] showed a lot of interest towards MRI (magnetic resonance imaging) evaluation after ACL reconstructions. When AM and TT techniques

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were compared, they also found a significant vertical angle in the coronal and sagittal plane for the TT reconstructions compared with the native ACL. In addition, the more horizontally can be the angle of the tibial tunnel, the closer can be the result, compared to the native ACL. When the tibial remnant stump was preserved, magnetic resonance imaging showed significantly larger grafts with progressive remodeling and no increase in the incidence of cyclops lesions[3]. Further researches could provided additional data to support the femoral tunnel drilling through the AM portal. When compared to the TT technique, it could offer better function and closer obliquity with respect to the native contralateral ACL[4-6]. With regard to the tibial tunnel aperture, the results are somewhat inconclusive between the two techniques. It has been shown that trans-tibial technique places the tibial tunnel in the same position as the AM procedure or more posterior in order to achieve a better placement of the femoral tunnel[5-8]. The overall increase in ACL reconstructions has led to an its higher prevalence in the population and, thus, in an increased occurrence of patients with postoperative symptoms requiring investigation. The majority of cases lead for revisions resulted caused by bad tunnel positioning with secondary impingement and/or instability. Most of the times this is caused by surgical and technical mistakes[9]. One study[6], reviewing patients for ACL revisions, found that 88% of knees resulted with graft outside the native tibial and femoral insertions. Many of them were entirely on the intercondylar femoral roof and one third extended posterior to the anterior cruciate ligament tibial attachment with TT technique[6]. In addition, almost half of the patients underwent one or more times in revisions without correction of the misplaced tunnels and, therefore, still with subsequent failures[6]. In addition to MRI, 3D volume could make the computer tomography (CT) an useful tool for planning accurate femoral tunnel positioning when aiming for anatomic ACL reconstruction. The direct insertion of the ACL is located in the depression between the resident's ridge and the articular cartilage margin on the lateral femoral condyle[10]. The same images are useful to evaluate the current tunnel positions and determine the revision operative strategy[11]. Given these premises, we aimed to investigate the utility of different imaging techniques (MRI, CT) in determining tunnel size, graft obliquity and complications after ACL reconstructions in the setting of preoperative planning of a single bundle anatomic revision.

Patients and Methods

From our database, selected MRI scannings of 40 ACL reconstructed knees with hamstrings or patellar autogenous graft which were confirmed by operative protocol as either AM technique (n=21) or TT technique (n=19). All indexed procedures were single bundle reconstructions, which have been performed by different surgeons using various fixation devices with an average of 6.29 (4-10) years ago for the TT group and 1.3 (0-3) years ago for the AM group. The MRI scans were given blinded, regarding the surgical technique, to two experienced examiners: a knee surgeon with over 150 ACL reconstructions per year and a radiologist from a knee and sports clinic; they were asked to determine the graft inclination relative to the tibia using Efilm DICOM viewer software (Figure 1A and B). The null hypothesis was that

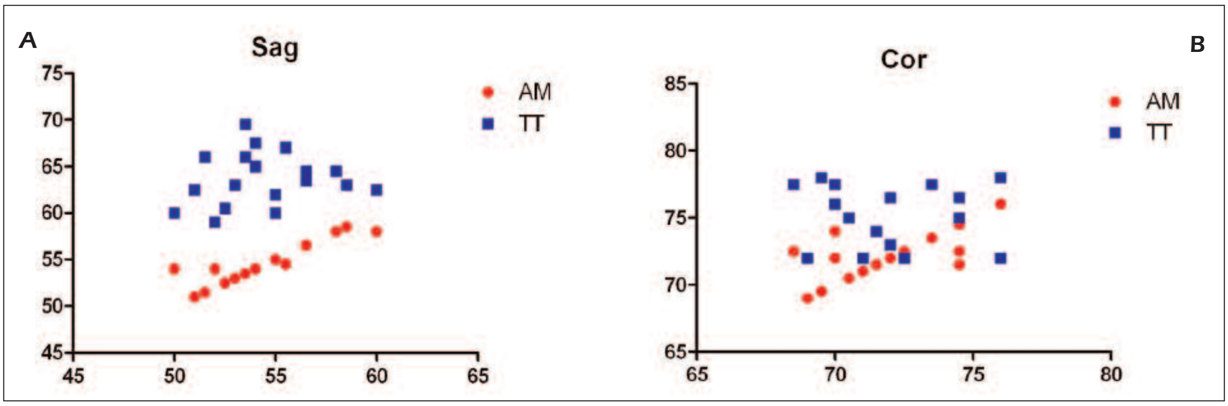

Figure 1. Tunnels position and Graft obliquity data on both sagittal *(A)* and coronal *(B)* planes.

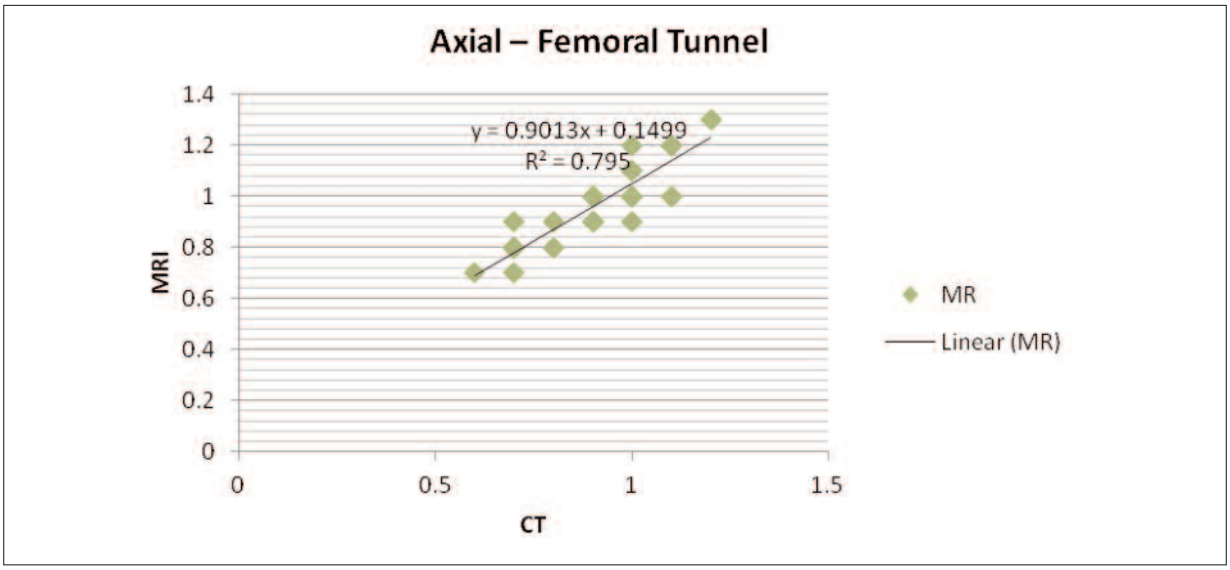

Figure 2. MRI/CT correlation of femoral tunnel size on axial views at the gape level.

there were no differences between the two groups. For statistical analysis we used the mean value for each case and processed the data using the non-parametric Kruskal-Wallis test to determine the difference in graft obliquity and tunnel placement in use. In addition, we retrospectively compared 29 symptomatic knees after anatomic single bundle (trans AM) and trans-tibial ACL reconstructions that had both MRI and CT scans at an average of 1.3 years postoperatively (2 months-5.7 years). We analyzed the correlation between the CT tunnel size and the graft obliquity values using the Pearson correlation and *t*-test compared to MRI (T2) (Figures 2 and 3).

Statistical Analysis

Statistical comparison between MRI sagittal and coronal plane obliquity for the AM portal and the TT portal using the one-tailed *t* test (data processed with SPSS, IBM) gave the following results, summarized in the following sagittal and coronal (Table I).

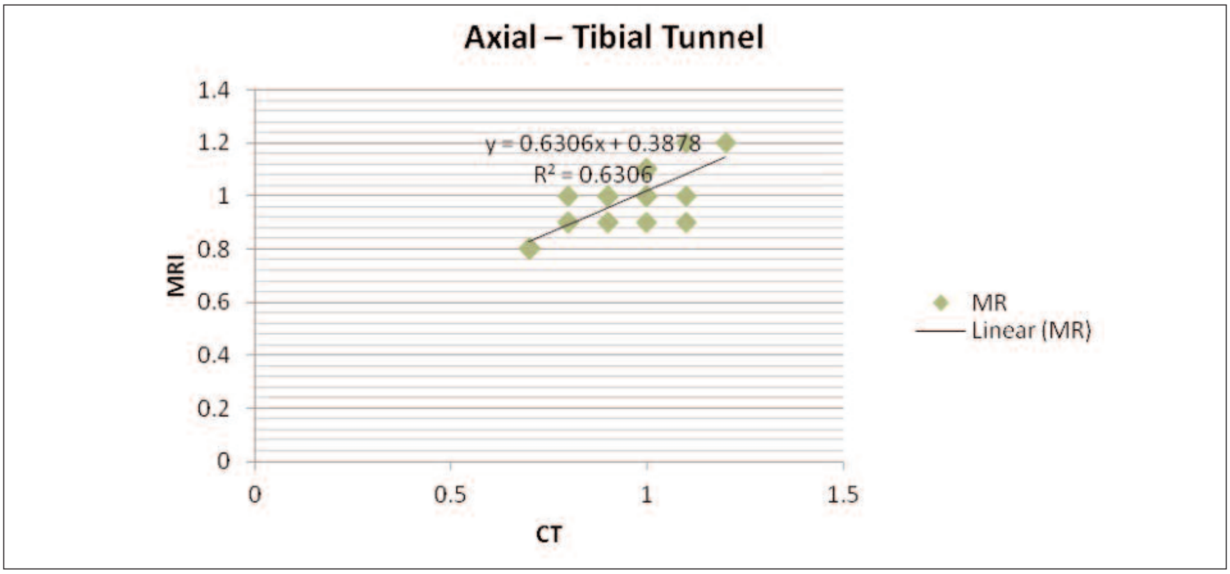

Figure 3. MRI/CT correlation of tibial tunnel size on axial views at the gape level.

Table I. MRI sagittal and coronal plane obliquity for the AM portal and the TT portals.

	Sagittal (degrees)	Coronal (degrees)
AM (n=21)	54.50 (SEM = 0.48)	72.38 (SEM = 0.41)
TT (n=19)	63.68 (SEM = 0.64)	75.47 (SEM = 0.52)
p (AM vs TT)	< 0.001	< 0.001
95% CI	-10.78 to -7.59	-4.42 to -1.76

AM: femoral tunnel drilled through the anteromedial portal; TT: femoral tunnel drilled through the tibial tunnel, n: number of subjects; SEM: standard error of mean; CI: confidence interval.

Results

Tunnels position and graft obliquity were found to differ on images in both sagittal and coronal planes (Figure 1A and B). Coronal graft obliquity averaged 72.38° (ranging from 69° to 76°) using the AM technique Figure 4) and 75.47° (ranging from 72° to 78°) with TT technique. Sagittal graft inclination angle was 54.5 (51-58.5) and 63.68 (59-69.5) respectively (Figure 5). We determined a statistically significant difference in graft obliquity and tunnel angles with a more anatomical favorable position in AM technique and in vertical results for TT technique. Radiological measurements showed less variance between the two groups. Axial measurements of the tunnel size at the level of the aperture were compared between MRI and CT. Results showed no correlation (R2 = 0.795 and 0.630 for the femur and tibia, respectively) (Figures 2 and 3). By comparison with the classical TT technique, the tibial tunnel placement resulted in a more vertical graft than native ACL (Figures 6). The 3D VRT CT was found to be a reliable way to determine tunnel placement as far as 5.7 years after the index surgery (Figure 7). On the other hand, MRI was a consistent and reliable method to determine the status of the neoligament (re-rupture or integration) as well as potential meniscal and cartilage associated lesions (Figure 8). Comparative MRI's of the above postoperative cases depicting a ruptured and a healed graft respectively after 2 and 5 years (Figure 9).

Discussion

MRI proves to be the most useful imaging method in determining the outcome after ACL reconstruction. It gives reliable information on graft healing, integrity, length, position, inclination angle, obliquity, impingement syndromes and potential associated lesions. It may even identify ACL impingement against PCL (posterior cruciate ligament) with the knee extended,

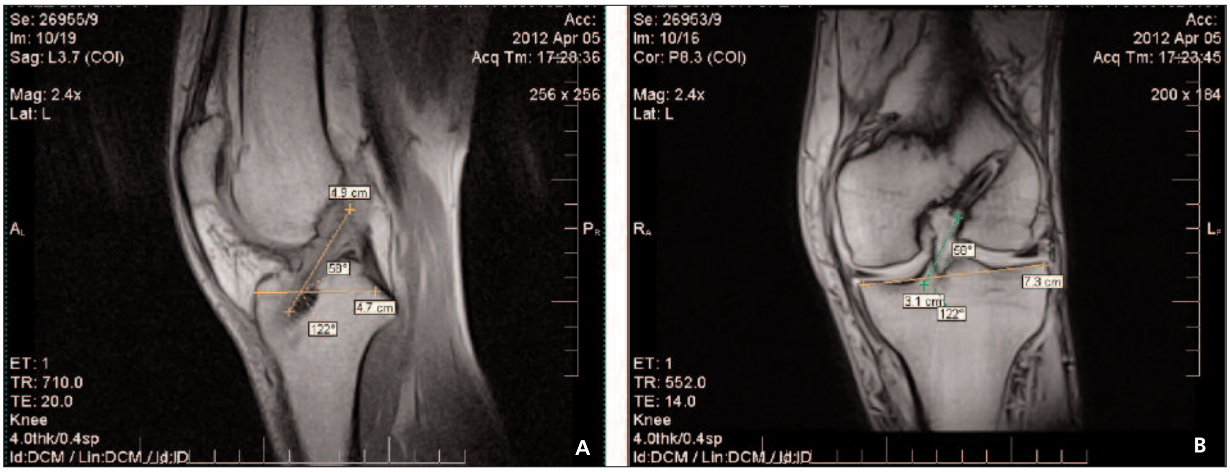

Figure 4. ***A, B,*** Sagittal and coronal T2 MRI exemplifying the trans AM graft obliquity measurements related to the tibial plateau.

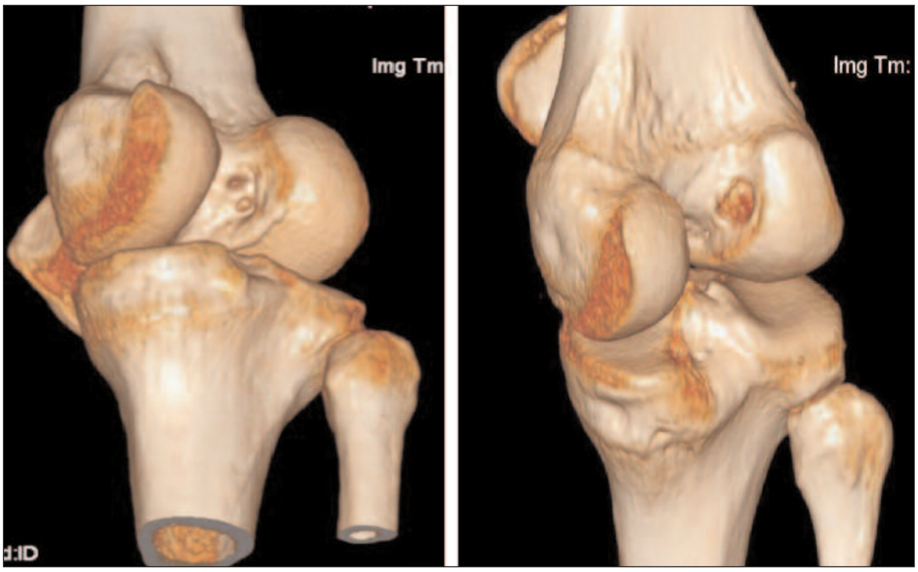

Figure 5. Comparative 3D VRT (volume rendered CT) of the over the top (trans TT) and anatomical (trans AM) positioning of the femoral tunnel.

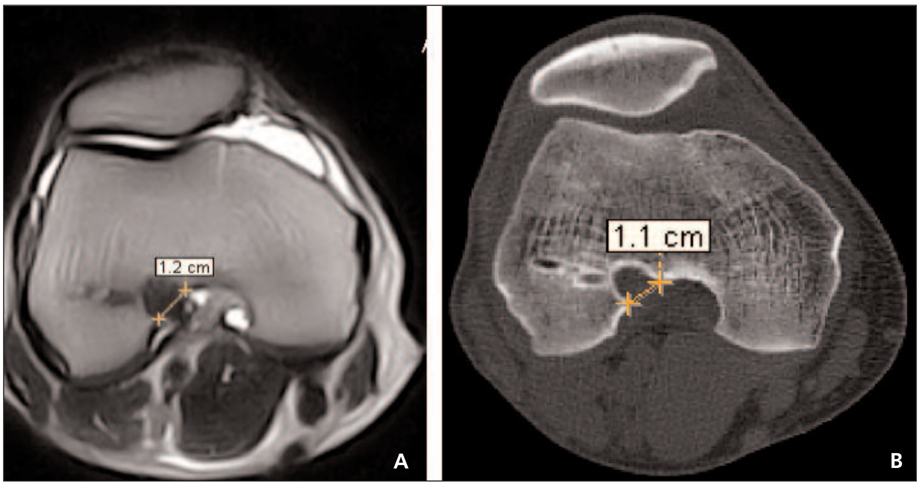

Figure 6. ***A, B,*** Axial T2 MRI and CT at the level of the femoral tunnel aperture, exemplifying the comparative sizing.

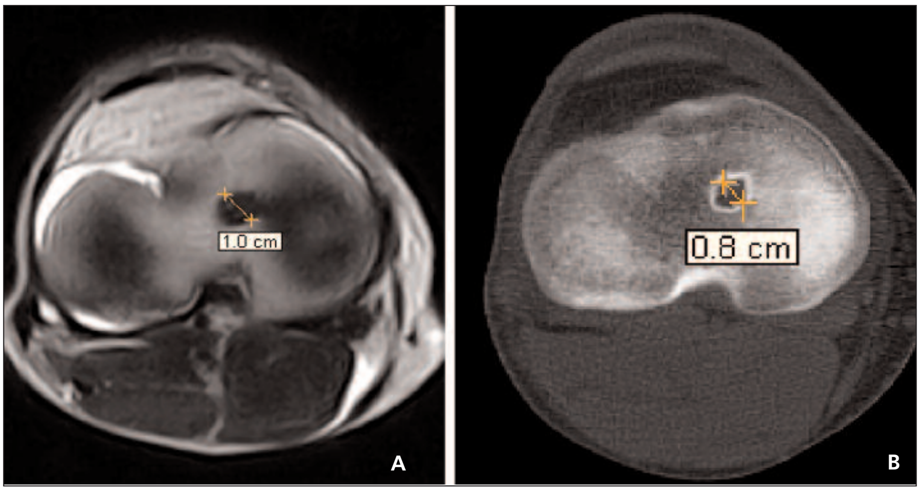

Figure 7. ***A, B,*** Axial T2 MRI and CT at the level of the tibial tunnel aperture, exemplifying the comparative sizing.

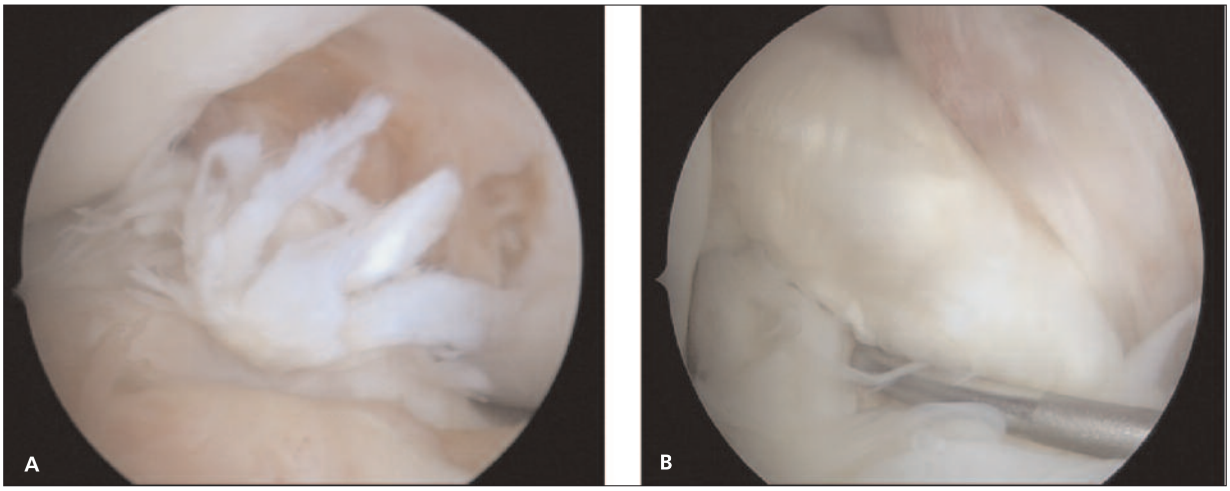

Figure 8. ***A, B,*** Arthroscopic views of the below cases through the lateral portal, depicting a ruptured and a healed graft, respectively (at 2 and 5 years postoperatively).

which cannot be detected by conventional arthroscopy[12]. A more anatomical graft positioning increases obliquity in coronal and sagittal planes and thus becomes difficult to assess both tunnels in a single slice. However, for a revision of ACL reconstructions, CT scans can offer a clearer imaging of tunnels and bone. A more anatomical graft positioning (trans AM) increases obliquity in both coronal and sagittal planes and it becomes difficult to assess both tunnels in a single slice (Figure 5). 3D CT reconstructed volumes (VRT) are reliable and can be used to assess the tunnel position regarding stability and outcome[13]. Although not as widely used, 3D MR imaging were proved accurate and could also be used for pre-operative templating in anatomic ACL reconstruction[14]. The anatomic single bundle reconstruction technique has been found to more accurately reproduce the femoral footprint and the orientation of the graft. By comparison with the classical TT technique, the tibial tunnel placement resulted in a more vertical graft than native ACL (Figure 4). Nonetheless, in many cases normal graft obliquity is not restored with either technique. This later finding is similar to that of Hantes et al[5] and it may be caused by the single bundle technique itself. The current standard requires large footprints to

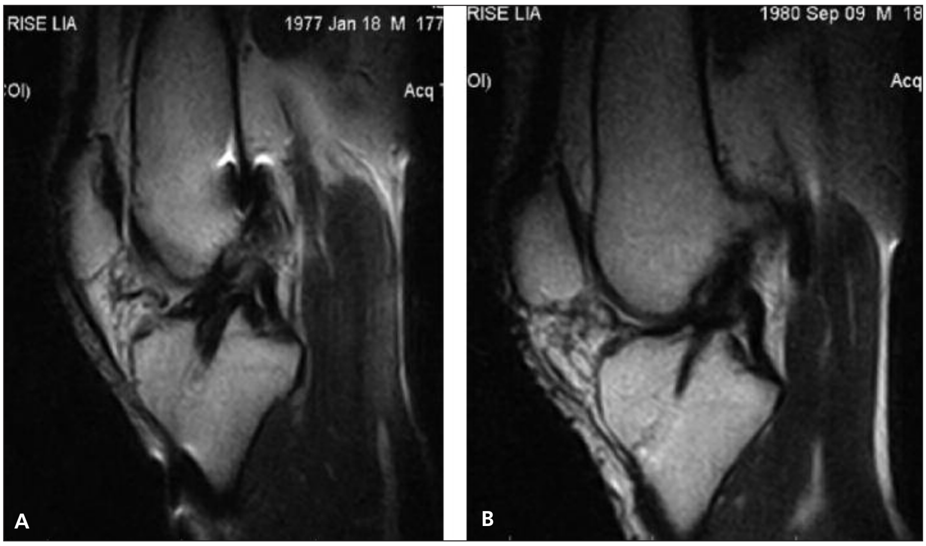

Figure 9. ***A, B,*** Comparative MRI's of the above cases depicting a ruptured and a healed graft respectively (at 2 and 5 years postoperatively).

be restored by double bundle procedure in order to provide a closer resemblance to the native architecture. Nevertheless, for smaller knees and footprints the double-bundle is no longer considered superior[15]. It is universally accepted that ACL reconstruction via trans-tibial technique fails to accurately position femoral and tibial tunnels within the natural insertion site[16]. In addition, freedom of femoral drilling through the AM portal will also allow for a more anterior placement of the tibial tunnel[8]. This, in turn, will lead to a more oblique and natural graft placement with improved restoration of anatomy and stability with ACL reconstruction compared with conventional trans-tibial drilling techniques[17].

Conclusions

MRI proves to be the most useful imaging method in determining an outcome after ACL reconstruction. However, for a revision of ACL reconstructions, CT could offer a clearer image of tunnels and bone stock. The anatomic single bundle reconstruction technique has been found to more accurately reproduce the femoral footprint and the orientation of the graft compared to the TT technique, where the appropriate tibial tunnel placement resulted in a more vertical graft.

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Conflict of Interest

The Authors declare that there are no conflicts of interest.

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