

Article— 3D CT analysis of the positioning of the femoral tunnel using single-bundle reconstruction of the ACL by drilling through an additionally created low medial approach

3D CT analysis of the positioning of the femoral tunnel using single-bundle reconstruction of the ACL by drilling through an additionally created low medial approach

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Abstract— Introduction: We analyzed the location of the femoral bone tunnel by performing 3D CT reconstructions postoperatively after single-bundle reconstruction of the ACL using an additional low medial approach.

Materials and methods: The data of 34 patients was analyzed by 3D CT reconstruction, after single-bundle reconstruction of the ACL. Images were analyzed according to the method of Bernard (1997) regarding the position of the femoral bone tunnel.

Results: The mean distance from the center of the femoral tunnel to the posterior surface of the femoral condyle along the line parallel to the line of Blumensaat (t) was $37.4\% \pm 6\%$. The mean distance from the center of the femoral tunnel to the line of Blumensaat along a line perpendicular to the line of Blumensaat (h) is $27\% \pm 3\%$. In the 4x4 grid, femoral tunnel centers were located—2 in the 2c box and 32 in the 2b box. The mean length of femoral tunnels was 30 ± 0.5 mm.

Conclusion: Using the technique of making an additional low medial approach during single-bundle reconstruction of the ACL allows to make a femoral bone tunnel in an anatomic position, namely between the foot-prints of the AM and PL bundle of the ACL.

Keywords: ACL reconstruction, Femoral tunnel positioning, additional low medial approach, 3D CT analysis

1. Introduction

The anterior cruciate ligament (ACL) is made up of two bundles, the anteromedial (AM) and the posterolateral (PL). The ACL acts as a stabilizer of the knee joint in relation to anteromedial instability. The AM bundle specifically has a stabilizing role in excessive anterior translation of the lower leg, while the PL bundle has an important role in rotational stability of the knee joint.

Traditional ACL reconstruction techniques using a non-anatomic single-bundle technique succeed in restoring anterior stability of the knee joint, but are not good at restoring rotator stability, a fact confirmed by the positivity of the Pivot-shift phenomenon^{1,2}. The use of anatomically sound techniques to repair the ACL results in more

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physiological kinematics of the knee joint and better rotational stability³. However, the technique with anatomical two-bundle reconstruction is technically difficult to perform and is not suitable for short patients and those with a narrow intercondylar notch of the femur. Therefore, we decided on an anatomical single-bundle technique, which is significantly easier to perform and with more reproducible good results⁴.

When performing a single-bundle anatomical reconstruction of the ACL, the transtibial approach may limit the possibilities for positioning the femoral tunnel. Many times the guide needle is out of anatomic position of the ACL in the femoral insertion area, being too high and back on the lateral femoral condyle⁵.

The current report describes a technique that can overcome the limitations of transtibial single-bundle anatomic reconstruction of the ACL.

Making an additional low medial approach is sufficient to facilitate positioning of the femoral tunnel in a more anatomical position between the footprints of the anteromedial (AM) and posterolateral (PL) bundles of the ACL.

The aim of this study was to analyze the positioning of the femoral bone tunnel using 3D CT reconstructions after single-bundle ACL reconstruction with the technique of making an additional low medial access was used (Fig1).



Fig.1 The figure shows the approaches for performing ACL reconstruct: 1- anterolateral 2- anteromedial 3- low medial 4 approach for making the tibial bone tunnel.

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2. Materials and methods

This study analyzed data from patients who underwent ACL reconstruction using a single-bundle anatomic technique with an additional low medial approach and usage of a fresh-frozen tibialis allograft. The study was conducted between 2018 and 2022. During this period, 34 patients underwent analysis of the position of the femoral tunnel by 3D reconstruction of CT imaging. The mean age of the study participants was 35.6 years (ranging from 21 to 49 years). The gender distribution of the participants was 27 men and 7 women. CT studies were performed at 12 postoperative weeks.

2.1. Surgical technique

The procedure begins with a routine examination of the knee joint in order to be able to identify other lesions of the joint that have not been detected until now. After visualizing the ACL lesion, the tendon allograft is thawed, then placed in an antibiotic solution. Finally, any remaining tissue on the tendon other than the ligamentous tissue is removed and the tendon is folded in half. Each end is sutured with #2 Ethibond suture. (Fig. 2)

The surgical technique consists of three steps: 1) marking the femoral tunnel and its preparation 2) marking the tibial tunnel and its preparation 3) passing the neoligament and its fixation.

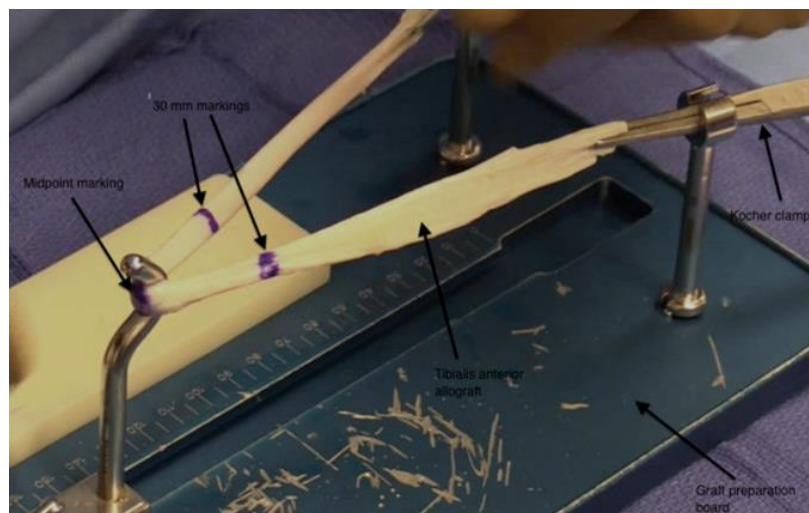


Fig. 2 The figure shows a processed Tibialis anterior tendon graft added in a tendon fiber preconditioner

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2.1.1 Femoral Tunnel Creation

The remainder of the ACL stump was carefully debrided using a shaver and ablator to show and identify the anatomical insertion of the AM and PL bundles at their proximal end. During the interventions, we tried to preserve as much of the ACL remnant as possible. Because most ACL ruptures occur proximally, minimal debridement is required to identify anatomic landmarks. The lateral intercondylar ridge, or the so-called “resident ridge”, which marks the upper border of the attachment site of the ACL in 90° flexion of the knee joint, and the lateral “bifurcate” ridge that separates the anterior medial and posterior lateral bundles of the ACL in the area of attachment to the femoral bone, were identified and used as starting points for making the femoral tunnel. (Fig 3) We mark the position for the femoral tunnel using the a microfracture device, using the anteromedial and low medial approaches for observation and instrumentation, due to the fact that the low medial approach provides a good starting point for instrumentation triangulation. The marking is placed in the central area between the footprints of the anterior medial and posterior lateral bundles, where it is believed that the anatomical position of the ACL is best reproduced through the single-bundle technique. Then we maximally flex the knee joint, thus changing the direction of drilling and create conditions for a maximally long tunnel in the lateral femoral condyle, and place the graduated lancet guide needle at the marked site and measure the length of the distance from the marked site to the lateral femoral cortex. This length usually varies between 3.5 and 4.5 cm. Then, using a cannulated bur, we drill the bone tunnel for the femoral insertion. The depth of the tunnel is usually between 3 and 4 cm. We aim to always leave 11 mm of space between the proximal end of the femoral tunnel and the lateral femoral cortex when using cortical support fixation devices so as not to compromise the integrity of the support cortex. The purpose of longer femoral tunnels is to create a larger contact surface between the graft and the bone tunnel to build more Sharpey fibers and greater neoligament strength.

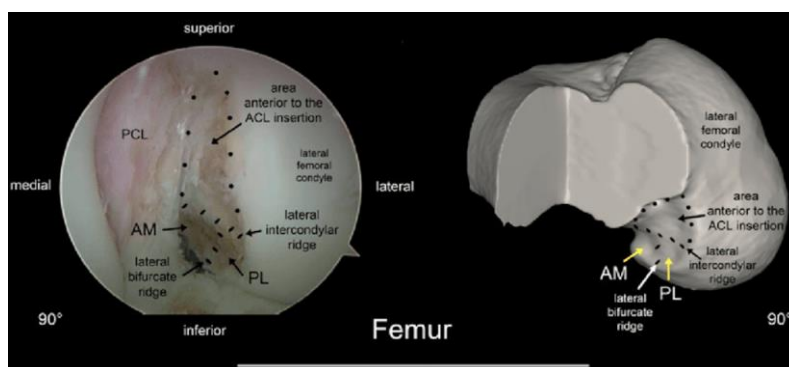


fig.3 The figure shows the two reference points and the footprints of the two bundles of the femoral insertion of the ACL seen by arthroscopic view (left) and by CT reconstruction (right)

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2.1.2 Tibial Tunnel Creation

Consistent with the anatomical studies of the position of the tibial insertion of the ACL by Forsythe et al. (6) we used the following reference points for the positioning of the tibial tunnel: the vector guide is placed in the area of intersection of the lines drawn from the inner edge of the anterior horn of the lateral meniscus and the base of the medial tibial eminence. (fig 4)

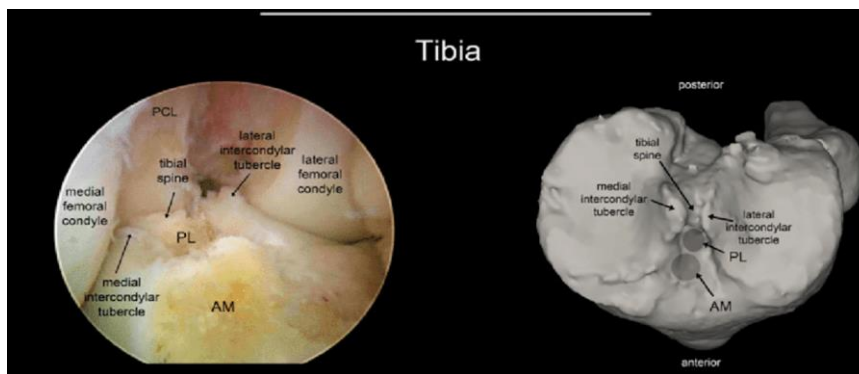


fig.4. The figure shows the anatomical reference points for locating the ACL insertion on the tibial plateau from an arthroscopic perspective (left) and from a CT reconstruction perspective (right)

After establishing the starting points, we pass the vector guide through the antero-medial or low medial approach and use it to place the guide needle. Normally, the opening of the tibial tunnel is located about 2.5-3.5 cm below and about 2.5-3.5 cm medial to the tibial tuberosity. After placing the guide pin, we assess the position of the pin and the future tibial tunnel relative to the two femoral condyles and the roof of the intercondylar notch. The guide pin and, accordingly, the future neoligament must be equidistant from the two femoral condyles to avoid damage to the neoligament during rotation of the knee joint. It is also checked at full extension of the knee joint for the presence of impingement of the future neoligament from the ceiling of the intercondylar notch. After we have made sure of the good positioning of the guide needle, we drill the tibial bone tunnel with a cannulated drill bit.

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2.1.3 Insertion of the allograft

Insertion of the allograft is accomplished by means of a guidewire coming proximally through the femoral tunnel and exiting through the external cortical outlet of the tibial tunnel. Proximal fixation is performed with a device for cortical support of the neoligament (TightRope), and distal fixation is performed with an interference screw. After placing the graft through the cortical fixation device using the guide wires of the device, it is passed through the femoral tunnel and fixed to the lateral cortex of the femur. This was followed by tightening the loop of the device and thus placing the neoligament in the femoral tunnel. The knee joint is then placed in 20 degrees of flexion and continues graft traction is performed. This was followed by placement of the interference screw in the tibial tunnel to achieve distal fixation of the graft. For all-soft tissue grafts, the size of the interference screw is chosen according to the formula $n-1$, where “n” is again the diameter of the bone tunnel. The other difference in the selection of the interference screw when it comes to all-soft tissue grafts is that the length of the screw should occupy almost the entire length of the tibial tunnel and allow its most distal notches to be in contact with the tibial cortex. This was followed by knee joint stability testing and arthroscopic inspection of the intra-articular components. This was followed by placement of an aspiration drain and closure of the approaches. The knee is again immobilized in extension and an ice or cryo bandage is applied.

2.2 3D analysis

Three-dimensional CT images were created using the Horos program based on OsiriX™ software, and the images were aligned to visualize the femoral tunnel. Analyses were performed according to the method of Bernard (1997)⁷. (fig 5)

All measurements were performed by an experienced orthopedic and trauma specialist and average values were used. Data for the location of the center of the femoral tunnels were presented as mean and standard deviation.

3. Results

The mean distance from the center of the femoral tunnel to the posterior surface of the femoral condyle along the line parallel to the line of Blumensaat (t) was $37.4\% \pm 6\%$. The mean distance from the center of the femoral tunnel to the line of Blumensaat along a line perpendicular to the line of Blumensaat (h) is $27\% \pm 3\%$. In the 4x4 grid, femoral tunnel centers were located—2 in the 2c box and 32 in the 2b box. The mean length of femoral tunnels was 30 ± 0.5 mm.

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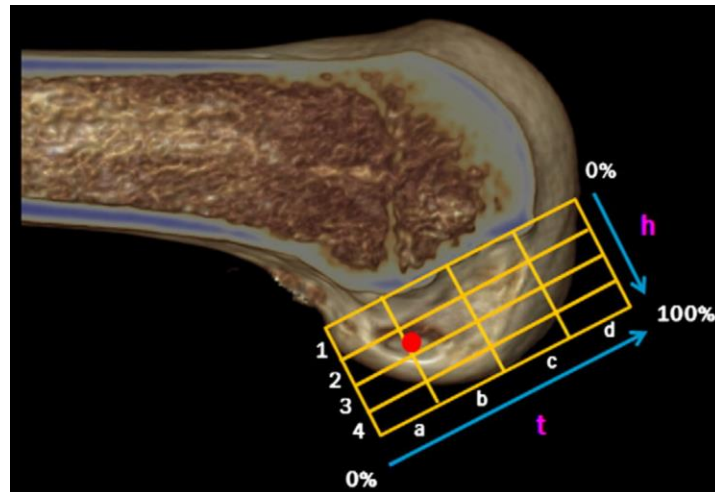


Fig.5. The figure shows how to measure the position of the femora tunnel using Bernard's method (1997) on a 3D model. t =line is parallel to the Blumensaat line and h =is a perpendicular line to the Blumensaat line

4. Discussion

The present study showed that the use of an additional low medial approach to make the femoral bone tunnel allowed its positioning in an anatomic position between the AM and PL bundles' footprints of the ACL in 95% of cases.

Creating the femoral bone tunnel using the standard transtibial technique is a commonly used and relatively easy technique to perform. However, using this technique we face the limitation of the position of the tibial tunnel, due to which there is a tendency for the guide needle to be directed towards the roof of the intercondylar notch of the femur⁸.

A number of reports have reported that techniques using an anteromedial portal allow the femoral bone tunnel to be created independently of the tibial tunnel and placed in a more anatomical position.^{9,10,11} But this approach can create risks of obtaining critically short tunnels and fracturing the posterior wall of the bony tunnel. Also, due to the surgeon's limited field of vision in joint hyperflexion, there may be a risk of iatrogenic damage to the cartilage of the medial femoral condyle when inserting the reamer over the guide needle.^{9,11}

The present method has all the advantages of the anteromedial approach and avoids all the disadvantages of the transtibial method. Once an additional low medial approach is made, the triangulation of the guide needle entry is greatly improved. Also, the additional low medial approach moves the reamer away from the cartilaginous surface of the medial femoral condyle, thus minimizing the risks of iatrogenic injury. The angle at which it is started is more favorable and greatly reduces the risks of extremely short

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tunnel lengths and the same direction reduces the risk of fracturing the posterior wall of the bone tunnel. Making additional approach also gives the surgeon better visibility and creates more space to place the necessary instruments in the proper position and at the proper angle of approach. This makes it easier to reproduce the correct position of the femoral tunnel between the AM and PL bundles. This technique has greater versatility and is applicable to all variations of the patient's knee anatomy. In the present study, in only two patients, the center of their femoral tunnel was in a border zone of a frame drawn in 4x4 grid, namely 2c. This shows that with the low medial approach, the risks of positioning the femoral tunnel to the roof of the intercondylar notch are significantly lower than when using the transtibial technique. When using the additional low medial approach technique, all femoral tunnels were a minimum of 30 mm in length, and all were able to retain 11 mm of residual length from the proximal end of the femoral tunnel to the cortex so as not to compromise the cortex when using graft cortical suspension device.

We did not use the devices for intraoperative measurement due to the fact that our technique is not a two-bundle ACL repair. Marking with a microfracture device in the area between the footprints of the AM and PL bundles of the ACL was used to create the bone tunnel, followed by a 3D assessment of the position.

Bernard's method (1997) is one of the most widely used methods for assessing the position of the femoral tunnel in the single-bundle or double-bundle reconstruction techniques of the ACL. Using this method, Colombet et al.¹² reported that their mean score for (t) was 26.4% of the AM bundle and 32.3% of the PL bundle, and the mean distance (h) was 25.3% of the AM bundle and 47.6% of the PL bundle in two-bundle reconstruction of the ACL. Zantop et al. (13) and Forsythe et al.⁶ reported similar results in their studies. The results of our study are similar to those of the aforementioned and closely approximate those of the study by Bird et al.¹⁴. (table 1).

Table.1 A comparison of studies looking at femoral bone tunnel positions accordingly to the Bernard method

Study	Parallel to the Blumensaat line (t) %		Perpendicular to the Blumensaat line (h) %	
	AM	PL	AM	PL
Colombet et al. (2006)	26.4	32.2	25.3	47.6
Zantop et al. (2008)	18.5	29.3	22.3	53.6
Forsythe et al. (2010)	21.7	35.1	33.2	55.3
Bird et al. (2011)	30		35	
This study	37.4		27	

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To analyze the position of the femoral tunnel we made 3D CT reconstructed images. Thanks to the reconstructions, we were able to visualize well regions that would otherwise be difficult to view, such as the medial aspect of the lateral femoral condyle.

Keto et al.¹⁵ compared the effects of different positions of the bone tunnels in single-bundle reconstruction of the ACL on the kinematics of the knee joint. According to their study, anatomic single-bundle ACL reconstruction, in which the graft is placed midway between the AM and PL bundles, achieves the best stability of all types of anatomic single-bundle reconstructions and most closely restores normal knee kinematics, including and rotatory stability. With the technique described in the present study, a femoral bone tunnel meeting these criteria can be created. (fig. 6). During the study, we found that this technique is applicable to all possible morphological variants of patients and good results can be expected from its use.

The limitations of this study are the fact that a small group of patients were included, no clinical outcomes were included, and that there was no control group. Regarding the lack of a control group, we compared the results we obtained with several other reports^{6,12-15} and obtained similar values. To overcome remaining limiting factors, a larger study is needed to prove the safety and effectiveness of this technique.

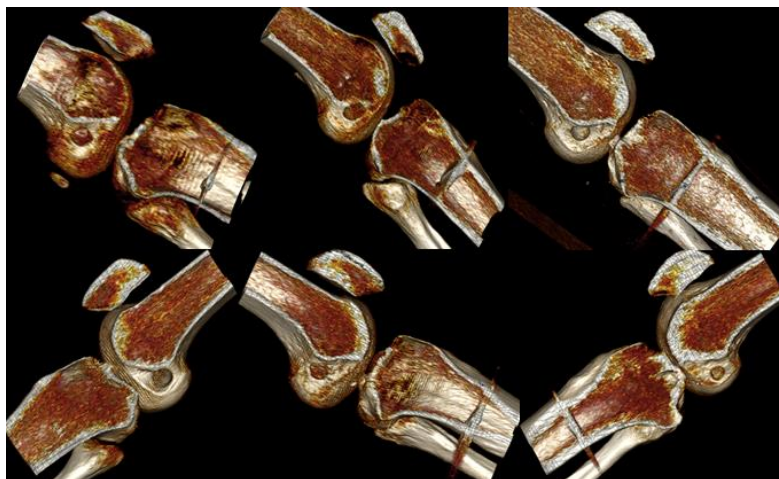


Fig.6 The figure shows the postoperative 3D CT reconstructions that confirm the anatomical position of the femoral tunnel

5. Conclusion

Using the technique of making an additional low medial approach in single-bundle reconstruction of the ACL allows to make a femoral bone tunnel in an anatomic position, namely between the AM and PL bundle attachment sites of the ACL.

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