International Journal of Research in Orthopaedics
Dutt S et al. Int J Res Orthop. 2019 Jul;5(4):656-660
http://www.ijoro.org

Original Research Article

DOI: http://dx.doi.org/10.18203/issn.2455-4510.IntJResOrthop20192679

How anatomical is our tunnel? A three dimensional CT evaluation of femoral tunnel in anatomic anteromedial single bundle anterior cruciate ligament reconstruction

Saurabh Dutt[1]*, Vinod Kumar[2]

[1]Sports Injury centre, Vardhman Mahavir Medical College and Safdarjung hospital, New Delhi, India
[2]Maulana Azad Medical College, New Delhi, India

Received: 14 December 2018
Revised: 08 February 2019
Accepted: 09 February 2019

***Correspondence:**
Dr. Saurabh Dutt,
E-mail: saurabhdutt22@yahoo.com

ABSTRACT

Background: ACL reconstruction has become a common orthopaedic procedure. The anatomy and biomechanics of ACL have been one of the most researched and debated topics in the orthopaedic literature. This has implication on the surgical procedure too with shift from traditional transtibial to more anatomic anteromedial ACL reconstruction. Anteromedial technique results in more anatomic femoral tunnel with graft positioned at the native insertion site. The tunnel position is crucial for better outcome after ACL reconstruction. The purpose of the study was to ascertain the femoral tunnel position made by anatomic single bundle reconstruction with the help of three dimensional computer tomography.

Methods: A prospective case series involving thirty patients with ACL tear who underwent anteromedial single bundle ACL reconstruction. Computer tomography scans were performed on thirty knees that underwent single bundle anteromedial ACL reconstruction. Three dimensional models were created and the data was analyzed according to coordinate system method. Femoral tunnel position was measured in proximal to distal and posterior to anterior directions. This data was compared with the already published reference data on anatomical tunnel position.

Results: Femoral tunnel centre on the medial wall of lateral femoral condyle was located at 35±9% in the posterior to anterior direction. In the proximal to distal direction, the tunnel was placed at 30±12%. Femoral tunnel was placed anteriorly as compared to anatomic anteromedial and posterolateral tunnel position. There was no significant difference in tunnel position in proximal to distal direction.

Conclusions: Femoral tunnel centre on the medial wall of lateral femoral condyle was located at 35±9% in the posterior to anterior direction. In the proximal to distal direction, the tunnel was placed at 30±12%. Femoral tunnel was placed anteriorly as compared to anatomic anteromedial and posterolateral tunnel position. There was no significant difference in tunnel position in proximal to distal direction.

Keywords: Anterior cruciate ligament reconstruction technique, Anatomical, Femoral tunnel, Computed tomography, Three dimensional reconstruction, Co-Ordinate axes method

INTRODUCTION

Our understanding of ACL anatomy and kinematics has evolved over time and this improved understanding has led to a renewed interest in the techniques for ACL reconstruction. For decades, conventional transtibial technique of femoral tunnel preparation was the gold standard for ACL reconstruction. But it has been shown to lead to non anatomic tunnel position and fails to restore normal knee function and biomechanics.[1-4]

There is now stress on anatomical reconstruction of ACL with graft secured to native insertion sites.[5] Securing the graft at the native insertion site has been shown to led to better results clinically.[5-6] Anteromedial portal technique is the currently preferred method of tunnel preparation and has been shown to produce anatomic reconstruction.[5] Computed tomography has emerged as a reliable method to evaluate the tunnel position post operatively.[7]

The purpose of this study was to retrospectively evaluate the three-dimensional positions of the femoral tunnel in patients who had undergone a single bundle anterior cruciate ligament reconstruction through AM portal with the help of computed tomography. Femoral tunnel positions were determined as described by Forsythe et al.[7] These tunnel positions were then compared with reference data of established anatomic double-bundle (anteromedial and posterolateral) tunnel positions and previous similar studies.[3,7]

METHODS

Thirty patients with ACL tear who underwent ACL reconstruction and follow up at department of orthopaedics at Maulana Azad Medical College, New Delhi were included in the study.

Study design

The study design was a randomized controlled trial.

Study duration

The study was conducted from May 2012 till June 2016.

Inclusion criteria

Patients included in the study were clinicoradiologically diagnosed cases of complete ACL tear with unstable knee within the age group of 18 to 50 years. Out of total 41 patients who underwent ACL reconstruction during the study period, 30 patients met the inclusion criteria.

Exclusion criteria

Exclusion criteria were age less than 18 or more than 50 years, patients with pre existing degenerative changes in the knee, patients with multi ligamentous injuries and patients with prior history of knee surgeries. 4 patients were excluded due to pre existing degenerative changes in the knee (on clinical examination and radiological investigations). 2 patients had multi ligament injury and 5 patients had revision surgery thus being excluded from the study.

Procedure

Computed tomography scans were performed on thirty knees in thirty patients who underwent an arthroscopic anteromedial single-bundle anterior cruciate ligament reconstruction. The surgical procedures were performed by two surgeons. There was no change in surgical method over the period of study. All the femoral tunnels were drilled while keeping the knee in 120 degrees of flexion. The time from surgery to the computed tomography scan was 6 months. Computed tomography scans were performed on helical (spiral) multi detector scanner (Somatom definition AS, 128 slices) with 0.625 mm thick slices and 0.6 mm incrementation using bone and standard algorithm by placing the patient in the supine position without administration of intravenous contrast. All research procedures were approved by the institutional review board. Tunnel measurements with use of three-dimensional computed tomography were performed as described in the literature.[7]

Femoral tunnel evaluation

Femoral tunnel positions were determined with use of anatomical coordinate axes system, as shown in Figure 1 (A-F), to facilitate comparisons with other published studies.[3,7] 3-D Reconstruction model of distal femur were made using volume rendering technique (VRT). Initially, the distal femur model was positioned horizontally in the strictly lateral position, where both femoral condyles were superimposed (A). The model was then rotated to a distal view, and the medial femoral condyle was virtually removed at the highest point of the anterior aperture of the intercondylar notch leaving the lateral femoral condyle (B, C, D). Finally, the model was rotated back to the strictly lateral position which provided end on view of medial wall of lateral femoral condyle and the femoral tunnel without any hindrance from medial condyle (F). Position of the centre of femoral tunnel was measured through co-ordinate axes method at lateral condyle's medial wall in notch area.

The femoral tunnel position was determined in the posterior to anterior and proximal to distal direction parallel to the corresponding anatomical axis. The posterior to anterior position were calculated as percentage of the distance from the line (L1) running through the posterior border of the medial wall of the lateral condyle to the line (L2) running through the most anterior point of the notch. Proximal to distal position were calculated as percentage of the distance from the line (L3) running through the proximal border of the notch to the line (L4) running through the distal point of the notch roof. These lines L1-L4 and the measurement method is the same as described by Forsythe et al.[7]

Posterior to anterior measurement for femoral tunnel was calculated as A/B. Proximal distal measurement were calculated as a/b.

A = Posterior to anterior distance of femoral tunnel from line through posterior border of medial wall of lateral condyle (L1)

B = Distance between lines through posterior border (L1) and most anterior point of the notch (L2) on medial wall of lateral condyle.

a = Proximal to distal distance of femoral tunnel from proximal border of the notch (L3).

b = Distance between lines through proximal (L3) and distal extent of the notch (L4).

Measurements were made in proximal to distal and posterior to anterior direction and expressed in percentage of the maximum dimension. Location of the tunnel was determined with mean and the standard deviation. The data obtained was compared with the previous studies that involved measurements through coordinate axes method.

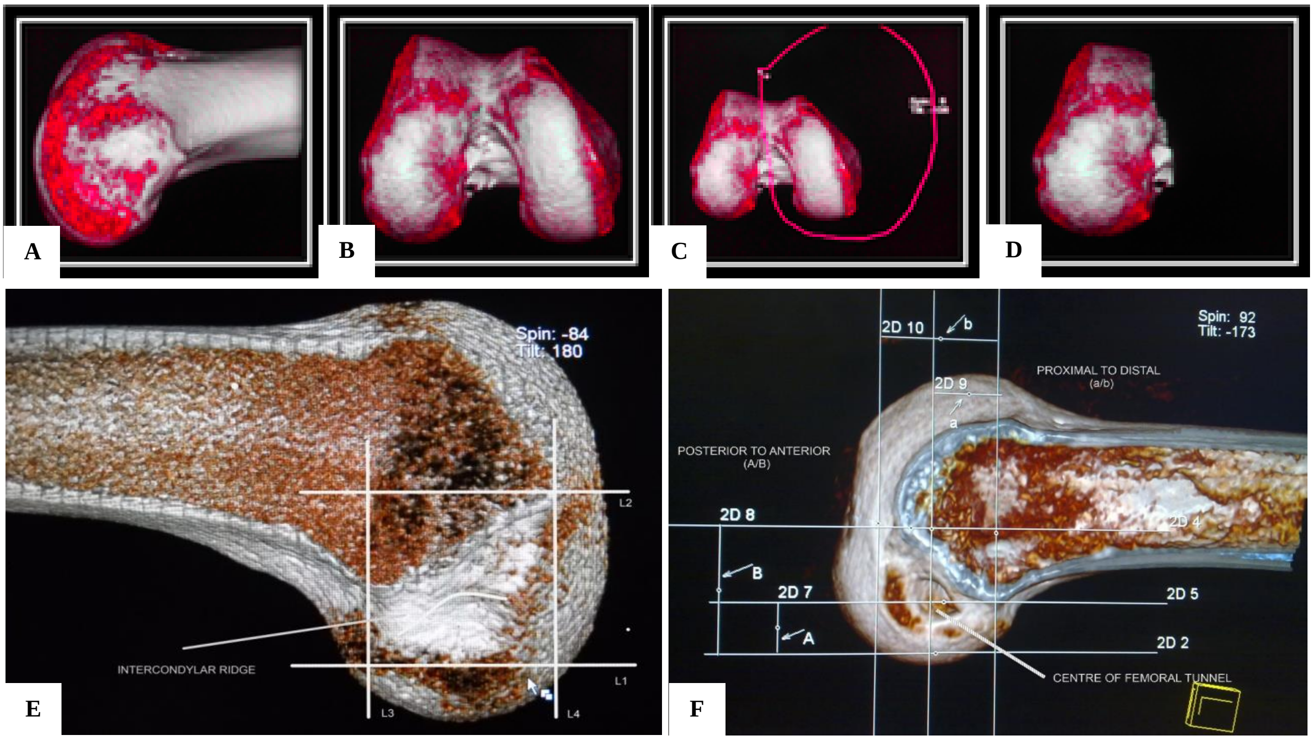

Figure 1: Post operative CT evaluation - 3D CT reconstruction images of femur (A) True lateral position (both femoral condyles superimposed); (B) rotated to distal view; (C) marking at highest point of the anterior aperture of the intercondylar notch; (D) medial femoral condyle virtually removed; (E) view of medial wall of lateral femoral condyle in a normal knee revealing intercondylar ridge and insertion site of ACL. Lines L1-4 as described in the text; (F) inside view of lateral condyle revealing femoral tunnel. The arrow points towards the centre of the femoral tunnel. Posterior to anterior measurement done by A/B and proximal to distal measurement done by a/b.

Ethical approval

The study was reviewed and approved by the institutional ethical committee at Maulana Azad Medical College, New Delhi. All the patients consented to participate in the study.

Statistical analysis

Independent t tests were performed to compare the tunnel position in our study. The significance level was set at $p<0.05$ to account for the comparison of the femoral tunnels. The inter observer and intra observer reliability of the co-ordinate axes method was calculated by determining intra class correlation coefficient and 95% confidence interval for the intraclass correlation coefficient.

RESULTS

Total thirty patients were included in the study. Computed tomography scans were performed on thirty knees in thirty patients (27 male and 3 female patients, with a mean age [and standard deviation] of 27.33±6.79 years; range, 19 to 44 years) and tunnel position was determined. Tunnel position as determined by co-ordinate axes method is summarized in table no.1. Reliability estimates for the co-ordinate axes method are presented in table no.2.

The mean posterior to anterior distance of the tunnel centre was 35±9% of the posterior to anterior height of the medial wall of the lateral femoral condyle (from F1 to F2). The mean proximal to distal distance of the tunnel centre was 30±12% of the proximal to distal depth of the lateral femoral condyle's medial wall (from F3 to F4).

DISCUSSION

The osseous landmarks of ACL attachment on the femoral condyle and the double bundle anatomy of ACL are now well defined and understood. Both the bundles attach posterior to the intercodylar ridge with bifurcating ridge separating the two bundles. This has placed the femoral insertion site more anterior and distal when compared to previous concepts about ACL footprint. This improved understanding has led to stress on more 'anatomical' reconstruction of the anterior cruciate ligament by placing the graft as near to the native insertion site in order to restore anatomy.[8,9] Double bundle reconstruction has shown improved rotational stability and improved anterior laxity.[10] This is shown to led to better kinematics of the knee.[11] But Double bundle technique has its own problems. The technique is complex and takes longer time to master. The two tunnels can merge if not created properly and in cases of smaller knee, double bundle technique can led to non anatomic tunnel placement. Hence double bundle technique has been questioned as technically being 'double trouble.[12] Thus there is focus on anatomical single bundle reconstruction technique which has been shown to have similar clinical results as that of double bundle technique.[13] This anatomic single bundle reconstruction technique strives to create tunnel at the mid bundle position that is in between the insertion sites of anteromedial and posterolateral bundles.[14] This reflects a change from previous single bundle reconstruction techniques that focused on anteromedial bundle only and positioned the graft at AM bundle site. Specific ancillary instruments (aimer) have been developed to facilitate the positioning of the tunnel necessary when performing anatomic single-bundle ACL reconstruction. This study was undertaken to evaluate the femoral tunnel position in anatomic single bundle reconstruction.

Comparison of our results with previous literature shows that our femoral tunnel were placed significantly anterior as compared to anatomical footprint ($p<0.05$).[7] In proximal to distal direction, our femoral tunnel centre is slightly distal to the anatomical anteromedial postion but this finding was insignificant ($p>0.05$). The anatomic posterolateral tunnel centre position was significantly distal to our tunnel centre but we didn't strive to create tunnel too posterior as we intended for more anatomic femoral tunnel which would be mimicking more of anteromedial to mid bundle position.

Comparing our result with the work of Kopf et al, there was significant difference in position of the tunnel centre.[3] The method of femoral tunnel preparation by Kopf et al was transtibial and we used Antero medial portal technique in our study. The centre of tunnel in Kopf's study was both significantly anterior and distal to centre of tunnel in our study ($p<0.05$). The transtibially drilled femoral tunnels were consistently positioned anterior to the anatomic femoral tunnel by antero medial portal.

This study shows that current anteromedial portal technique is better than transtibial technique but not full proof in making perfectly anatomical femoral tunnel as there is tendency to make the femoral tunnel more anteriorly than the anatomical footprint. The tunnel in our study was more anatomic than the tunnel created via transtibial technique in which the tunnel was significantly anterior and distal. This reinforces the current understanding that transtibial technique leads to non anatomic tunnel position.[3]

Our tunnel position was compared with the reference data from the cadaveric study in double bundle ACL reconstruction. We found that tunnel through AM portal in our study was still higher than the anatomical footprint. The reason for this anterior tunnel position could be inaccurate placement of the aimer device or the constraint in using anteromedial portal for tunnel preparation. A remedy to this can be the accessory anteromedial portal as advocated by bedi et al that can be utilized for more anatomical tunnel preparation.[5] We could not find any prior published study on Indian patients that evaluated femoral tunnel position by coordinate axes method.

CT and 3D reconstruction with subtraction imaging provides an end on view similar to the one achieved arthroscopically. The landmarks used in CT evaluation can be observed during arthroscopic assessment of the knee and help the surgeon in creating near anatomical tunnel position. Computed tomography is an effective and reliable tool for determining the tunnel position and it reduces the ambiguity associated with tunnel position ascertained through landmarks like blumensaat's line which give only one dimensional picture of the three dimensional tunnel.

Limitations

A limitation of this study was that the ACL reconstructions were performed by a single surgeon. Thus there can be bias due to the particular technique of that surgeon. Multiple operating surgeons can reduce this bias and render tunnel evaluation more reliable. Another drawback of this study was that the CT scans of the knee were performed at an interval of 6 months and not in immediate post operative period. The tunnel could have widened and the aperture could have migrated from the original position. In our knowledge, such tunnel aperture migration has not been reported so far.

There is paucity of studies on tunnel assessment in ACL reconstruction with coordinate axes method and it is the first study of its kind in Indian patients to the best of our knowledge. Our study can be used as a source for comparison and reference for tunnel evaluation in ACL reconstruction.

CONCLUSION

To conclude, anteromedial ACL reconstruction led to less anatomic tunnel than expected though it was more anatomical than the tunnel produced by transtibial method. There is further scope of improvement in tunnel placement through accessory anteromedial portal or use of outside –in technique for more anatomic femoral tunnel. CT with 3D reconstruction was employed for tunnel position measurement which is an effective method to ascertain tunnel position and is easily reproducible. We advocate use of CT for assessment of tunnel position in ACL reconstruction.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the institutional ethics committee

REFERENCES

1. Biau DJ, Tournoux C, Katsahian S, Schranz P, Nizard R. ACL reconstruction: a meta-analysis of functional scores. Clin Orthop Relat Res. 2007;458:180-7.
2. Fithian DC, Paxton EW, Stone ML, Luetzow WF, Csintalan RP, Phelan D, et al. Prospective trial of a treatment algorithm for the management of the anterior cruciate ligament-injured knee. Am J Sports Med.2005;33:335-46.
3. Kopf S, Forsythe B, Wong AK, Tashman S, Anderst W, Irrgang JJ. Nonanatomic tunnel position in traditional transtibial single-bundle anterior cruciate ligament reconstruction evaluated by three-dimensional computed tomography. J Bone Joint Surg Am. 2010;92:1427-31.
4. Tashman S, Kolowich P, Collon D, Anderson K, Anderst W. Dynamic function of the ACL-reconstructed knee during running. Clin Orthop Relat Res. 2007;454:66-73.
5. Bedi A, Altchek DW. The Footprint anterior cruciate ligament technique: An anatomic approach to anterior cruciate ligament reconstruction. Arthroscopy. 2009;25:1128-38.
6. Jepsen CF, Lundberg-Jensen AK, Faunoe P. Does the position of the femoral tunnel affect the laxity or clinical outcome of the anterior cruciate ligament-reconstructed knee? A clinical, prospective, randomized, double-blind study. Arthroscopy. 2007;23:1326-33.
7. Forsythe B, Kopf S, Wong AK, Martins CAQ, Anderst W, Tashman S, et al. The location of femoral and tibial tunnels of anatomic double-bundle anterior cruciate ligament reconstruction analyzed by three-dimensional computed tomography models. J Bone Joint Surg Am. 2010;92:1418-26.
8. Karlsson J. Anatomy is the key. Knee Surg Sports Traumatol Arthrosc. 2010;18:1.
9. Pombo MW, Shen W, Fu FH. Anatomic double bundle anterior cruciate ligament reconstruction: Where are we today? Arthroscopy. 2008;24:1168-77.
10. Jarvela T. Double bundle versus single bundle anterior cruciate ligament reconstruction: A prospective, randomize clinical study. Knee Surg Sports Traumatol Arthrosc. 2007;15:500-7.
11. Zantop T, Diermann N, Schumacher T, Schranz S, Fu FH, Petersen W. Anatomical and anatomical double bundle anterior cruciate ligament reconstruction: Importance of femoral tunnel location on knee kinematics. Am J Sports Med. 2008;36:678-85.
12. Harner CD, Poehling G. Double bundle or double trouble? Arthroscopy. 2004;20:1013–4.
13. Markolf KL, Park S, Jackson SR, McAllister DR. Anterior- posterior and rotatory stability of single and double bundle anterior cruciate ligament reconstructions. J Bone Joint Surg Am. 2009;91:107-18.
14. Bird JH, Carmont MR, Dhillon M, Smith N, Brown C, Thompson P, et al. Validation of a new technique to determine midbundle femoral tunnel position in anterior cruciate ligament reconstruction using 3-dimensional computed tomography analysis. Arthroscopy. 2011;27:1259-67.

Cite this article as: Dutt S, Kumar V. How anatomical is our tunnel? A three dimensional CT evaluation of femoral tunnel in anatomic anteromedial single bundle anterior cruciate ligament reconstruction. Int J Res Orthop 2019;5:656-60.