Accurate Positioning of Femoral and Tibial Tunnels in Single Bundle Anterior Cruciate Ligament Reconstruction Using the Indigenously Made Bernard and Hurtle Grid on a Transparency Sheet and C-arm

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Abstract: Many factors determine the outcome of the anterior cruciate ligament reconstruction surgery. The single most important factor, also well within the control of a surgeon, is tunnel placement. It is difficult to accurately determine the center of the anterior cruciate ligament foot print, and many a times it is also difficult to accurately define the intercondylar and bifurcate ridge. This makes determination of the accurate entry point of the guidewire difficult. We have printed our indigenously formed grid (equidistant boxes) on an old-fashioned transparency sheet. We use a fluoroscopy (C-arm) shot intraoperatively in the lateral position and superimpose this sheet to determine the position of the guidewire by calculating the percentage of boxes. We aim at 27.7% in proximal to distal and 37.5% in anterior to posterior on the femur side and 45% in front to back and medial to lateral on the tibial side. C-arm is freely available, but the inbuilt grid facility may be available in only the higher version of C-arms. Our indigenously designed grid can be easily used across the globe with ease to achieve accuracy in tunnel placement without violating anatomy and without any extra cost.

Arthroscopic anterior cruciate ligament (ACL) reconstruction is a commonly performed surgery nowadays. Its success and failure are determined by many factors. Some of these factors are beyond the control of the surgeon. The literature is unanimous on one point that the incorrect tunnel position is the single most common cause of failure.[1,2] The concept of the anatomical attachment, orientation, and function of the ACL has been a matter of debate for long. Some recent studies have shown that the ACL is attached as a single footprint on the femoral side (the ribbon concept).[3] To determine the center of the bundle, many people rely on anatomical landmarks. In some studies, it has been shown that even these landmarks are not consistent and may be absent in many patients. If we routinely clear the sidewall of the notch of soft tissue by radiofrequency coblation to try to accurately identify the anatomic landmarks, this may have an effect on functional outcome because retaining soft tissue has been shown to be relevant for postreconstruction proprioception.[4] If the remnants are preserved, it is difficult to determine where the center of the footprint is within those remnants. It becomes very subjective when we take center of the foot print and anatomical landmarks into consideration for placing tunnels in the femur and tibia. Various studies have concluded the center of the anteromedial and posterolateral bundle of ACL on the femur and tibial side, and the average value for a single bundle ACL reconstruction has been shown to be at 29% (proximal to distal) on the x-axis and 37% (anterior to posterior) on the y-axis (knee in 90° of flexion).[5-7] The center of the entire tibial footprint has been estimated to be at the midpoint of the centers of the 2 bundles at 44% (anterior to posterior).[8,9] Keeping this in view, we tried to use intraoperative fluoroscopy (C-arm) for accurately localizing the starting point of our tunnel.

Designing of the Grid on Transparency

The C-arm that we have (model: GE OEC Birvo 715 Prime, GE Hua Lun Medical Systems, China) does not have inbuilt facility of formation of a grid system or measurement. We indigenously thought of printing the

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The authors report that they have no conflicts of interest in the authorship and publication of this article.

Received October 11, 2016; accepted February 2, 2017.

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2212-6287/16980/$36.00
http://dx.doi.org/10.1016/j.eats.2017.02.005

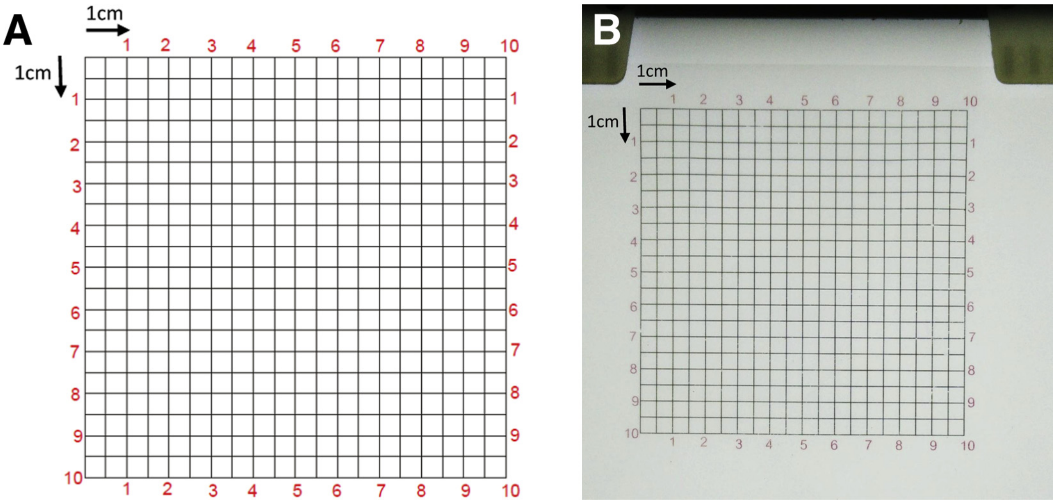

Fig 1. (A) Designing of the grid on the Microsoft Word program version 2010 (Microsoft, Redmond, WA) using the insert table tool command. One can change the width of the boxes by right clicking on the table and selecting the command "table properties." Inside "table properties" one can change the desired width and height of the boxes to make all of them of equal length and breadth. (B) Picture of the grid after printing of the boxes on the transparency sheet.

grid on locally available polyester film sheets (transparency sheets) used commonly for overhead projection in teaching. They have been manufactured by de'Smat in India. Each sheet is of A4 size (210 mm × 297 mm) and compatible with photocopier and laser printers. After designing the grid in the form of a table (20 × 20), equidistant and equal size boxes in the Microsoft Word program version 2010 (Microsoft, Redmond, WA), using the insert table tool (Fig 1A), it was printed on this transparency sheet (Fig 1B).

Surgical Technique and Use of Transparency Grid While Performing Arthroscopic ACL Reconstruction Using Fluoroscopy (C-arm)

The patient is placed in the supine position and a tourniquet applied high up on the thigh (Video 1). A bolster is placed near the foot end to keep the knee at 90° of flexion and a side support at the level of the tourniquet to prevent falling of the limb sideways. Standard anteromedial and anterolateral portals were made and the graft was harvested from the proximal tibia. Through the anteromedial portal or accessary medial portal a guide pin (or a microfracture awl) is kept at the desired point over the medial aspect of the lateral femoral condyle, which the surgeon thinks it to be the center of the tunnel placement. C-arm is draped and then brought in the lateral position (Fig 2) to acquire the lateral image of femoral condyles (overlapping to each other). The indigenously designed grid is superimposed on this C-arm image and aligned on the intercondylar ridge and along the anteroposterior width of the lateral femoral condyle (as described by Bernard and Hertel).[10,11] The percentage of the position of the entry point (determined by the position of the tip of the pin) is determined by calculating the number of boxes back to front (proximal to distal) and anterior to posterior (as described by Bernard and Hertel[11]) (Fig 3). The position of the guide pin is adjusted if it is not corresponding to 27% in proximal to distal and 37% anterior to posterior on the lateral femoral condyle in lateral projection. Once the surgeon decides about the entry point, he goes ahead and does the drilling of the pin and subsequent reaming as per the set standard described for endobutton loop (Endobutton CL Ultra, Smith & Nephew, Andover, MA).

Similarly for the tibial tunnel, the aiming device is put and a lateral image on C-arm is acquired to determine the position of the pin entry on the tibial condyle. The indigenously designed transparency grid is superimposed again on the C-arm image over the proximal aspect of the tibia along its maximum width in the

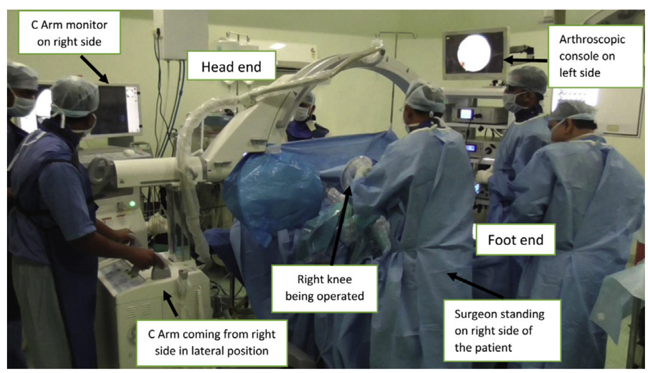

Fig 2. Right knee. Arthroscopic anterior cruciate ligament reconstruction underway. C-arm is brought from the right side in the horizontal position to get a lateral image of the right knee, which is at 90° of flexion. The arthroscopic console is on the left side and the C-arm monitor is on the right side. The surgeon is standing on the right side of the patient.

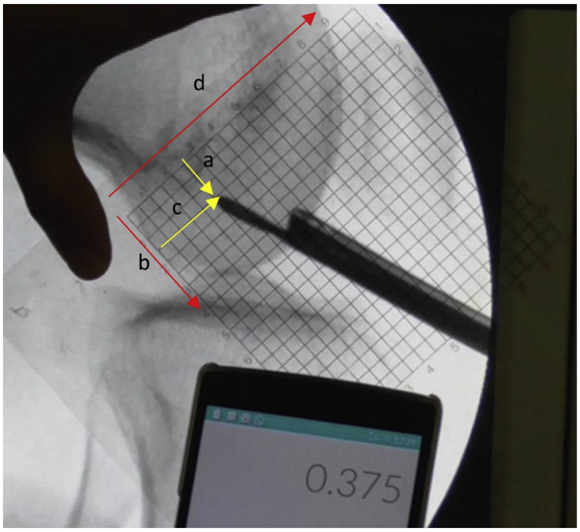

Fig 3. Calculating the position of the pin entry. In proximal to distal, divide "c" (number of boxes from back to the tip of the guide pin) by "d" (total number of boxes from proximal to distal). In this case, 5/18 = 27.7% in proximal to distal. In determining the position of the pin in anterior to posterior, divide "a" (number of boxes from top to tip of guide pin) by "b" (number of boxes from anterior to posterior). In this case, 3/8 = 37.5% in the anterior to posterior position.

anteroposterior direction (Fig 4). The calculation is performed and told to the surgeons in percentage about the position of the guidewire entry (as described by Amis and Jacob[8]). We aim to be at 44% (front to back) along the total lateral width of the tibial condyle. The surgeon shifts the aiming device according to the values given by measurement. Once the point is decided, the surgeon goes ahead and drills and reams the tunnel as per the standard techniques and uses biodegradable screws (BIORCI Screw, Smith & Nephew) for tibial side fixation.

Discussion

Getting the tunnel right is of paramount importance.[1,2] In this regard, it is important to either use an anatomical landmark or go by the remnant of the remaining ACL foot print. Study has shown that determining the correct entry point on the basis of anatomical landmarks is not always accurate. Finding the remnant of the native ACL is also difficult, especially in chronic cases. The position of the tunnel placement thus becomes very subjective. To get the position right, people have used navigation.[12-14] The navigation technique is good, but the equipment is costly and has a potential risk of damage to bone and stress riser due to pin insertion. The other method of getting the tunnel position right is by scrutinizing the cases already performed with a computed tomography scan and evaluating the tunnel position.[15] One can get feedback by performing a computed tomography scan of his or her already performed cases and change the tunnel position in subsequent cases. Using intra-operative fluoroscopy gives instant and important feedback to the surgeon and can effectively be used by the surgeon as an additional guide to locate the exact center of the femoral and tibial tunnel placement.[16-18] C-arm is ubiquitously present in an orthopaedic theatre and all orthopaedic surgeons and technicians are familiar with its application. Just using C-arm is

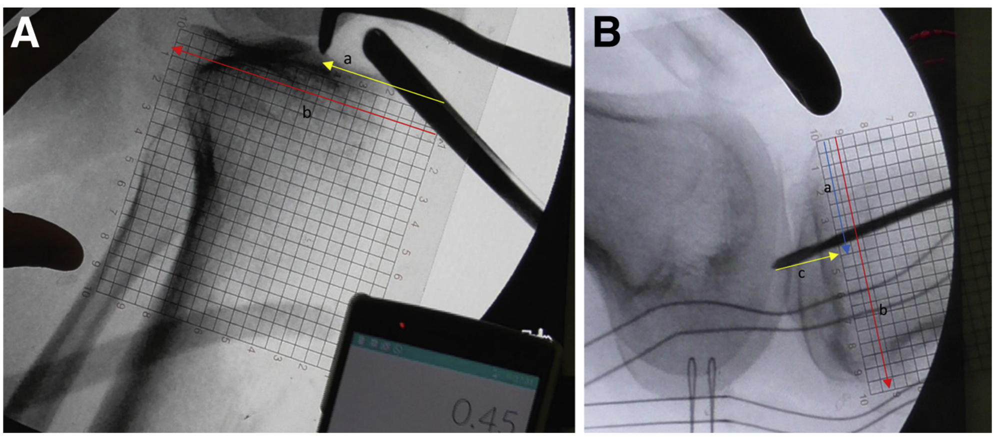

Fig 4. (A) Determining the position of the aiming device by getting a lateral image on C-arm and positioning the grid on the proximal aspect of the tibia. Calculate the number of boxes from front to the tip of the aiming device (a) and divide it by the total number of boxes from front to back (anterior to posterior) (b) along the maximum proximal width of the tibia (a/b). In this case, 9/20 = 45%. (B) After passing the guidewire through the aiming device in the tibia, its position can be determined in percentage from front to back along the width of the tibial plateau. Drop an orthogonal line (c) from the tip of the wire, where it has existed inside the joint, to the line connecting the anterior and posterior width of the tibia (b). Calculate the number of boxes from front to back (anterior to posterior) where the line c meets the line b and then divide it by the total number of boxes from front to back (anterior to posterior) along the line b (a/b). In this case, 9/20 = 45%.

Table 1. Pearls and Pitfalls of the Technique

Pearls	Pitfalls
1. Inexpensive to design and print the grid	1. Radiation exposure
2. Easy to use and reproduce the technique	2. One value may not suit all the patients
3. Very short learning curve	3. Increases the surgical time initially
4. Mimics the anatomical anterior cruciate ligament	4. Has not been tested in the transtibial technique of femoral tunnel placement

not an answer, but to be more effectively using it and to get the values of 27% and 37% on the femoral side and 43% on the tibial side,[8,11] we need to have measurement on the image. The inbuilt measurement facility is only available in high-end C-arms, and thus our indigenously designed grid on a transparency sheet comes in very handy. It is not only cheap but also very easy to use. The calculation can easily be performed by a calculator available on mobile phones. This method is reproducible and any technician or resident can be trained to give intraoperative values to the surgeon (Table 1). According to the literature, in America alone, ACL reconstruction is performed at a rate of 175,000 per year, with 85% by surgeons who perform fewer than 10 per year.[19] Probably a similar situation, where more number of ACL reconstruction surgeries are being performed by the surgeons who do not operate it very often, exists in other parts of the world too. It is very important for these surgeons to have extra feedback for tunnel placement while performing surgery. Even those who routinely perform these surgeries can also be benefitted by increasing the precision in their tunnel placement.

An important limitation of this technique is that either the radiographer or floor nurse or the unscrubed resident needs to be trained regarding how to put the transparency sheet with grid on the C-arm image and how to perform the calculations. Also this technique involves very minimal radiation exposure to the surgical team as well as to the patient (Table 2).[20] Although the number of shots are very limited and with good understanding among the team members, it can be cut down to as low as 5 to 6 shots only. But there may be a learning curve, and initially it may involve more numbers of shots. The calculations can be practiced on saved images after or before surgery in the presence of the surgeon by the person who will be performing it intraoperatively. There is also a concern whether one value fits all the patients (27% in proximal to distal and 37% in anterior to posterior on the femoral side and 45% front to back on the tibial side).[8,11] Hence more research is needed in this area, but use of this indigenously designed grid will definitely add extra precision in surgeons' armamentarium.

Our indigenously designed grid system on a transparency sheet is very economical, easy to use with reproducible results. It can be used around the globe because this sheet is available everywhere.

Table 2. Advantages and Limitations of the Technique

Advantages	Limitations
1. Brings accuracy and objectivity in tunnel placement	1. C-arm in the operating field can hamper the arrangement of arthroscopic equipment
2. Consistency in tunnel placement by the surgeon	2. Draping of C-arm is needed
3. Preservation of remnants of the anterior cruciate ligament thus preserving proprioception	3. Technique has not been tried for the leg hanging down position with a thigh holder because it may be difficult to take C-arm shot
4. Better functional outcome with accurate tunnel placement	4. Difficult to use C-arm with offset guide

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