Technical Note

# All-Inside Tibial Tunnel Drilling: How to Calculate a Safe Drilling Length to Avoid Anterior Cortex Violation

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**Abstract:** The all-inside technique for bone tunnel drilling during ligament reconstruction procedures (ACL, PCL etc.) is gaining popularity as a bone preserving, less invasive technique with the potential for more rapid recovery. To preserve the advantages of closed-socket tunnels, it is essential not to violate the cortex during retro-drilling. The risk of cortical breach is higher with the tibial tunnel compared to the femoral one due to the obliquity of the tunnel relative to the cortex. Our purpose is to introduce a trigonometric formula, which allows the surgeon to calculate the safe tibial tunnel drilling length during all-inside ligament reconstruction and explain its proof.

## Introduction

The all-inside technique for bone tunnel drilling during ligament reconstruction procedures (ACL, PCL etc.) is gaining popularity as a bone-preserving, less-invasive technique with the potential for more rapid recovery.[1,2] All-inside tunnel drilling is a modification of the classical technique in which incomplete tibial and femoral tunnels are retro-drilled from inside the joint, preserving cortico-cancellous bone at the end of the "blind socket".[2-4] Some features of this technique include dual suspensory graft fixation, decreased bone removal, and smaller skin incisions. In order to preserve these advantages it is important not to compromise the cortical bone during retro-drilling. The risk of cortical breach is higher with the tibial tunnel compared to the femoral one due to the increased obliquity of the tunnel relative to the cortex (Fig 1, Video 1). The purpose of this article is to introduce a trigonometric formula that allows the surgeon to calculate a safe tibial tunnel drilling length during all-inside cruciate ligament reconstruction and explain its proof.

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## Surgical Technique

Our trigonometric formula allows the surgeon to quickly calculate a safe tibial tunnel drilling length using 1 preoperative radiograph measurement (the posterior tibial slope), and 3 easily obtained intraoperative measurements (the tibial drill guide angle, the tibial tunnel radius, and the distance from the joint (i.e., ACL or PCL footprint) to the tibial cortex measured on the tibial drill guide).

The proof of the formula consists of 8 steps.

### Step 1: Calculate Posterior Tibial Slope

The posterior tibial slope ($\alpha$) is measured on a lateral knee radiograph, as previously described[5] (Figs 2-3).

### Step 2: Tibial Drill Guide Positioning

The intra-articular arm of the Arthrex (Naples, FL) retroconstruction tibial drill guide is positioned parallel to the tibial plateau in the sagittal plane and perpendicular to the anteromedial cortex in the axial plane (Figs 4 and 5).

### Step 3: Tunnel Radius Assessment

Calculate the radius ($r$) of the tibial tunnel dividing the planned tibial tunnel diameter by two (Fig 6).

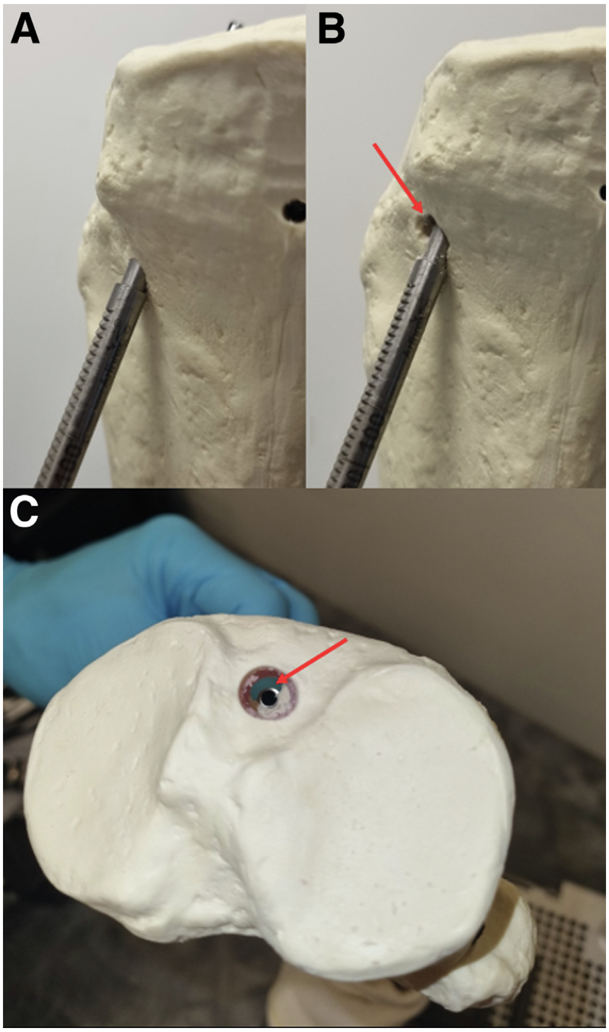


**Fig 1.** Sagittal view of the Arthrex retroconstruction stepped tibial drill guide malleted into the proximal tibia of a sawbones model. (A) Note the obliquity of the drill guide relative to the proximal tibial cortex. Sagittal view of sawbones model after retro-drilling to the tip of the guide. (B) Despite the 7-mm stepped tip, the anterior tibial cortex has been breached (red arrow). (C) ″Bird's eye view″ of the tibial tunnel after violating the anterior cortex (red arrow).

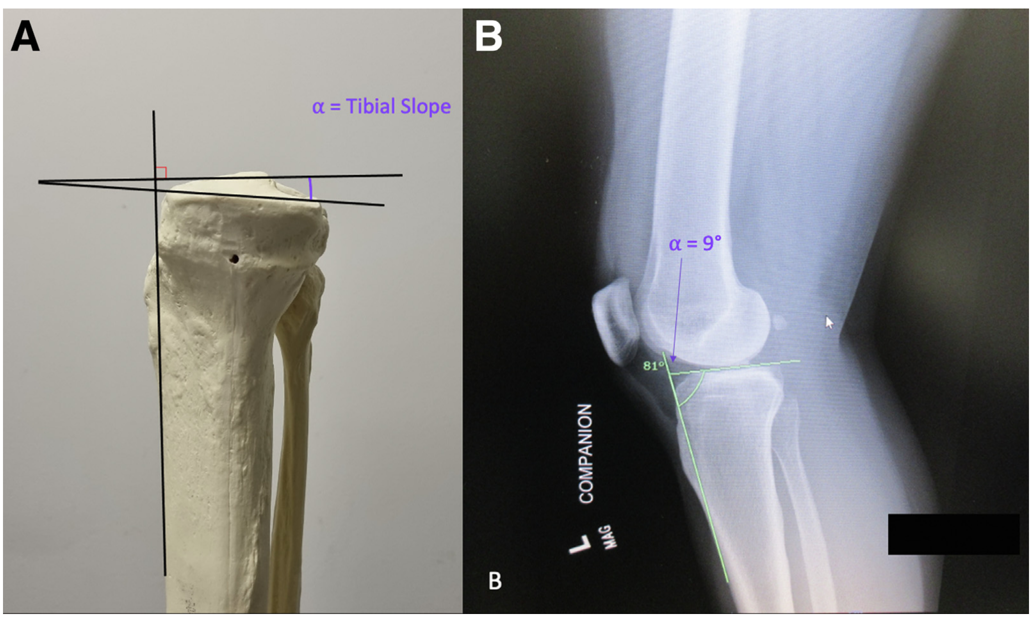


**Fig 2.** Posterior tibial slope measurement using anterior tibial crest on sawbones model from a sagittal view (A) and on a lateral knee radiograph (B).

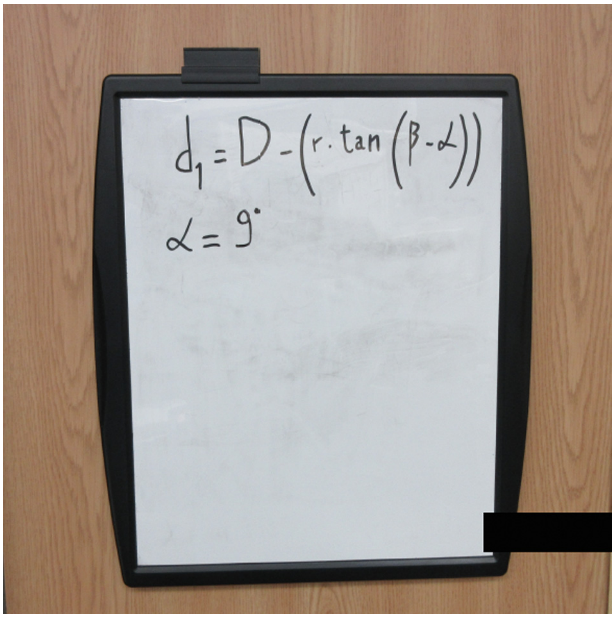


**Fig 3.** Operating room whiteboard with tibial safe drilling length formula and tibial slope angle (α).

### Step 4: Tibial Drill Guide Measurement

The stepped drill sleeve is positioned flush to the bone. The drill guide angle (ß) and the length from the ACL (or PCL) stump to the tibial cortex (*D*) are recorded (Figs 7 and 8). The length measured on the drill guide (*D*) is equal to the sum of $d_1$ and $d_2$ ($D = d_1 + d_2$) where $d_1$ represents the safe drilling length.

### Step 5: ABC Angle Determination

Considering the triangle ABC (Fig 9), the sum of the internal angles measures 180° ($\beta + \gamma + \delta = 180$). The tibial guide is parallel to the tibial plateau, so gamma angle measures 90° minus the tibial slope ($\gamma = 90 - \alpha$). Consequently, we can calculate delta angle by subtracting the drill guide angle and gamma angle from 180° ($\delta = 180^\circ - \beta - \gamma \rightarrow \delta = 180^\circ - \beta - (90 - \alpha) \rightarrow \delta = 90^\circ - \beta + \alpha$).

### Step 6: $d_2$ Length Determination

Considering the triangle $AB_1C_1$ (Figs 10 and 11) and applying basic trigonometry formulas, we know that the tangent of epsilon is equal to the opposite cathetus divided for the adjacent cathetus ($\tan \varepsilon = d_2/r$). Consequently, $d_2$ length is the product of the radius and

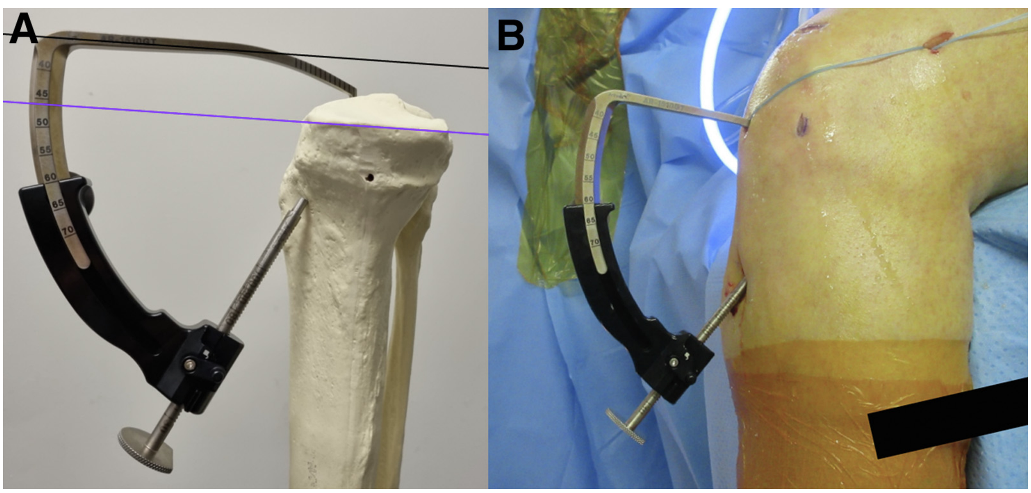


**Fig 4.** Tibial drill guide positioning in the sagittal plane keeping the intra-articular arm parallel to the tibial plateau on sawbones model (A) and on the patient during surgery (B).

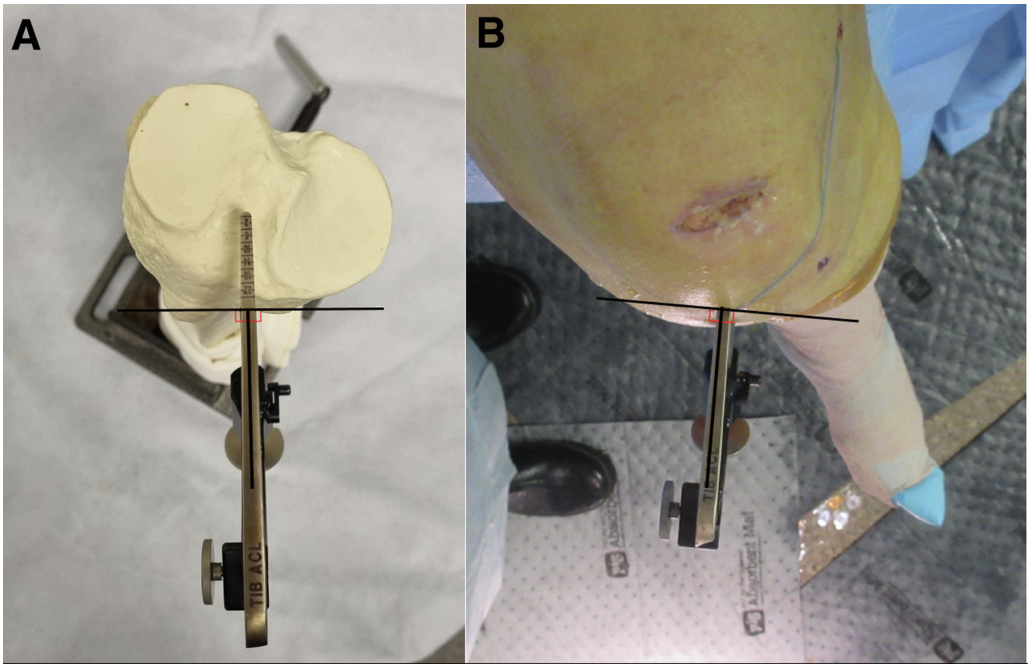


**Fig 5.** Tibial drill guide positioning in the axial plane keeping it perpendicular to the tibial anterior cortex on sawbones model (A) and on the patient during surgery (B).

the tangent of epsilon ($d_2 = r \cdot \tan \varepsilon$). Considering that $AB_1C_1$ is a rectangular triangle, The sum of epsilon and delta angle is 90°, so epsilon is equal to 90° minus delta ($\varepsilon + \delta = 90° \rightarrow \varepsilon = 90° - \delta$). Considering that $\delta = 90° - \beta + \alpha$ (see Step 5), we can affirm that epsilon angle is equal to β minus α angle ($\varepsilon = 90° - (90° - \beta + \alpha) \rightarrow$

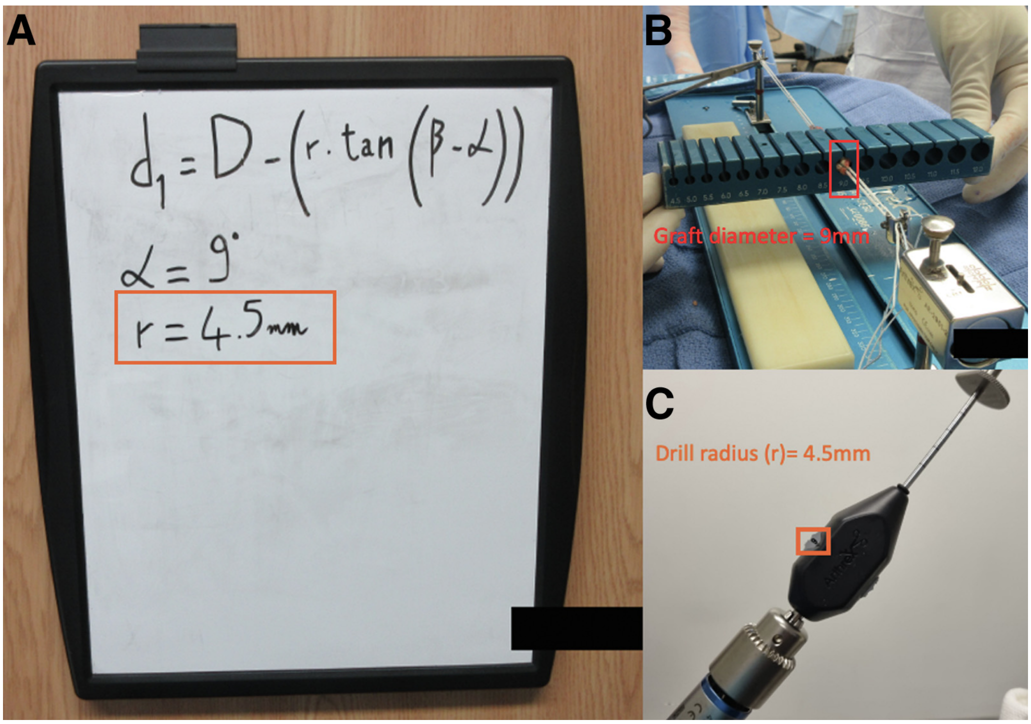


**Fig 6.** (A) Operating room whiteboard with tibial safe drilling length formula and tibial tunnel radius (r) . (B) Graft sizing tool determines the quadriceps tendon graft diameter and, consequently, the tibial tunnel diameter and radius . (C) Extraarticular sagittal view of the flip cutter set with the established diameter.

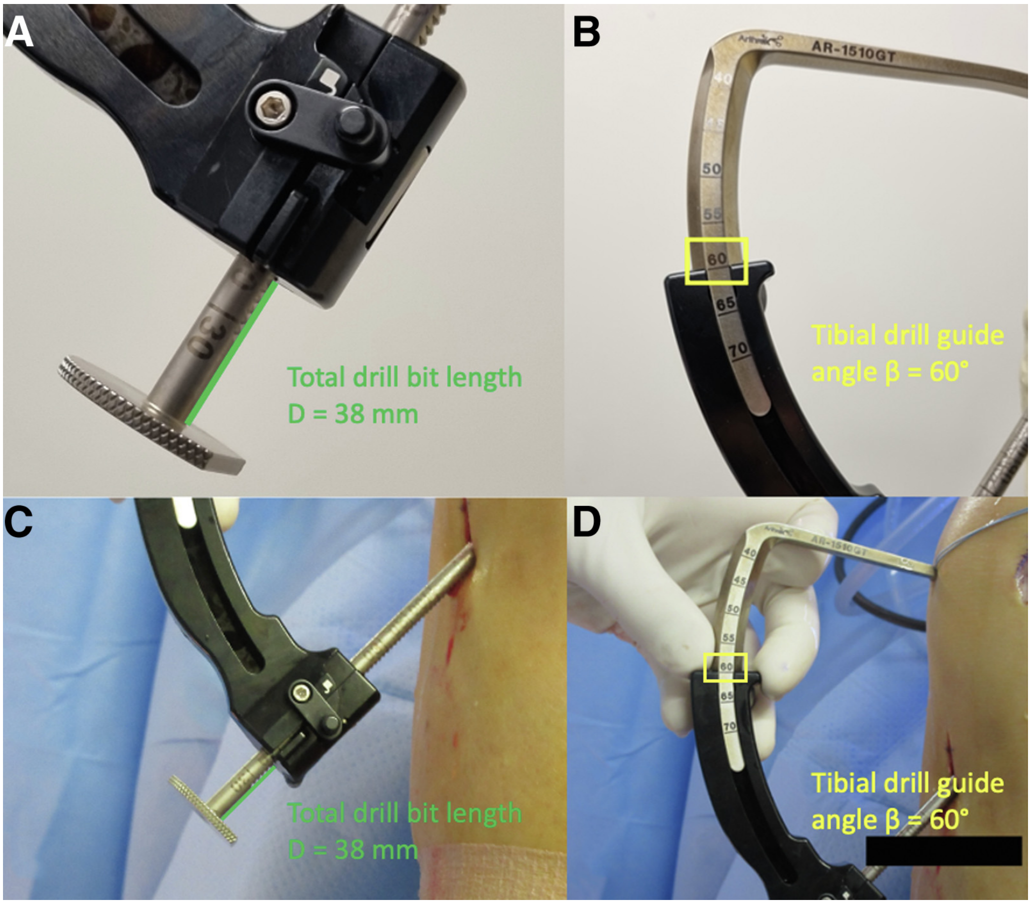


**Fig 7.** (A and B) Extraarticular sagittal view of the flip cutter during measurement of the distance from the ACL tibial footprint to the anterior tibial cortex. (C and D) Drill guide angle on sawbones model and on the patient during surgery.

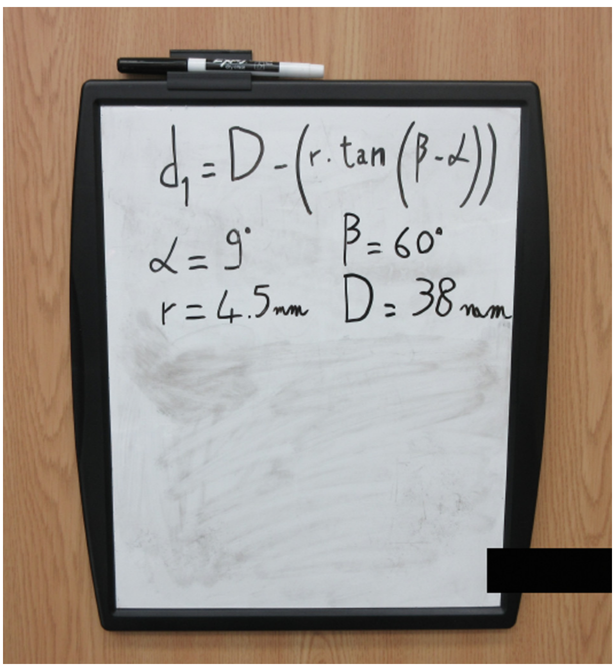


**Fig 8.** Operating room whiteboard with tibial safe drilling length formula, drill guide angle (β), and distance from ACL tibial footprint to anterior tibial cortex (*D*).

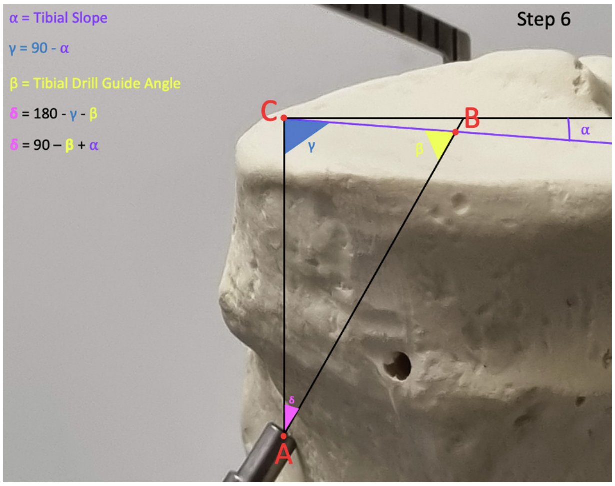


**Fig 9.** Trigonometric simulation of Delta angle (δ) determination considering ABC triangle with sagittal view of the sawbones model on the background. Considering the triangle ABC the sum of the internal angles measures 180° ($\beta + \gamma + \delta = 180$). The tibial guide is parallel to the tibial plateau, so gamma angle measures 90° minus the tibial slope ($\gamma = 90 - \alpha$). We can calculate delta angle by subtracting the drill guide angle and gamma angle from 180° ($\delta = 180° - \beta - \gamma \rightarrow \delta = 180° - \beta - (90 - \alpha) \rightarrow \delta = 90° - \beta + \alpha$).

$\varepsilon = \beta - \alpha$). Therefore, $d_2$ is the product of the radius and the tangent of the drill guide angle minus the tibial slope ($d_2 = r \cdot \tan(\beta - \alpha)$).

### Step 7: Final Formula Determination

The final formula determination is shown in Fig 12. Considering that $D = d_1 + d_2$, we can affirm that the total length measured on the drill guide is equal to the sum of $d_1$ and the product of the radius and the tangent of beta minus alpha [$D = d_1 + (r \cdot \tan \beta - \alpha)$]. Consequently, the safe drilling length ($d_1$) is the difference between the total length measured on the drill guide ($D$) and the product of the radius of the tibial tunnel and the tangent of tibial drill guide angle (β) minus the tibial slope (α):

$$d_1 = D - (r \cdot \tan(\beta - \alpha))$$

## Step 8

Then, one must calculate the safe drilling length and retro-drill the tibial tunnel (Figs 13, 14, and 15).

## Discussion

In order to perform a suspensory graft fixation and to maintain closed-socket tunnels, it is essential to

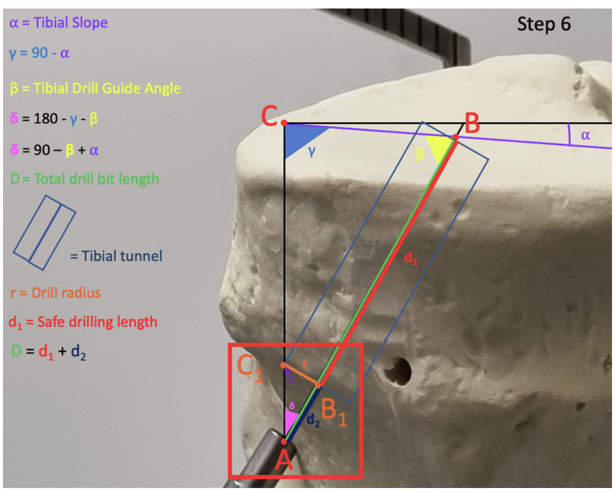


**Fig 10.** Trigonometric simulation with sagittal view of the sawbones model on the background highlighting the total drill bit length ($D$), tibial tunnel (blue rectangle), drill radius ($r$), the safe drilling length ($d_1$) and the triangle $AB_1C_1$. The total drill bit length ($D$) is equal to $d_1$ plus $d_2$ ($D = d_1 + d_2$).

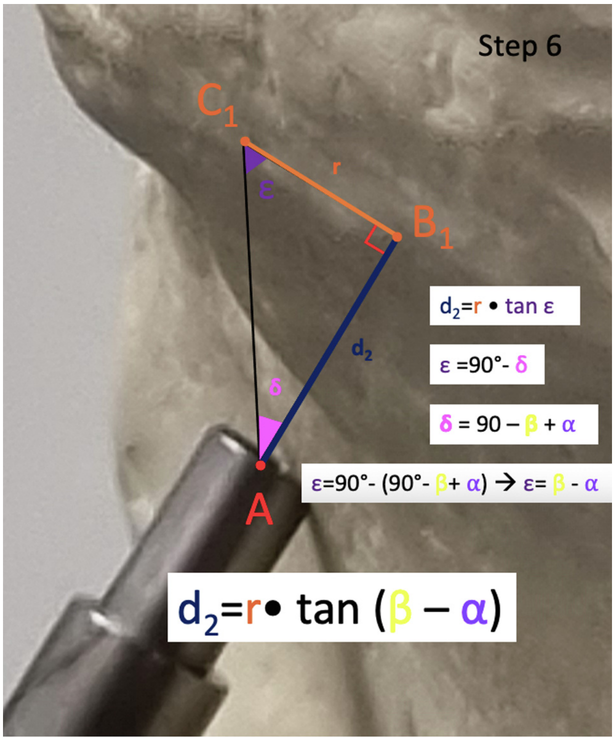


**Fig 11.** Trigonometric simulation with sagittal view of the sawbones model on the background. Considering the triangle $AB_1C_1$ and applying basic trigonometry formulas, we know that the tangent of epsilon (ε) is equal to the opposite cathetus divided by the adjacent cathetus ($\tan \varepsilon = d_2/\mathrm{r}$). Consequently, $d_2$ length is the product of the radius and the tangent of epsilon ($d_2 = r\cdot \tan \varepsilon$). Since $AB_1C_1$ is a rectangular triangle, epsilon is equal to 90° minus delta ($\varepsilon + \delta = 90° \rightarrow \varepsilon = 90° - \delta$). Considering that $\delta = 90° - \beta + \alpha$, we can affirm that epsilon angle is equal to beta minus alpha angle ($\varepsilon = 90° - (90° - \beta + \alpha) \rightarrow \varepsilon = \beta - \alpha$). Therefore, $d_2$ is the product of the radius and the tangent of the drill guide angle minus the tibial slope ($d_2 = \mathrm{r}\cdot \tan(\beta - \alpha)$).

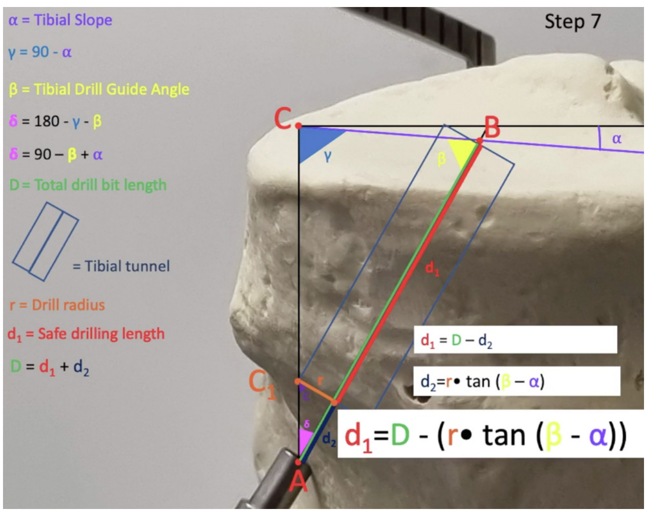


**Fig 12.** Trigonometric simulation with sagittal view of the sawbones model on the background. Considering that $D = d_1 + d_2$, we can affirm that the total length measured on the drill guide is equal to the sum of $d_1$, and the product of the radius and the tangent of beta minus alpha ($D = d_1 + (\mathrm{r}\cdot \tan \beta - \alpha)$). Consequently, $d_1 = D - [r\cdot \tan(\beta - \alpha)]$.

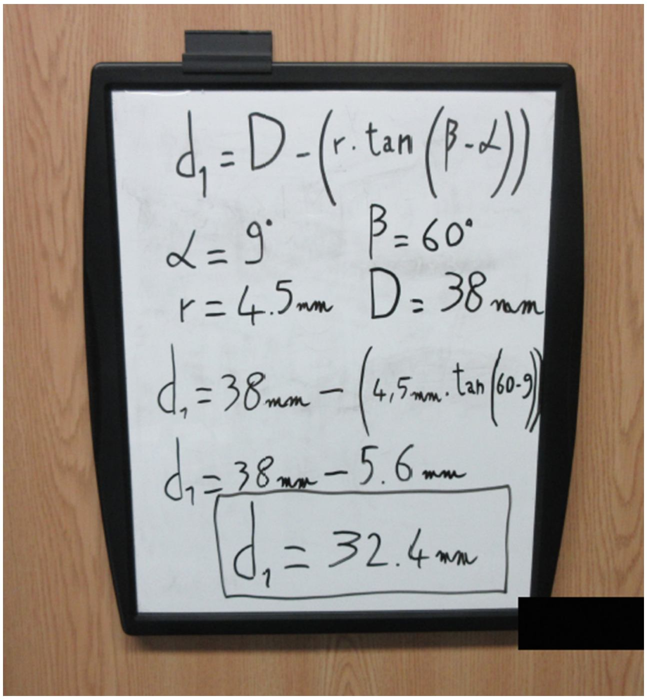


**Fig 13.** Operating room whiteboard with safe drilling length calculation.

preserve the cortex during all-inside cruciate ligament reconstruction. A long (safe) tibial tunnel gives the surgeon the confidence to harvest a longer graft (increasing the surface area of the graft available to heal within the tunnel), and it ensures that the surgeon will be able to appropriately tension the graft. However, accidental reaming of the anterior tibial cortex risks compromising tibial fixation, and subsequent failure of the graft. The risk of violating the cortex during retro-drilling is increased with the tibial socket due to the obliquity of the tibial tunnel relative to the cortex (Fig 1, Video 1). This is in contrast to the femoral tunnel, which is typically more perpendicular to the femoral cortex.

Our formula allows the surgeon to calculate a safe drilling length for the tibial tunnel during surgery with a few easy measurements (tibial slope, tibial drill guide angle, tibial drill guide, total length, and radius of the tibial socket) (Fig 13-15, Table 1). Tibial slope is measured from the preoperative lateral radiograph, while the other measurements are obtainable during the surgery with no additional steps. Calculating the safe drilling length for tibial tunnel is a risk-free and costless step that allows for more accurate planning of tibial socket length and angle. Although the surgeon will likely not be able to solve the formula in their head, any nurse, anesthesiologist, or implant representative with a smart phone can use the calculator function on their device to solve the formula (Table 1).

The drill guide for the Arthrex Flip Cutter III has a 7-mm stepped tip, which is malleted into the bone prior to tunnel drilling. The purpose of this stepped tip is allowing the surgeon to safely retro-drill all the way to the impacted tip of the drill guide, leaving 7 mm of bone between the “bottom” of the tunnel and the cortex. Although this reliably occurs for the femoral tunnel, where the drill guide is roughly perpendicular to the cortex, for tibial tunnel, retro-drilling to the tip of the stepped drill guide risks violating the anterior tibial cortex due to the obliquity of the drill guide relative to the tibia (Fig 16, Video 1).

Our formula rests on two assumptions that may not be true in every cruciate ligament reconstruction surgery, resulting in some limitations. First, we assume that the anteromedial cortex of the tibia is parallel with the anterior crest of the tibia, as seen from a lateral radiograph projection. When the tibial drill guide is distal to the proximal tibia metaphyseal flare (tibial drill guide angles greater than approximately 45°), this assumption is valid. If the surgeon desires a tibial drill

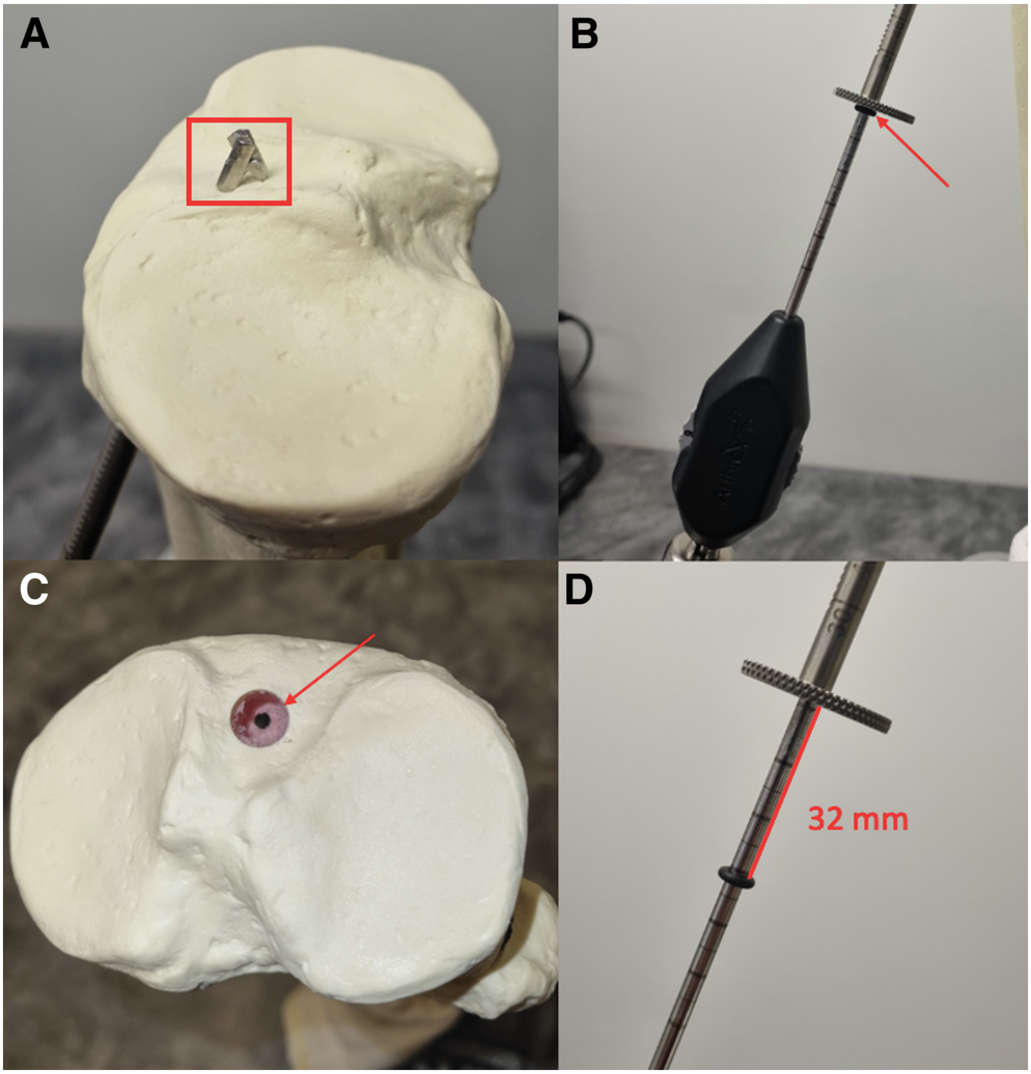


**Fig 14.** Sagittal view of the sawbones model with Flip cutter blade in contact with tibial plateau (A), grommet (red arrow) set at zero (B) before drilling. Bird's eye view of the closed socket tibial tunnel after drilling (C) a 32-mm tibial tunnel (D).

guide angle less than 45°; however, this assumption loses validity. In those instances, because of the decreased obliquity of the drill guide relative to the tibia, the stepped drill guide, if properly malleted into the bone, should protect the surgeon from retro-drilling the anteromedial cortex of the tibia. Second, we assume that the intra-articular arm of the tibial drill guide is positioned parallel to the tibial plateau in the sagittal plane, and perpendicular to the anteromedial cortex of the tibia in the axial plane. Variability in the location of the arthroscopic portals and/or surgical technique could modify these parameters (Table 1); however, using our formula, we have determined that 10° of variability in either direction results in only a few millimeters difference in the calculated safe drilling length.

It deserves mentioning that there are "bailout" techniques in cases of anterior tibial cortex violation from retro-drilling. These include using a larger (i.e., 20-mm diameter) button to secure the graft, tying the sutures over a screw and washer, or drilling a full, "open-socket," tibial tunnel and using an interference screw for tibial fixation. While it is unquestionably wise to have these implants available in case the anterior tibial cortex is accidentally violated, it is less time-consuming and less expensive to use our formula and avoid this complication in the first place.

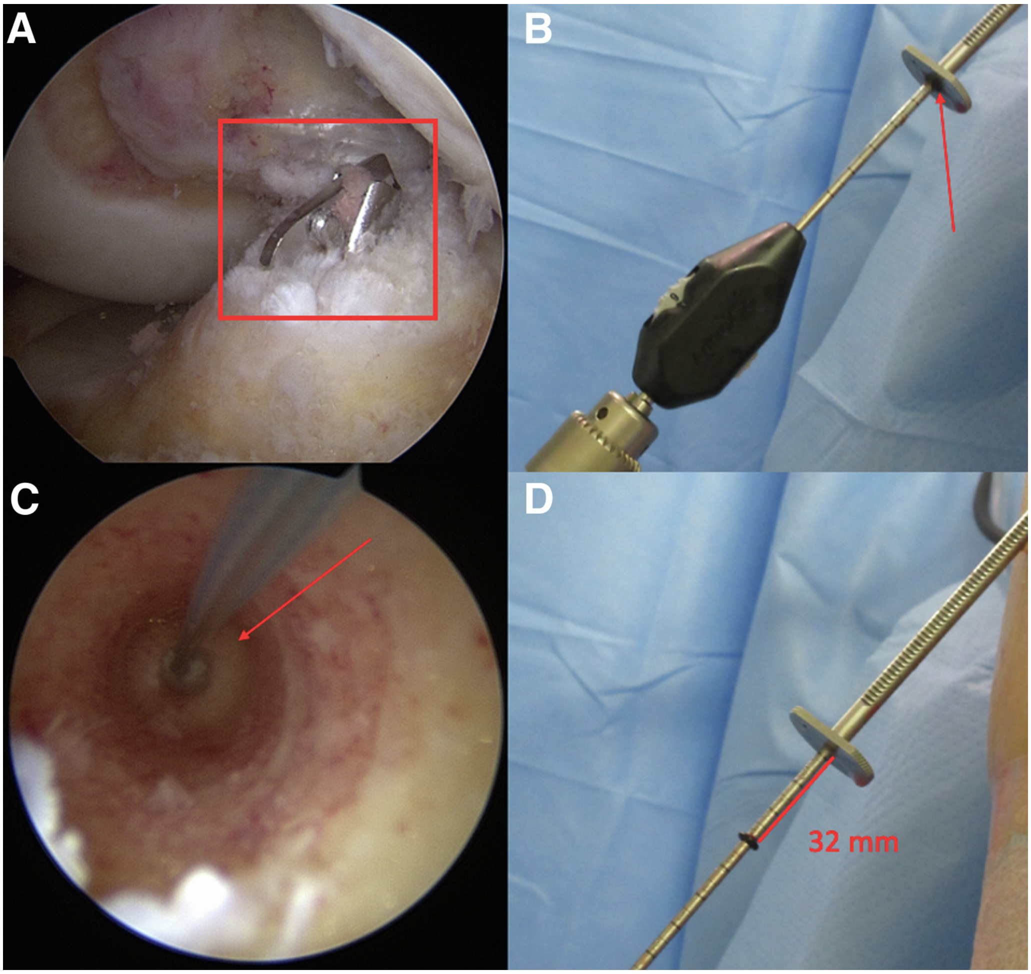


**Fig 15.** Arthroscopic view, left knee, from the anterolateral portal of the Flip cutter blade in contact with tibial plateau at the torn ACL tibial footprint (A), extra-articular sagittal view of the grommet set at zero (B) before drilling. Arthroscopic bird's view with a 70° scope from the anterolateral portal of the closed socket tibial tunnel (red arrow) after drilling (C) and extraarticular sagittal view of the grommet after drilling a 32-mm tibial tunnel (D).

**Table 1.** Strengths and Limitations

| Strengths | Limitations |
| --- | --- |
| Ability to calculate the longest tibial tunnel possible without breaching the anterior cortex | Not positioning the drill guide parallel to the tibial plateau results in slight variability. |
| Does not prolong surgery time | Solving the trigonometric formula requires a smart phone; difficult to do the math in one's head |
| Prevent intraoperative complications (anterior cortex breach, insufficient tunnel length for tensioning) | |
| No additional risks or costs | |


**Fig 16.** Sagittal view of the sawbones model with the stepped drill guide malleted into the bone. Note the obliquity of the tibial drill guide relative to the anteromedial cortex. The inferior part of the stepped guide contacts the cortex first, so the tip of the guide is less than 7 mm into the bone.

In conclusion, calculating the tibial safe drilling length is a risk free and costless step that could help the surgeon avoid anterior tibial cortex violation during all inside cruciate ligament reconstruction.

## References


1. De Sa D, Shanmugaraj A, Weidman M, et al. All-inside anterior cruciate ligament reconstruction—A systematic review of techniques, outcomes, and complications. *J Knee Surg* 2018;31:895-904.
2. Goyal T, Das L, Paul S, Choudhury AK, Sethy SS. Outcomes of retro-drilled all-inside tibial tunnel vs complete tibial tunnel techniques in anterior cruciate ligament reconstruction—a comparative study. *Eur J Orthop Surg Traumatol* 2022;32:523-532.
3. Buranapuntaruk T, Kongrukgreatiyos K, Itthipanichpong T. All-inside arthroscopic anterior cruciate ligament reconstruction and internal brace with recycling suture. *Arthrosc Tech* 2021;10:e2429-e2434.
4. Waly AH, ElShafie HI, Morsy MG, et al. All-inside anterior cruciate ligament reconstruction with suture tape augmentation: Button tie-over technique (BTOT). *Arthrosc Tech* 2021;10:e2559-e2570.
5. Çullu E, Aydoğdu S, Alparslan B, Sur H. Tibial slope changes following dome-type high tibial osteotomy. *Knee Surg Sports Traumatol Arthrosc* 2005;13:38-43.