



Arthroscopic Intercondylar Notch Bone Marrow Aspiration During Anterior Cruciate Ligament Reconstruction

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Abstract: The anterior cruciate ligament is the most commonly injured ligament, with up to 10% of surgery failure. Atraumatic instability in the early postoperative period (<6 months) occurs as the result of poor surgical technique, failure of graft integration, or early mechanical overload during rehabilitation. Engineered cell therapy is a developing resource designed to increase the rate of tendon-to-bone interface healing. We describe a simple and safe technique to harvest mesenchymal stem cells by arthroscopic bone marrow aspiration from the intercondylar notch.

The anterior cruciate ligament (ACL) is the most commonly injured ligament in the knee, with an up to 10% rate of surgery failure.¹ Atraumatic recurrent instability in the early postoperative period (<6 months) occurs as the result of poor surgical technique, failure of graft integration, or early mechanical overload during rehabilitation.²

Engineered cell therapy is a developing resource designed to increase the rate of tendon-to-bone incorporation. The isolation of connective tissue progenitor cells—which are stem cells with the capability of self-renewal; multilineage differentiation; and formation of terminally differentiated cells such as tendons, cartilages, and ligaments—is performed from bone marrow aspiration. Bone marrow stem cells assist in

graft osteointegration by overexpressing transforming growth factor beta 1 proteins, the most important fibrotic inducer and an ossification promoter.³

Usually, the performance of bone marrow aspiration is at the iliac crest. Despite being secure and effective, a technique at an anatomical site that implies less morbidity, infection potential, and surgical time it is preferred. Therefore, we describe an efficient 3-stage procedure (Fig 1) to harvest connective tissue progenitor cells from the intercondylar notch.

Surgical Technique

After approval from the ethical and institutional review board, patients were eligible for inclusion only after giving their permission to participate through a signed informed consent.

Preparation and Positioning

With the patient placed supine on the operating room table, and after the induction of anesthesia, we conduct bilateral stability and range-of-motion tests. Before preparation and sterile draping of the lower limb, we support the placement of a well-padded, high-thigh nonsterile tourniquet, and if using a leg post, shifting the patient closer to produce a proper valgus when needed. After sterile drape, an assistant drops the end of the bed, allowing a 90° flexion.

Diagnostic Arthroscopy

We perform a diagnostic knee arthroscopy through the standard portals (anteromedial and anterolateral),

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The authors report the following potential conflict of interest or source of funding: D.F. is a paid consultant at Stryker and Smith & Nephew; R.C. is a paid consultant at Stryker and Smith & Nephew; and A.V. is a paid speaker for Arthrex and De Puy Synthes. Full ICMJE author disclosure forms are available for this article online, as [supplementary material](#).

Received April 22, 2019; accepted July 20, 2019.

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2212-6287/19526

<https://doi.org/10.1016/j.eats.2019.07.022>

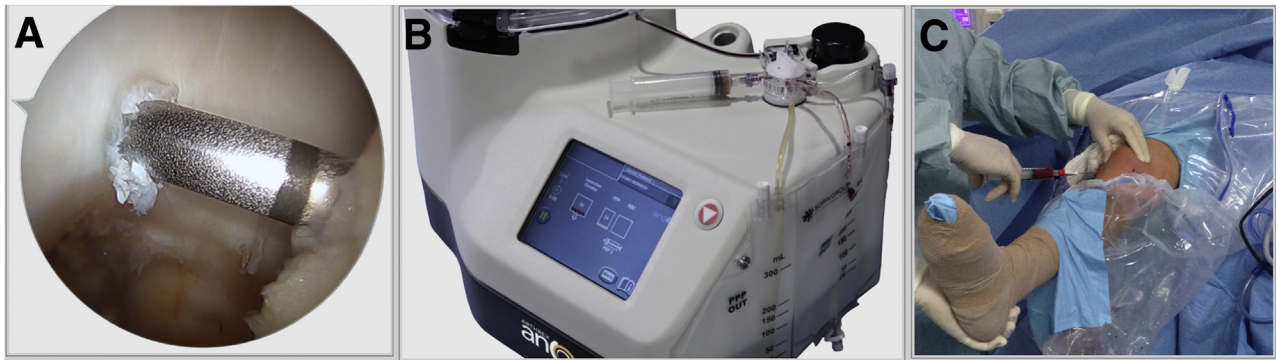


Fig 1. A 3-stage sequential procedure (bone marrow harvest from the femoral notch, leukocyte-poor platelet concentrate preparation, and biological graft augmentation) during the anterior cruciate ligament reconstruction using the Arthrex Angel cPRP & Bone Marrow Processing System kit. (A) Trocar insertion at the femoral notch apex of the right knee—usually at the center of the femur or 5 mm lateral to the lateral edge of the posterior cruciate ligament insertion—seen from the anterolateral portal with the patient on the supine position. (B) Preparation of leukocyte-poor platelet concentrate from bone marrow aspirate through centrifugation and concentrated red cells separation by wavelengths using the Arthrex Angel cPRP & Bone Marrow Processing System kit. (C) Biological graft augmentation with leukocyte-poor platelet concentrate preparation through the anterolateral arthroscopic portal after arthroscopic confirmation of a satisfactory ACL reconstruction. (ACL, anterior cruciate ligament.)

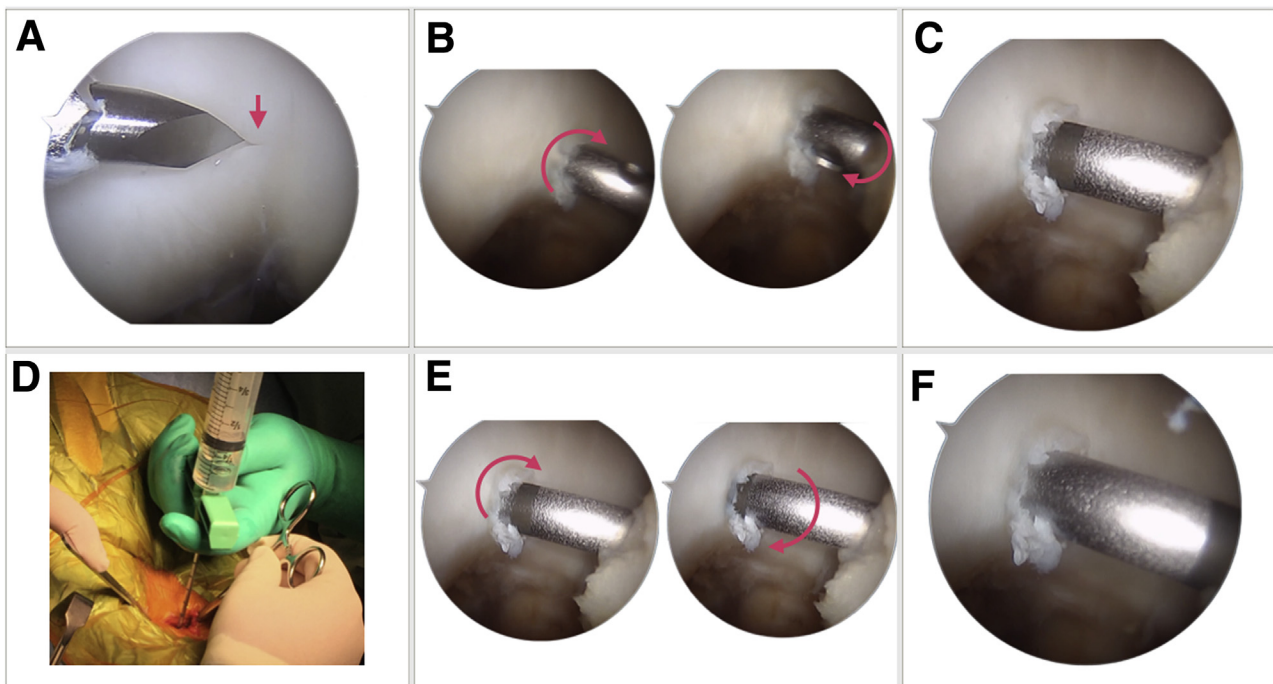


Fig 2. Arthroscopic extraction of bone marrow shown step-by-step from the identification of the entry point of the trocar in the intercondylar notch to the aspiration of the bone marrow during the reconstruction of a right anterior cruciate ligament seen from the anterolateral portal with the patient on the supine position, except for (A), which is seen from the anteromedial portal. (A) Identification of the desired entry point at the femoral notch apex at 5 mm from the lateral edge of the PCL insertion. (B) At the desired entry point, insert a 14-gauge trocar through the anteromedial portal turning it clockwise. (C) Insert the trocar a depth of approximately 30 mm. (D) Remove the stylet, and attach a 10-mL syringe to discard the first milliliter of the aspirated bone marrow, then with a 30-mL syringe preloaded with 4 mL of a heparinized solution, proceed to aspirate slowly. (E) Turn the trocar 90° clockwise every 2 mL of aspirated bone marrow. (F) Withdraw the trocar 0.5 cm every 8 mL of aspirated bone marrow, until obtaining the 60-mL sample. In (A), the arrow is pointing to the desired entry point at the femoral notch apex. In (B) and (E), the arrows show the direction of the movement to insert the trocar. (PCL, posterior cruciate ligament.)

Table 1. Step-by-Step Process

Steps	
1. Patient positioning	- After anesthesia induction, bilateral stability and range of motion is assess. - Place a well-padded high-thigh nonsterile tourniquet. - Shift the patient closer to the leg post to produce a proper valgus when needed. - After sterile drape, an assistant should drop the end of the bed allowing a 90° flexion.
2. Diagnostic arthroscopy	Through the standard portals (anteromedial and anterolateral), pay special attention to the integrity of the other ligaments, the femoral notch width and the presence of associated injuries.
3. Graft harvest	- With the patient's knee flexed 90°, perform a 3-cm long incision over the pes anserinus. - To protect the medial collateral ligament, elevate the sartorial fascia from proximal to distal with a blunt object. - Longitudinally incise the sartorial fascia and expose the gracilis and semitendinous tendons. - Release the deep portion of the sartorial fascia with a blunt right-angle clamp. - Whip stitch the ends of both tendons. - With a stripper harvest the tendons from distal to proximal.
4. Graft preparation	- Remove muscle fibers and unstable portions from the grafts. - Measure the length of each tendon to plan the correct graft configuration. - Simulate the graft configuration to determine the appropriate length and diameter.
5. Bone marrow cell harvest	- Insert a 14-gauge trocar through the anteromedial portal. - Introduce the trocar 30 mm deep into the femoral notch apex. - Turn off the arthroscopic fluid. - Remove the stylet. - Discard the first milliliter of blood. - With a 30-mL syringe preloaded with a heparinized solution slowly aspirate 60 mL of bone marrow.
6. Biological augmentation	Under direct arthroscopic vision through the anteromedial portal, apply platelet-rich plasma at 7% to the tibial tunnel, the femoral tunnel, and the graft.

paying particular attention to the ligaments' integrity; the femoral notch width; and associated pathologic injuries such as the presence of loose bodies, chondral injuries, or meniscal ruptures.

Bone Marrow Cell Harvest

Video 1 and **Figure 2** show how before drilling the femoral and tibial tunnels, we insert a 14-gauge trocar (Bone Marrow Aspirate kit; Arthrex, Naples, FL) through the anteromedial portal, and when the tip of the device is at the desired entry point, we introduce the trocar at an approximately 30 mm depth, turning it clockwise. Our desire entry point is at the femoral notch apex, usually at the center of the femur or 5 mm lateral to the lateral edge of the posterior cruciate ligament insertion. After inserting the trocar, an assistant turns off the arthroscopic fluid, and we remove the stylet and attach a 10-mL syringe to discard the first milliliter of the aspirated bone marrow. Then, with a 30-mL syringe preloaded with 4 mL of a heparinized solution (5 mL of 1000 IU/mL of sodium heparin + 5 mL of sterile saline + 8 mL of anticoagulant citrate dextrose), we slowly aspirate bone marrow, turning the trocar 90° clockwise every 2 mL and withdrawing the needle 0.5 cm every 8 mL until obtaining 60 mL of bone marrow to process it in

the Arthrex Angel cPRP & Bone Marrow Processing System. On average, bone marrow harvesting is a 10-minute procedure.

Preparation of Leukocyte and Platelet Concentrate from Bone Marrow Aspirate

After properly assembling the Arthrex Angel cPRP & Bone Marrow Processing System with a 20-mL syringe attached to the platelet-rich plasma port, we introduce the blood mixed with the heparinized solution into the whole blood compartment and adjust the volume of blood to 60 mL for the software to set an adequate centrifugation time and force. At the end of the centrifugation cycle, the blood components will pass through a platelet sensor that uses wavelengths to separate the concentrated red cells and platelet-poor plasma into its respective compartments and the leukocyte-poor, platelet-rich plasma into the attached syringe.

Biological Augmentation of the Graft

After arthroscopic confirmation of a satisfactory ACL reconstruction, the femoral tunnel, the tibial tunnel, and the graft are augmented with platelet-rich plasma at 7% (Angel cPRP & Bone Marrow Processing System; Arthrex) through an intraarticular injection.

Table 2. Surgical Pearls and Pitfalls of Arthroscopic Intercondylar Notch Bone Marrow Aspiration During Anterior Cruciate Ligament Reconstruction

Pitfalls	Pearls
I. Bone marrow sample coagulates easily.	IA. Add a heparinized solution to the needle used for aspiration.
II. Bone marrow sample may usually be less than 60 mL.	IB. Discard the first milliliter of aspirated bone marrow.
III. May be difficult to achieve the correct angle to insert the trocar at the femoral notch apex.	IIA. Add autologous blood to the bone marrow sample for adequate preparation of leukocyte and platelet concentrate.
IV. After introducing the trocar, it is possible not to obtain a bone marrow sample when aspirating.	IIIA. Insert the trocar through the anteromedial portal.
	IIIB. The femoral notch apex is 5 mL to the lateral edge of the PCL insertion.
	IVA. Introduce the trocar at approximately 30 mL of depth, turning it clockwise.
	IVB. Turn the trocar 90° clockwise every 2 mL of bone marrow.

PCL, posterior cruciate ligament.

Discussion

We had a 30% rate of mild adverse events at short-term follow-up and have not experienced reinterventions or reports of severe complications such as intraoperative fractures, deep-vein thrombosis, or infections (superficial incisional, deep incisional, or septic arthritis). Also, we found a significantly greater surgical time in the intervention group when compared with the control group (50 ± 8 minutes in the control group vs 65 ± 11 minutes in the bone marrow group; $P < .01$). To our knowledge, these are the first rates of adverse events reported with this technique.

Mesenchymal stem cells have received much attention as an engineered cell therapy because of the diversity and high concentration of growth factors they possess, making them a promising regenerative approach in various musculoskeletal tissues such as ACL reconstructions, the most performed treatment for ACL rupture.^{4,5} Although many patients report excellent results with the procedure, 37% remain with instability and 42% to 90% have osteoarthritis during the next 12 years,⁶ which has stimulated the research of biological processes to achieve a faster tendon to bone healing and acquisition of native ligament properties in the graft.

However, some clinical outcomes with the use of biological adjuvants—such as the time of graft maturation assessed by magnetic resonance imaging and histology—are contradictory.⁷⁻⁹ In our experience, we had a slightly lower rate of mild adverse events at

short-term follow-up than the reported by Beitzel et al.,¹⁰ and all the complications found were the most commonly reported during standard ACL reconstructions (without arthroscopic bone marrow aspirate),¹¹ making an association with the previously described procedure very unlikely. Moreover, recent analysis suggests that these complications have weak evidence for association with return to sport.¹² To date, we have performed the procedure in a small sample of 23 patients, which makes the difference in surgical time very likely be due to a type II error.

Although the outcomes of adverse events and surgical time differences are not the subject of discussion in this article, we believe it is of the utmost importance to briefly inform the reader about the data in which we base our judgment to support as a safe procedure the bone marrow aspirate through the anteromedial portal during ACL reconstruction.

As our outcomes and the contradictions reported in the literature can be due to several factors, such as small series, little statistical validity, or high treatment heterogeneity, we believe that a safe and reproducible technique (Table 1) would help in the realization of better-quality studies to help to determine the real value of the engineered cell therapy. The aforementioned approach can be done during the ACL reconstruction from the same standard arthroscopic portals and has a negligible learning curve (Table 2). The only limitation we could argue is the increase in surgical time (Table 3). In conclusion, the bone marrow

Table 3. Advantages and Disadvantages of Bone Marrow Aspiration from the Femoral Intercondylar Notch

Advantages	Disadvantages
1. Decrease morbidity	1. Increase surgical time
I. Can be done through a standard arthroscopic portal (anteromedial portal) during the same reconstruction procedure.	I. The process of harvesting and augmenting the graft represents on average 15 extra minutes.
II. The absence of another surgical site decreases the risk of a potential infection and pain sites.	
2. Safe procedure	
I. We found similar complication rates between treated and untreated patients.	
II. From our preliminary results on complication rates, we infer that it is a replicable procedure with a negligible learning curve	

aspiration from the femoral intercondylar notch during an ACL reconstruction is safe and reproducible. Nevertheless, the surgical time increases significantly.

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