Technical Note

Simultaneous Arthroscopic Anterior Cruciate Ligament Reconstruction Using Double Suspensory Technique and Medial Open-Wedge, High Tibial Osteotomy

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Abstract: Anterior cruciate ligament reconstruction (ACLR) is generally performed regardless of knee malalignments. However, there are some indications for either staged or simultaneous ACL reconstruction and realignment procedures, such as high tibial osteotomy (HTO). Simultaneous HTO-ACL reconstruction has the apparent benefit of a single surgical procedure with a faster recovery than a staged procedure, and it produces good clinical outcomes. Several techniques have been described for simultaneous ACLR and medial open wedge HTO. The tibial tunnel preparation and graft fixation are the most challenging part of the procedure. Recent studies on comparison of fixation of tibial tunnel graft using suspensory fixation versus bioabsorbable screws have shown superior results of more bone preservation and less graft rupture. We assumed suspensory fixation on the tibial side with bone preservation might be more reliable in patients who received ACLR and open wedge HTO at the same time. Therefore, we described our technique of simultaneous open-wedge HTO and ACLR using double suspensory graft fixation.

Introduction

The incidence of ACL injuries is estimated 0.38 per 1,000 yearly in the North America. Therefore, ACL reconstruction (ACLR) has gained considerable attention and expectancy to restore patients to preinjury level of function these days.[1] Recent evidence shows that realignment of the joint is not as crucial as maintaining joint stability, especially in patients with ACL injury, but there are still some indications coming up with the importance of combined knee realignment and ACLR procedures.[2] Indications for osteotomy in ACL-deficient varus knee include varus alignment with early medial compartment arthritis (Ahlbäck grades 1-3), previous meniscectomy, and medial compartment overload, meniscal or chondral injury (candidate for meniscal transplant or cartilage repair), increased posterior tibial slope >12° in the sagittal plane,[3] and presence of double or triple varus.[4,5] Table 1 several techniques have been previously described for high tibial osteotomy (HTO) and ACLR, either as a single- or double-stage procedure. However, simultaneous ACLR-HTO have been previously described with good clinical outcomes.[5-7] The ACLR techniques used bone-patella, tendon-bone, or hamstring grafts fixed by either suspensory method or bioabsorbable interference screws. Various types of tibial realignment osteotomies, including open wedge[8,9] and close wedge osteotomy,[10] have been described using staples,[11] Tomofix,[12] or Puddu plates[9] for fixation used.

Herein, we described a surgical technique for simultaneous ACLR using semitendinosus tendon graft with double suspensory fixation and open wedge HTO procedure, using Tomofix plate (Depuy Synthes, Oberdorf, Switzerland).

Surgical Technique

Patient Positioning

After spinal or general anesthesia, the patient is placed in supine position on a radiolucent table with a

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Table 1. Indications for Combined ACL-HTO

- Medial-compartment osteoarthritis (Ahlbäck grades 1-3) + varus malalignment + ACL tear (with symptomatic anteroposterior instability)
- Medial-compartment osteoarthritis (Ahlbäck grades 1-3) + varus malalignment + failed ACL reconstruction
- Failed ACL reconstruction due to increased tibial slope >12
- Double or triple varus with an ACL tear
- Varus malalignment + ACL tear + meniscal or chondral (candidate for meniscal transplant or cartilage repair)

Adapted from Bonasia DE, Dettoni F, Palazzolo A, Rossi R. Opening wedge high tibial osteotomy and anterior cruciate ligament reconstruction or revision. *Arthrosc Tech* 2017;6:e1735-e1741.

lateral post, which helps achieving valgus force during surgery (see Video 1). C-arm is positioned on the opposite side. Tourniquet is positioned in the proximal thigh, and the knee and calf are hung from the edge of the surgical bed at 90° of flexion in a way that knee movements are not restricted and knee hyperflexion is allowed. Prophylactic intravenous antibiotics (2 g of cefazolin or 1 g of vancomycin in case of hypersensitivity to cephalosporins) and tranexamic acid (1 g) are administered. After surgical skin prep and draping, the insertion points of anterolateral, medial, and anteromedial portals are identified and marked. Sterile plastic sticking is placed on the surgical site, and the tourniquet (200-300 mmHg) is inflated on the basis of patient's blood pressure (Fig 1).

Graft Harvest and Preparation

A 7- to 8-cm vertical anteromedial incision 1 cm distal to the joint line is made between the tibial tubercle and posteromedial tibial cortex, giving access for both graft harvest and tibial osteotomy. The semitendinosus graft is then harvested by traditional approach with an open-end tendon stripper. To obtain a minimum of 6-cm quadruple graft, it is necessary to have a 24-cm semitendinosus length (Fig 2).

Graft preparation and passage were done using the technique introduced by Silva et al.,[13] by which a quadruple semitendinosus graft was prepared attached on both sides to two adjustable-length loop cortical buttons: ToggleLoc Device (Zimmer Biomet, Warsaw, IN) with ZipLoop™ Technology for the femur and ToggleLoc XL Device (Zimmer Biomet) with Inline ZipLoop Technology for the tibia. Thereafter, the graft construct was placed under tension at 300 N for 2 minutes, and its length was measured both before and after tensioning (Fig 2).

Femoral Tunnel Preparation

The arthroscopic anteromedial working and anterolateral visual portals are placed to detect any accompanying knee joint lesions in the first place by the standard arthroscopic system. In the next step, while visualizing through anteromedial portal, femoral tunnel was drilled with inside-out transportal technique through the medial portal at the center of native ACL footprint by means of flexible size 2 guidewire (Zimmer Biomet). The femoral tunnel is reamed over the guidewire (Zimmer Biomet) with a 4.5-mm cannulated reamer (Zimmer Biomet) to perforate the lateral cortex of the femur and create a complete tunnel. After removing the guidewire, the tunnel length is measured by arthroscopic depth gauge from the anteromedial portal, and the guidewire is repositioned. Usually, a length of 23-27 mm reaming is done, which is the same size as the graft diameter created with a cannulated

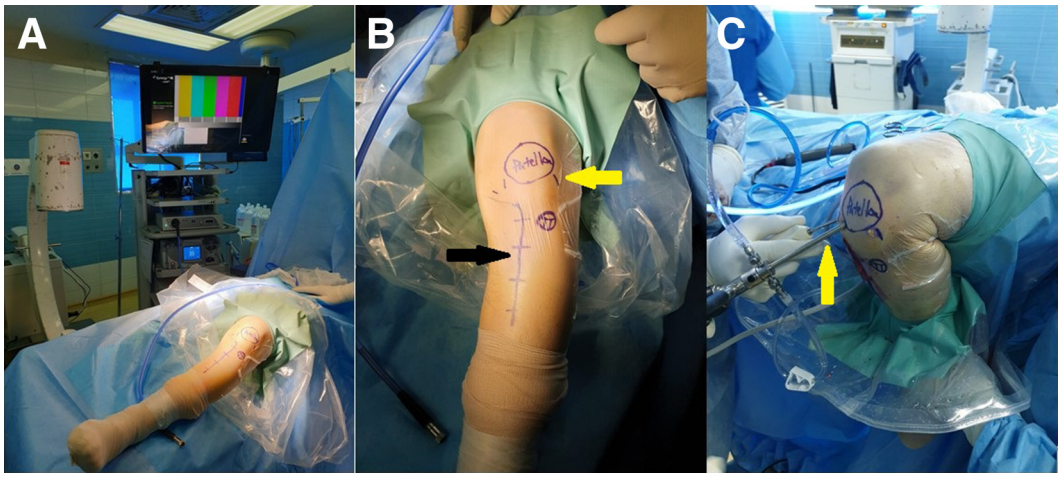

Fig 1. (A) Patient's supine position on a radiolucent table having the C-arm on the opposite side of the surgery. (B). The left leg is prepped for knee osteotomy and arthroscopy at the same time. The entry points of medial and lateral arthroscopy portals and patella are marked (yellow arrow). Also, a single 7-8-cm incision is marked (black arrow) medial to the tibial tubercle for both HTO and graft harvesting. (C) Patient's knee should be able to hyperflex to 110° during the arthroscopy, and the medial visual portal (yellow arrow) is inserted for primary diagnostic arthroscopy of left knee.

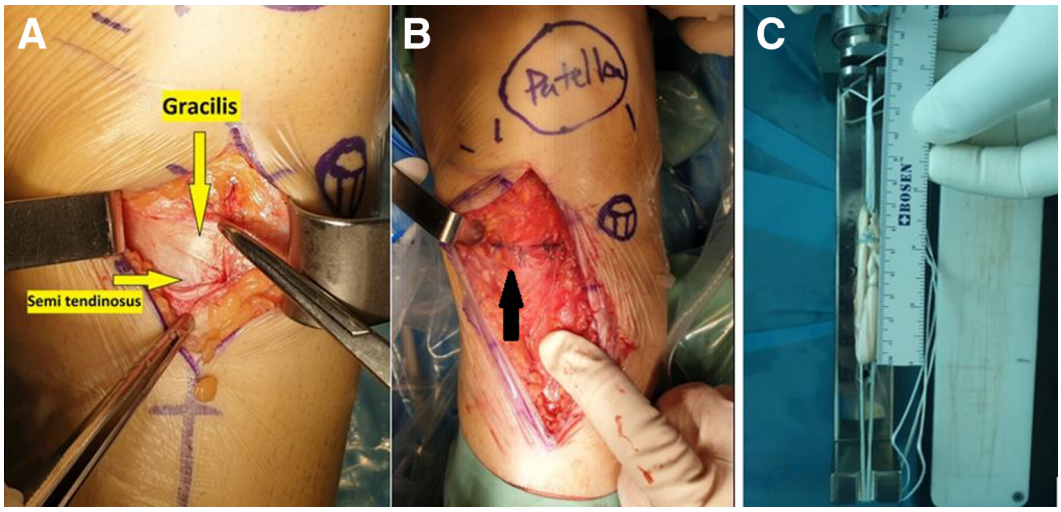

Fig 2. (A) Single incision for both graft harvest and osteotomy of the left knee. After incising the fascia, semitendinosus and gracilis tendon (yellow arrows) insertion are explored at the tibial cortex (B) Fascia closed (black arrow) after graft harvest making the site prepared for HTO. (C) Quadruple semitendinosus autograft fully prepared under tension in proper size and length by Silva technique attached to two Toggle Loc buttons at each ends.

reamer (Zimmer Biomet). Then a shuttle suture from the lateral thigh, and the medial portal is placed in the femoral tunnel (Fig 3).

Medial Open Wedge HTO

Now by placing the leg in full extension and using our previous harvesting longitudinal skin incision, the subcutaneous tissues and the fascia are divided by retracting the pes tendons distally, and the medial collateral ligament (MCL) insertion is partially released by passing a periosteal elevator beneath from the tibia. After inserting a retractor behind the tibia, a guide wire is positioned under fluoroscopic guidance from medial to lateral and from distal to proximal, starting around 50 mm below the medial joint line (more distal than the traditional HTO procedure), aiming at the tip of the fibular head (around 1 cm below the lateral joint line). The patellar tendon and the posterior neurovascular structures are being protected using blunt retractors (Fig 4).

Medial open wedge osteotomy is done parallel to the tibial slope with a thin oscillating saw preserving a lateral cortical hinge. The anterior ascending osteotomy is performed at an angle of around 110° to the transversal saw cut, ending behind the patellar tendon. The osteotomies are completed by advancing the blades of the osteotomies up to around 1 cm from the lateral tibial cortex. The mobility of the osteotomy is checked using a gentle valgus force, and then, it is slowly spread by placing the bone spreader in the dorsomedial intercortical portion of the osteotomy gap until the desired opening angle is reached. The guidewires are removed carefully. The prepared Tomofix plate (Depuy Synthes) is inserted on the medial side of the tibia plateau, generally positioned in a more posterior position to leave more room for the anteromedial of the tibia for

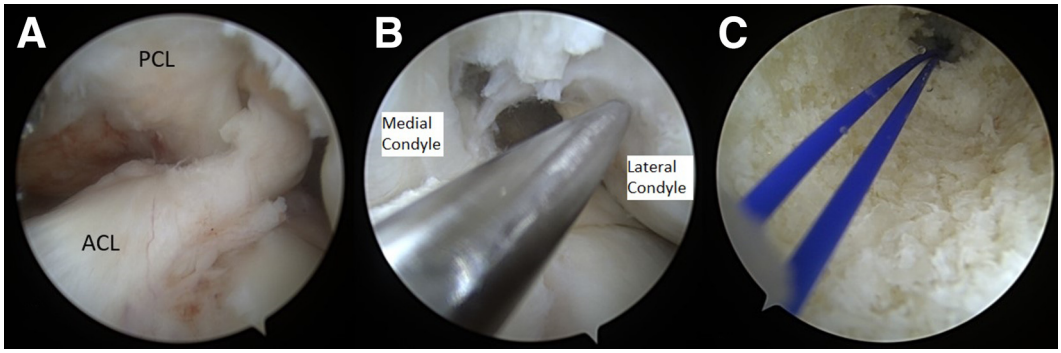

Fig 3. (A) ACL tearing of left knee on the anterolateral portal view. (B) Femoral tunnel guide wire placement in proper position at the lateral femoral condyle. (C) Inside femoral tunnel, Nylon suture is passed through. ACL, anterior cruciate ligament; PCL, posterior cruciate ligament.

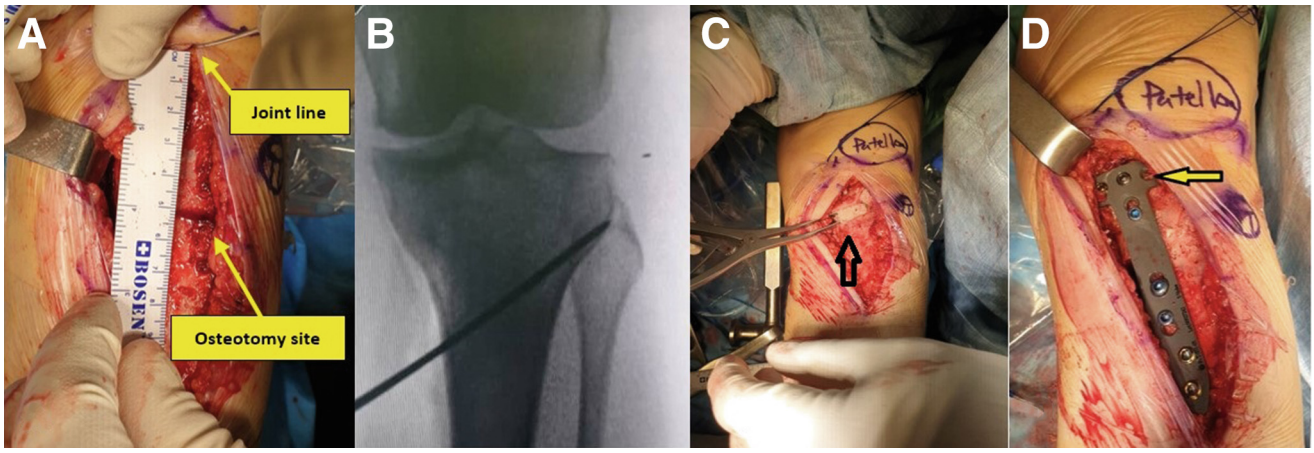

Fig 4. (A) Joint line of left knee is located by placing a needle (upper yellow arrow). The osteotomy site is marked 50 mm distal to the joint line few millimeters below the standard high tibial osteotomy (HTO) procedure (lower yellow arrow). (B) Guide pin is inserted for the osteotomy and checked by C-arm for proper positioning toward fibular head from lateral cortex at the previous marked distance from the joint line. (C) After opening the wedge to the right size, it is filled with cancellous bone allograft (black arrow). (D) Tomofix (Depuy Synthes, Oberdorf, Switzerland) plate is used for HTO fixation, placing the plate more distal and medial, leaving the most lateral hole empty (yellow arrow) not to interfere tibial tunneling.

tibial tunnel compared with isolated HTO. The distal portion of the plate must be aligned with the tibial diaphysis to avoid anterior or posterior cortical overhang. All screws are positioned except for the proximal anterior locking screw, to avoid hitting the tibial tunnel. At the end of this step, cancellous bone cube allograft is inserted in the osteotomy site (Fig 4).

Tibial Tunnel Preparation

During the next step a Director Tibial Guide (Zimmer Biomet) set at 55° and is positioned under arthroscopic visualization on the anatomic tibial ACL footprint, allowing the Guidewire to be drilled through the center of the native ACL footprint. Afterward, the cortex at the distal end of the tibial tunnel is removed with a reamer. Then, a cannulated plunger (Zimmer Biomet) is inserted, over the K-wire. The harvesting tube (Zimmer Biomet) is then impacted in a rotating manner over the k wire in order to remove the cancellous bone which is saved to be returned in place at the final step. Next, the tibial tunnel is reamed through the subchondral bone (Fig 5).

Graft Passage and Fixation

Finally, the adjustable graft loop is marked from the proximal tip of the cortical suspensory button, as well as the length of the whole femoral tunnel, and then the depth of reamed femoral graft tunnel marks on the graft. Also, the length of the graft inside the joint is marked, usually 25 to 30 mm long. The femoral adjustable graft loop is pulled into the femoral tunnel, through the tibial tunnel, until the mark on the graft loop reaches the tunnel aperture, under direct arthroscopic visualization, indicating that the button has

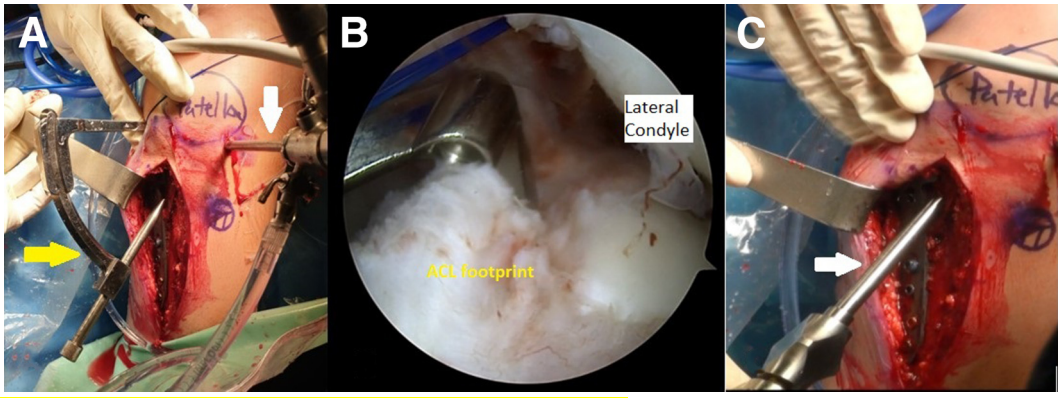

Fig 5. (A) Tibial tunnel guide (yellow arrow) is placed properly at 55° on the tibial cortex just lateral to the plate, and the anterolateral portal (white arrow) is used to help proper placement of guide (B) at the footprint of anterior cruciate ligament insertion on tibial plateau. (C) After passing the Guidewire through the angle guide, the tunnel bone is removed by bone harvesting tube (white arrow) and saved for tunnel grafting at the end of the procedure.

Table 2. Pearls and Pitfalls of Simultaneous ACL Reconstruction Using Double Suspensory Technique and HTO

Pearls
Patient positioning is important. The surgeon should be able to bring the knee through full extension to hyperflexion during the surgery.
The surgical procedure should be performed in the following order: arthroscopy and preparation of femoral tunnel, osteotomy and fixation, preparation of tibial tunnel, and fixation of the graft.
The osteotomy plate should be positioned more proximal and posterior to make enough room for tibial tunnel.
Leave the anterior screw hole empty in the proximal part of the plate to avoid interfering with the tibial tunnel.
Keep enough space between the tibial tunnel entrance and the plate to allow proper seating of distal button on the bone.
Pitfalls
Do not change the proximal tibial slope during proximal tibial osteotomy by preoperative measurement of sagittal slope and keep one to two proportion of anterior versus posterior osteotomy site openings.
Unwanted fracture extending to the extra articular lateral tibial cortex may occur. Leave 1 cm from the lateral cortex to avoid this complication.
Keep at least 1.5-cm distance between the osteotomy and the cartilage on the coronal view to minimize the possibility of intra-articular tibial fracture.
Advise the patient to quit smoking or using nicotine products to prevent tibial nonunion.
As the ToggleLoc ZipLoop has no string for flipping the button, the button flip technique cannot be used in this procedure. You can follow the proximal Endobutton in the femoral tunnel by viewing through the far medial portal to ensure that it will seat on the lateral femoral cortex.

exited the femoral cortex proximally and is ready to flip. Once the button flips, the graft is pulled back to ensure solid femoral fixation. Next, the femoral pull suture is tensioned to pull the graft up into the femoral tunnel. Pearls and pitfalls and advantages and disadvantages of this technique are represented in Table 2 and Table 3, respectively.

Then, the tibial tensioning sutures are pulled until the graft and the button are seated in the tibial tunnel and cortical tibial bone, while the knee is in 30° of flexion, and the assistant performs the reverse Lachman maneuvers. Then, the bone dowel is compacted into the tibial tunnel, with the knee in full extension. At the end, the tension of the graft and its relation to the notch during knee range of motion will be checked. The tension of graft could be increased if necessary using the tensioning sutures on the tibial side. Finally, after checking fixation stability during the knee range of motion, the joint is irrigated, and the surgical wound is closed by monofilament absorbable sutures (Fig 6).

Postoperatively, there is no need for knee immobilization, and active closed-chain range of motion is initiated the day after surgery, and the patient is allowed to bear partial weight for 6 weeks. Early postoperative radiograph is shown in Fig 7.

Discussion

ACLR is generally performed regardless of knee malalignment; however, there are several indications for which corrective osteotomy is necessary to reduce load in the medial knee compartment or soft tissue tension in the lateral and posterolateral corner of the knee (Table 1).[4] Although it is possible to correct knee malalignments and ligamentous reconstructions in 2 stages, simultaneous HTO with ACLR has the apparent benefit of a single surgical procedure with a faster recovery than a staged procedure and less hospitalization costs.[4,6,7] Besides, various surgical techniques have been described for either the ACLR or HTO procedure, each of them has its advantages and disadvantages.[14-17] In the current technique, we presented combined

Table 3. Advantages and disadvantages of simultaneous ACL Reconstruction Using Double Suspensory Technique and HTO

Advantages	Disadvantages
• Achieving better knee stability compared with HTO alone • Opening wedge osteotomy allows fine tuning correction of varus deformity. • HTO can postpone the need for a joint replacement procedure. • Helps prevent stretching and failure of the grafts in cases of concurrent ACL instabilities and varus malalignment • Better ACL graft incorporation after returning the bone dowel graft. • Preserving the tibial bone stock for potential later ACL revision. • Single incision for both procedures leaving less scar • It reduces the cost of treatment because both surgeries are performed at the same time. With this method, bungee and windshield wiper effects of ACL graft are probably minimized.	• Chance of unwanted tibial fracture • Longer rehabilitation than single procedures alone • Risk of nonunion is higher in opening osteotomies, comparing with lateral close wedge osteotomies • Alterations in bone anatomy can challenge future conversion to total knee replacement • Loosening of the adjustable loop in comparison to the fixed loop following cyclic loading in biomechanical studies More operative time and technical demanding surgery

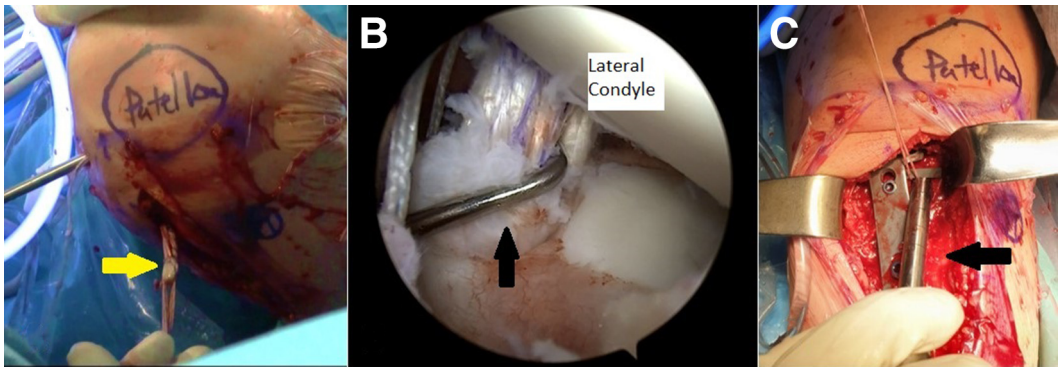

Fig 6. (A) Transtibial passing through the quadruple semitendinosus autograft (yellow arrow). (B) Graft proper tension is checked through arthroscopy by anterolateral visual portal after fixation of femoral and tibial Endobutton at the cortices by use of medial probe (black arrow). (C) Previous removed bone is put back in place (black arrow) after locking the Endobutton, filling the tibial tunnel with cancellous bone autograft.

ACLR using double suspensory graft fixation introduced by Silva et al. and medial open wedge osteotomy with proper adjustment to reduce the risk of interfering with the tibial tunnel and graft fixation.

The ACLR using the all-inside technique is referred to as producing the bone tunnel from the articular side of the tibia instead of traditional full-length tunneling through the knee joint and outer cortex.[17] The suspensory cortical button is commonly used for the graft fixation method in this technique. Having greater graft thickness with biomechanically higher durability, significant maintenance of flexion strength, no windshield wiper or bungee cord effect, and less bone tunnel widening are the described superiorities of double suspensory technique using suspensory graft fixation.[14-16] The double suspensory technique has several advantages in comparison to traditional full-length tunneling, such as bone mass preservation in both femur and tibia, decreased postoperative pain due to less cortical violation and smaller incisions, using a single hamstring tendon harvest, which produces a thicker graft (folded twice becoming quadrupled, as previously described) and less donor side morbidity, along with better knee flexion due to preservation of the gracilis tendon.[14,17-21] On the other hand, probable drawbacks of all-inside reconstruction include the more complex surgical learning curve, more extensive ACL tibial stump excision, longer operation time, and suspensory cortical tibial fixation.[18,19,22-24]

In a systematic review and meta-analysis by Fu et al.,[25] all-inside reconstruction led to thicker graft for reconstruction and less tibia tunnel widening than bioabsorbable interference screw fixation. Also, no clinical superiority was found in functional outcomes, knee laxity, or failure rate. The biomechanical evaluation also showed a high stiffness and resistance with a very low elongation after cycling in the quadruple semitendinosus graft construct using two cortical buttons and adjustable loops.[26]

Moreover, in the study conducted by Monaco et al., they found increased tibial tunnel widening measured by CT scan because of using hamstring tendon autograft with suspensory femoral and bioabsorbable interference screw fixation of tibial side in comparison to double suspensory fixation method. However, there was no significant difference in the clinical outcomes between the two groups.[27] Also in the meta-analysis presented by Browning et al., comparing the clinical outcomes between suspensory and aperture fixation of ACL reconstruction autografts, they concluded that there was arthrometric stability improvement along with fewer failures due to graft rupture using suspensory fixation compared to aperture fixation group.[28] Therefore, the current literature supports that both aperture and suspensory fixation have comparable clinical outcomes. However, suspensory fixation of the tibial side has the advantage of preserving bone stock, which is very important in an already open-wedge

Fig 7. Postoperative radiograph after simultaneous realignment HTO + ACL reconstruction using double suspensory technique and tunnel bone grafting.

HTO, leading to better union and less cortical disruption.

There is no need for using larger-sized bioabsorbable screws used in other methods, which make metaphysis and cortex of tibia more vulnerable to fractures and bone loss. There are some modifications in open-wedge HTO to provide more space in proximal tibia for tunnel placement and screw fixation. These measures include transfer of the osteotomy site 5 mm distally, placement of the plate as posterior as possible in the proximal portion, and leaving the anterior screw hole in the proximal plate empty. We believe that suspensory fixation is more feasible and bone preserving in the available space in proximal tibia after an open-wedge HTO. This technique might result in better clinical outcome and less reconstruction failure in patients undergoing simultaneous ACLR-HTO procedure.

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