Technical Note

Posterior-Medial Meniscal Root Repair Through Lateral Tibial Tunnel Combined With Medial Opening Osteotomy and Homologous Graft

Rodrigo Araújo Goes, M.D., M.Sc., Raphael Serra Cruz, M.D., M.Sc., Douglas Mello Pavão, M.D., M.Sc., Thiago Alberto Vivacqua, M.D., M.Sc., André Luiz Siqueira Campos, M.D., M.Sc., Phelippe Augusto Valente Maia, M.D., M.Sc., Rodrigo Salim, M.D., Ph.D., and José Leonardo Rocha de Faria, M.D., M.Sc.

Abstract: When there is a rupture in the meniscal roots or close to them, the menisci suddenly and considerably reduce their capacity to absorb the axial mechanical load that passes through the knee, quickly leading to the development of a process of chondral degeneration. The varus deformity of the lower limb (when the mechanical axis crosses the medial compartment of the knee) favors this type of injury owing to the overload in the medial compartment. When the patient has both varus deformity and medial meniscal posterior root injury, there is a clear indication for surgical realignment of the affected lower limb. There is still not a consensus regarding combining meniscal root repair with corrective osteotomy, although there is a tendency to perform both procedures aiming at long-term joint preservation. We present a safe alternative technique for simultaneous medial meniscal posterior root repair using a lateral tibial transosseous tunnel associated with a valgus-producing high tibial osteotomy with homologous bone grafting, allowing a full return to daily activities and sports.

The menisci have bony insertions in their posterior and anterior extremities called "meniscal roots."[1,2] These structures allow for efficient impact absorption. When there is a rupture in the meniscal roots or close to them, the menisci suddenly and considerably reduce their capacity to absorb the axial mechanical load that passes through the knee, quickly leading to the development of a process of chondral degeneration.[3-10]

The most commonly reported root tears are described at the medial meniscal posterior root (MMPR), affecting mostly women aged between 40 and 70 years. It is observed that most patients do not have a well-defined trauma history. However, they usually report sudden pain in the posteromedial region of the knee, as well as an inability to tolerate weight bearing on the affected limb, and they may have a history of mild trauma.[5,11-13] Obesity, middle age, and lower-limb varus alignment are the main risk factors for MMPR injury.[5]

Patients in the acute phase usually do not report improvement in symptoms even with the use of powerful analgesic medications. This lack of improvement occurs because of the sudden increase in the mechanical load that is almost entirely transferred to the chondral femoral and tibial surfaces after a root tear occurs.[9,14] The varus deformity of the lower limb (when the mechanical axis crosses the medial compartment of the knee) favors this type of injury[14,15] owing to the overload in the medial compartment.[16-18] When the patient has both varus deformity and MMPR injury, there is a clear indication for surgical realignment of the affected lower limb.[19,20] There is

From the Sports Medicine Center, National Institute of Traumatology and Orthopedics of Brazil, Rio de Janeiro, Brazil (R.A.G.); Knee Surgery Center, National Institute of Traumatology and Orthopedics of Brazil, Rio de Janeiro, Brazil (R.S.C., D.M.P., P.A.V.M., J.L.R.d.F.); Fowler Kennedy Sports Medicine Clinic, London, Ontario, Canada (T.A.V.); Federal Hospital of State Servants, Rio de Janeiro, Brazil (A.L.S.C.); and Ribeirão Preto Medical School, University of São Paulo, Ribeirão Preto, São Paulo, Brazil (D.M.P., J.L.R.d.F., R.S.).

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Address correspondence to José Leonardo Rocha de Faria, M.D., M.Sc., Instituto Nacional de Traumatologia e Ortopedia Jamil Haddad, Av Brasil, 500, São Cristovão, Rio de Janeiro, Brazil, CEP 20940-070. E-mail: drjoseleonardorocha@gmail.com

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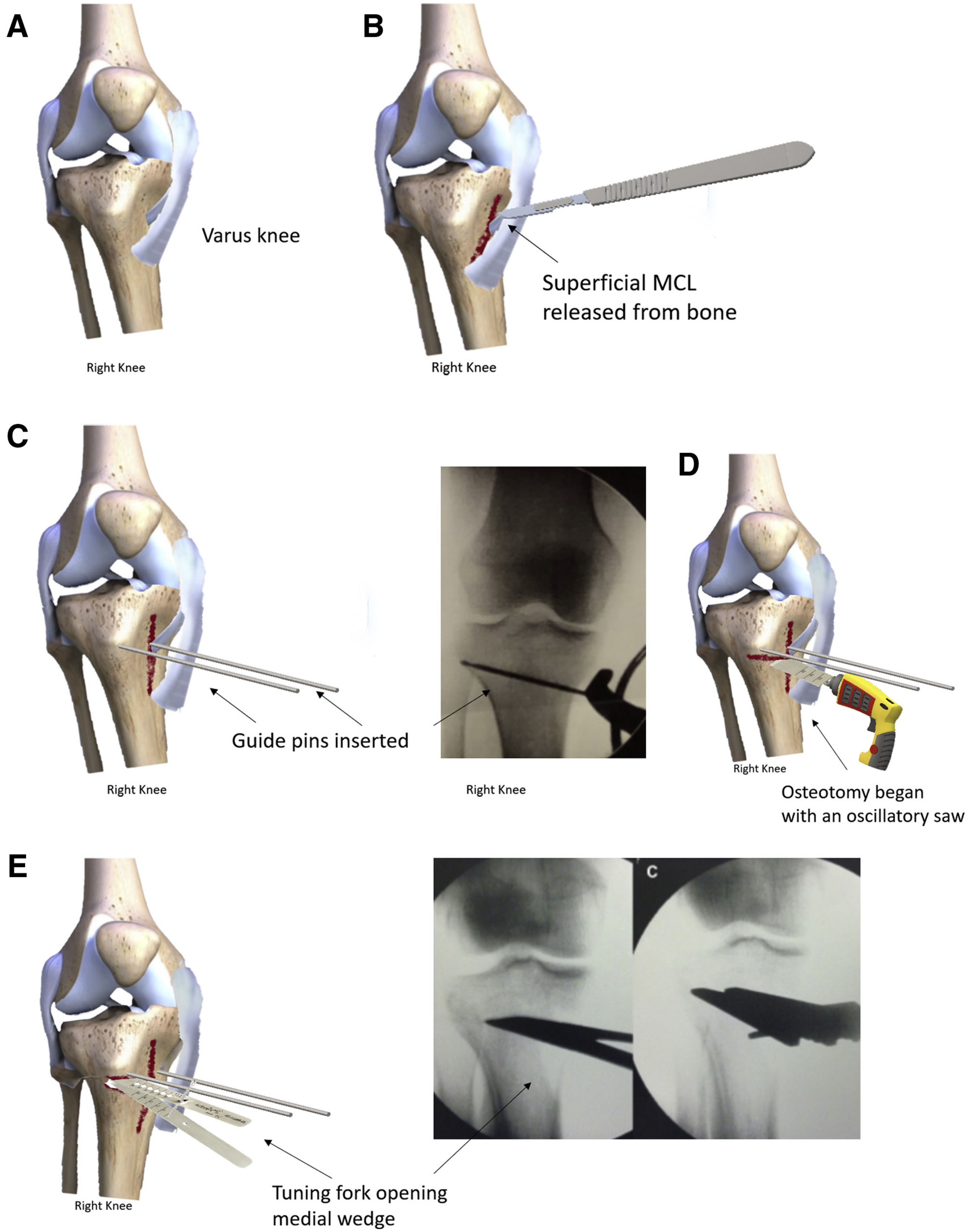
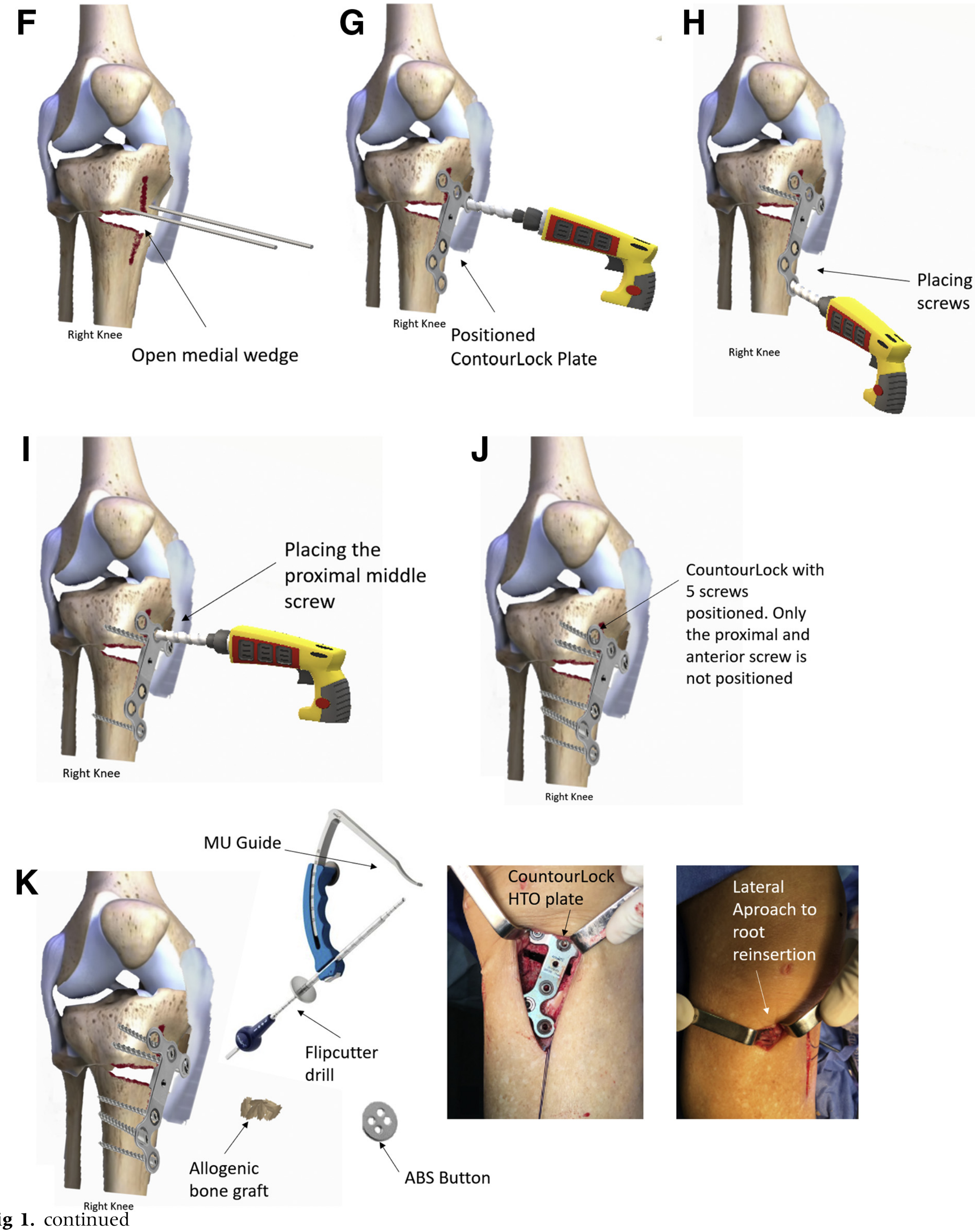


Fig 1. (A) Ligament anatomy of right knee with varus deformity depicting medial collateral ligament. (B) Subperiosteal dissection of superficial medial collateral ligament (MCL). (C) Guidewires are inserted in the medial aspect of the tibia, 4 cm distal to the joint line. On the radioscopic image, the overlap of the guidewires confirms the parallelism (right knee side). (D) Tibial osteotomy begins with an oscillating saw in the medial cortex of the tibia. (E) The osteotomy is gradually opened with spreaders



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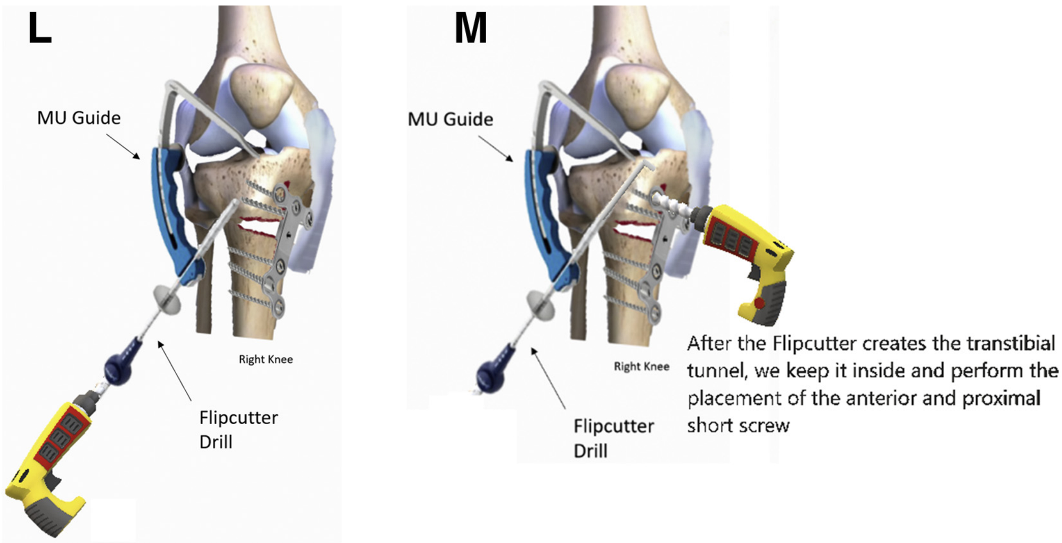
still not a consensus regarding combining meniscal root repair with corrective osteotomy, although there is a tendency to perform both procedures aiming at long-term joint preservation.[21,22]

Performing a high tibial osteotomy (HTO) simultaneously with a meniscal root reinsertion may be very challenging, especially regarding the possible positioning conflict between the tibial tunnel created to fix the root at the anterior cortex of the tibia and the anterior screws used to fix the opening-wedge tibial plate. We present a safe alternative technique for simultaneous MMPR repair using a lateral tibial



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transosseous tunnel associated with a valgus-producing HTO with homologous bone grafting, allowing a full return to daily activities and sports.

Surgical Technique

Positioning and Preparation

After receiving spinal anesthesia associated with selective blockage in the adductor canal, the patient is positioned supine on the operating table. A pneumatic cuff is positioned high on the thigh, and a 10-cm gel pad is placed under the ipsilateral gluteal region so that the injured lower leg remains in approximately 15° of internal rotation, keeping the patella straight upward. It is paramount during patient positioning to evaluate whether the hip, knee, and ankle are accessible by the fluoroscopic C-arm to allow the assessment of the mechanical axis. A padded lateral support is attached to the operating table lateral to the tourniquet to facilitate opening of the medial compartment during valgus stress. The injured limb is then prepared with an aseptic technique, and sterilized surgical drapes are applied.

Medial Opening Valgus Osteotomy

A 6-cm longitudinal incision is made in the anteromedial surface of the proximal tibia. The hamstring tendons are identified, retracted, and repaired with absorbable sutures (Fig 1A). The superficial medial collateral ligament is identified and subperiosteally dissected, with its distal insertion kept intact (Fig 1B). The medial head of the gastrocnemius is protected with a retractor placed along the posterior cortex of the tibia to protect the neurovascular bundle. The patellar tendon is identified by blunt dissection and secured with a hook-shaped retractor. Under fluoroscopic view, 2 guidewires are inserted 4 cm distally to the joint line, obliquely, directed toward the fibular head (Fig 1C).

Osteotomy is performed with the aid of an oscillating saw and osteotomes, just below the guidewires, which are kept as a strategy for preventing undesired fracture and intra-articular injury (Fig 1D). It is important not to complete the osteotomy at the lateral cortex of the tibia because this region is going to work as a hinge for the correction opening. With the aid of an osteotome jack and spreader-type retractors, a medial wedge is slowly opened until the mechanical axis reaches the preoperative planning point (Fig 1 E and F). Again, it is very important not to violate the lateral cortex of the tibia at this step. Then, a 6-hole plate (with 3 proximal and 3 distal holes) (ContourLock HTO Plate; Arthrex, Naples, FL), with a graduated trapezoidal wedge (5, 7.5, 10, 12.5, or 15 mm), is inserted into the osteotomy site, with the longer side aligned with the posterior cortex of the tibia and used to keep the wedge open (Fig 1G).

after it has been completed with osteotomes. (F) Osteotomy with planned opening. (G) Positioning of ContourLock HTO plate to fix osteotomy and placement of proximal-posterior screw. (H) Placement of distal screw. (I) Placement of proximal middle screw. (J) View of ContourLock HTO plate with 3 distal screws and 2 proximal screws positioned. (K) Multi-use (MU) guide used for making tibial tunnel of meniscal root; allograft to be used in osteotomy; ABS button, with plate already positioned with visualization of 6-cm access; and visualization of anterolateral access used for positioning MU guide and introduction of FlipCutter drill. (L) The MU guide is positioned, and the FlipCutter drill is introduced to make the transtibial tunnel through lateral access. (M) After the FlipCutter drill creates the transtibial tunnel, we keep the cannula in the tunnel while placing the anterior-proximal screw of the plate to avoid convergence between this screw and the tunnel.

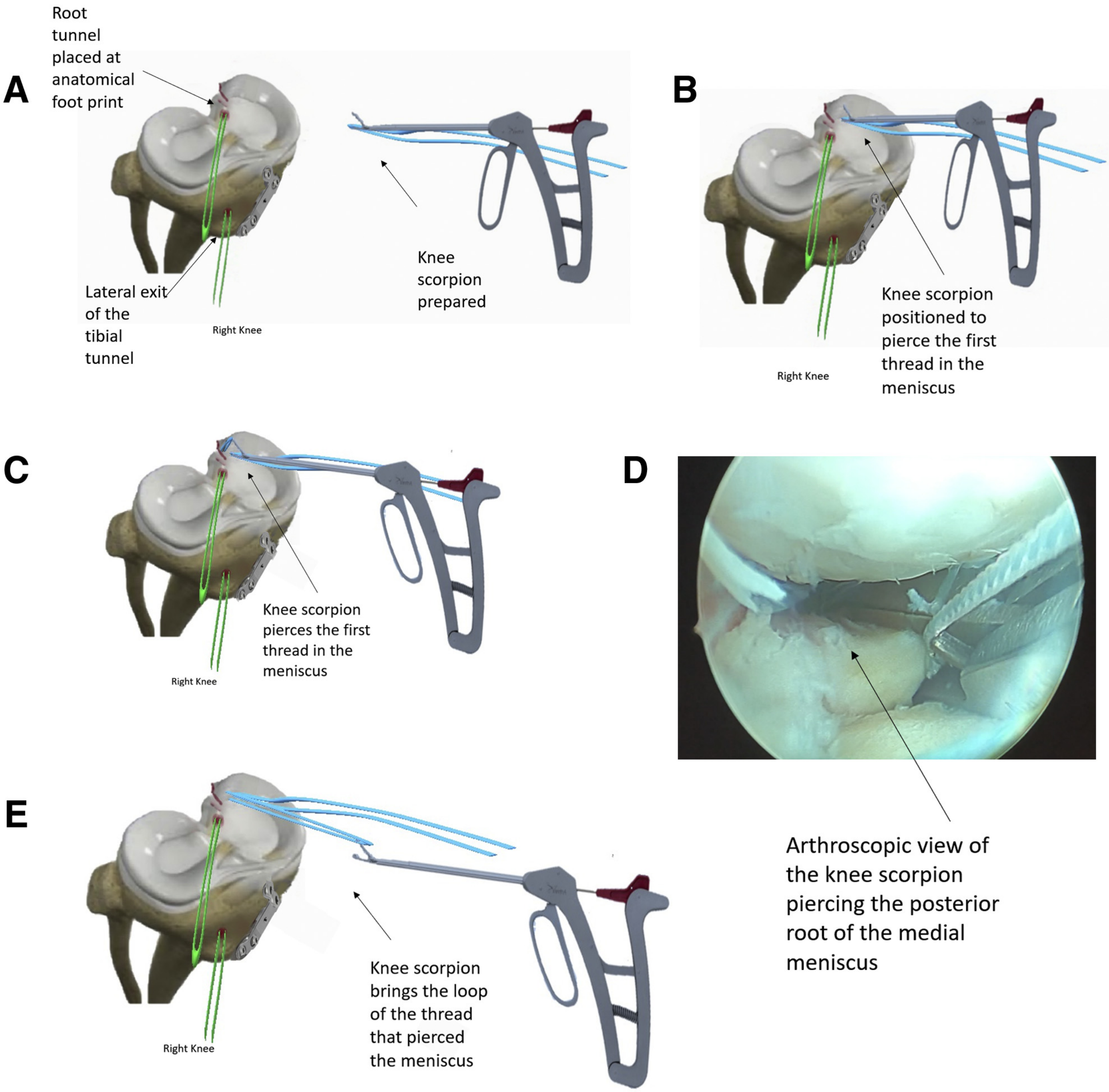
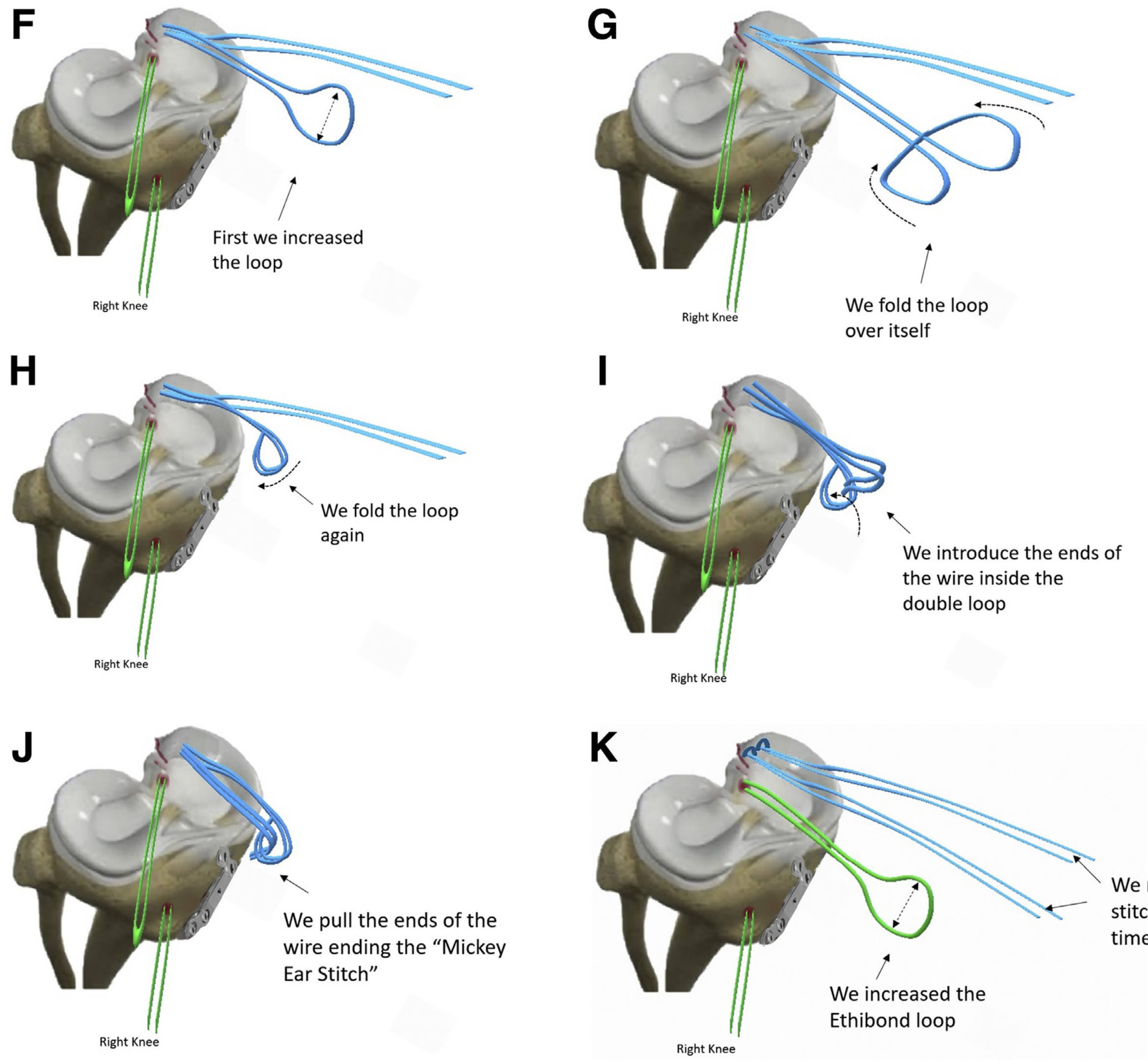


Fig 2. (A) Posterior root of medial meniscal tear, with Ethibond thread loop transported through lateral transtibial tunnel, and Knee Scorpion meniscal suture device symmetrically loaded with suture thread. (B) Knee Scorpion, positioned inside joint, prepared to pass meniscal suture thread through posterior meniscal root of medial meniscus. (C) Knee Scorpion clamp passing suture loop through posterior root of medial meniscus. (D) Arthroscopic view of suture loop passing through posterior root of medial meniscus with aid of Knee Scorpion clamp. (E) Passing of meniscal suture loop outside joint through medial portal (right knee side). (F) Enlargement of loop. (G) Folding of loop over itself to create 2 loops ("Mickey ears"). (H) Connection of 2 loops to create double loop. (I) Passing free end of suture inside double loop. (J) Pulling the free end of the thread makes the loop run toward the meniscal root, reducing it. (K) The aforementioned steps are repeated to make a second stitch on the meniscal root. (L) Passing of free ends of meniscal suture threads inside Ethibond loop to transport them through tibial tunnel. (M) Arthroscopic view of last step. (N) Schematic view of suture threads passed through lateral tibial tunnel. (O) Arthroscopic view of meniscal root being reduced when pulled by suture threads through lateral tunnel. (P) Fixing of suture threads with multiple knots over ABS button. (Q) Final aspect of fixation through mini-lateral access. (R) Allograft to be inserted into osteotomy. (S) An anterior-proximal screw is introduced in a safe position. (T, U) Introduction of allograft into osteotomy site.

Radioscopic image control is performed in the sagittal plane to ensure that the tibial slope is maintained. Another precaution and suggestion in cases of techniques associated with osteotomy is to place the plate as far posterior as possible. This increases the anterior area available for the placement of screws and



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for the creation of the tunnel(s) in the tibia, reducing the risk of convergence. In addition, positioning the plate posteriorly at the tibia helps prevent an unwanted increase in the tibial slope. The plate is then fixed with 5 locked screws: only 2 proximal screws—the most posterior screws—and 3 screws distal to the osteotomy (Fig 1J). The most anterior of the proximal screws should only be placed after the tibial tunnel is created.

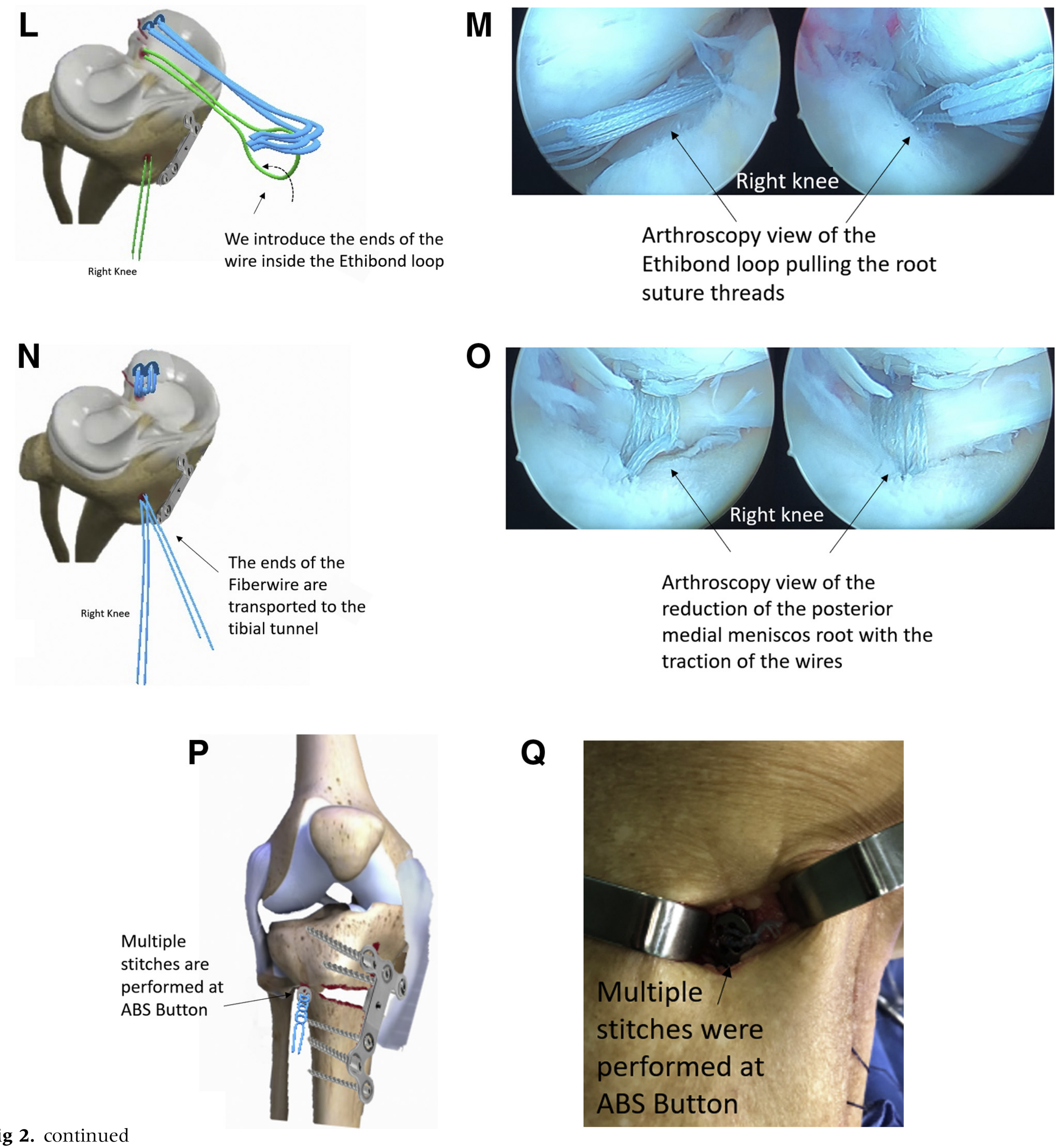
Arthroscopic Diagnosis and Confirmation of MMPR Rupture

After limb exsanguination, the tourniquet is inflated 150 mm Hg over the patient's systolic blood pressure. The anterolateral portal is first created; then, under a direct arthroscopic view, the anteromedial portal is created. With the aid of an arthroscopic probe, a thorough joint inspection is carried out with special attention to the diagnostic confirmation of the MMPR lesion and the status of the cartilage of the lateral compartment and lateral meniscus.

MMPR Repair and Tibial Tunnel Construction

Releasing the superficial medial collateral ligament before the osteotomy increases the medial tibiofemoral space, making the handling of instruments in the posteromedial region easier, as well as reducing the risk of damage to the cartilage. Under direct arthroscopic visualization through the anterolateral portal, a multi-use (MU) guide (Arthrex), calibrated to 55° of inclination, is introduced through the anteromedial portal and positioned posteriorly to the medial tibial spine, at the footprint of the posterior root (Fig 1 K and L).

A small, 2-cm access is created on the lateral edge of the proximal tibia with the soft tissue under the skin dissected until the tibial bone is reached (Fig 1K). From this access, the guidewire entry point is positioned



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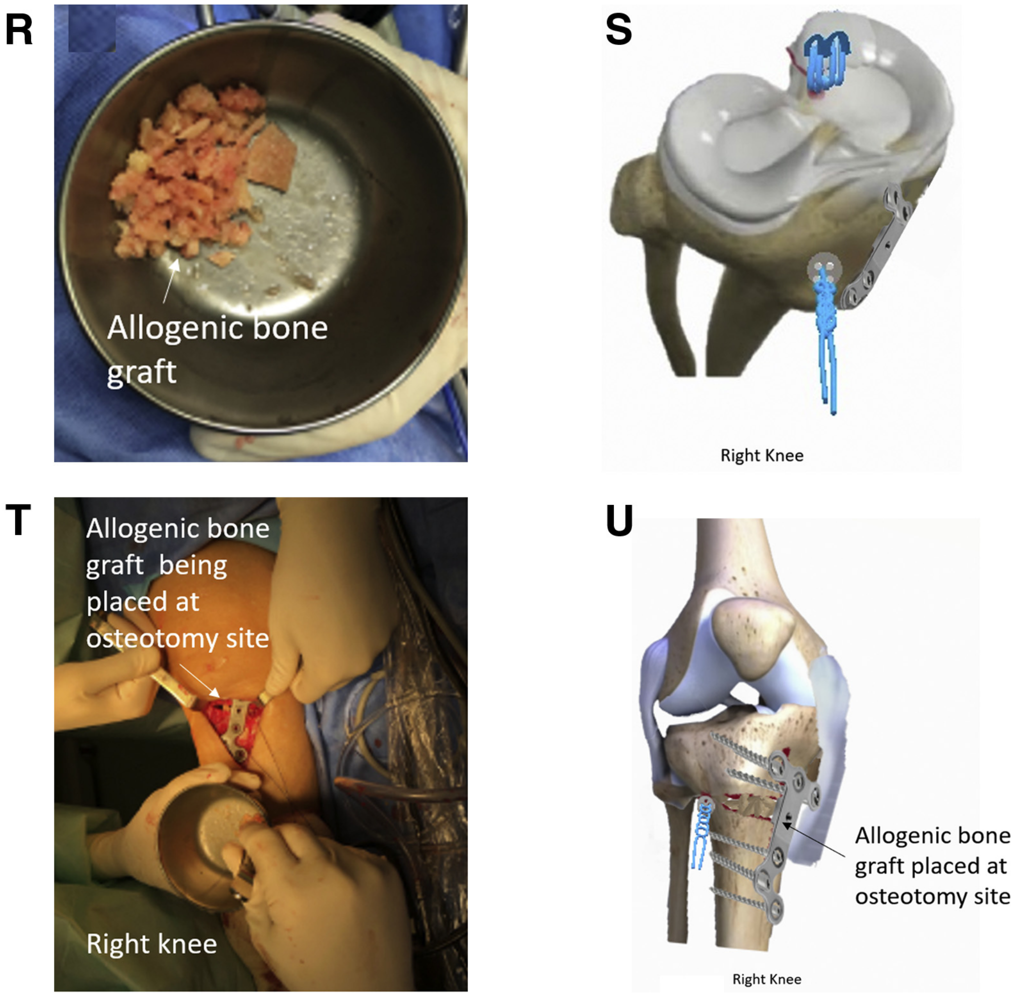
toward the MMPR footprint, avoiding confluence with the 2 proximal screws of the osteotomy plate, already in place.

The bone tunnel for fixation of the meniscal root is drilled with a No. 6-0 FlipCutter device (Arthrex) (wire and drill), proximally and anteriorly to the screws of the osteotomy plate (Fig 1L). When the guidewire reaches the articular space, the drill mode is activated and a 10-mm-long tunnel is drilled in a retrograde manner. The drill mode is then turned back into the guidewire mode, and the device is withdrawn from the joint. The cannula of the FlipCutter drill must be kept in the tunnel while placing the anterior-proximal screw of the plate to avoid convergence between this screw and the tunnel (Fig 1M). Furthermore, the cannula facilitates the entry of an eyelet pin, loaded with a No. 2-



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0 Ethibond loop transport thread (Ethicon, Somerville, NJ). Once inside the joint, the loop of the thread is pulled out through the anteromedial portal using a 2-finger forceps (Fig 2A).

With the aid of a Knee Scorpion device (Arthrex) through the anteromedial portal, 2 stitches using No. 2-0 FiberWire thread (Arthrex) are applied to the medial stump of the meniscus, at 3 mm and 5 mm from the free edge of the injured root. The knot is stabilized in the form of a double loop (Fig 2 B-J, Video 1).

Wire Transport, Binding, and Bone Grafting

The threads of the meniscal suture and transport thread are pulled through the anteromedial portal simultaneously so that all threads exit through the same portal without interposition of synovial tissue. The suture threads are passed through the loop of the transport thread (No. 2-0 Ethibond), which is then pulled out through the tibial tunnel (Fig 2 K-O) toward the lateral cortex of the tibia. The meniscal suture threads are released from the transport thread and secured to an ABS suture button (Arthrex) in this region (Fig 2 P and Q). The correct tension of the threads guarantees the reduction of the meniscal root within the bone tunnel under arthroscopic control. The incisions are carefully washed, and the bone allograft is inserted into the osteotomy site (Fig 2 R-T).

After the tourniquet is released, it is advisable to perform a review of hemostasis. Conventional suturing of the wounds is performed, and an occlusive dressing is applied. We recommend the use of an inguinal-malleolar knee immobilizer to protect the repair. Postoperative radiologic evolution and incision healing are assessed within 2 weeks (Fig 3).

Rehabilitation

The key to successful rehabilitation after the described procedure is to understand the final goals of treatment: healing of the meniscus and consolidation of the osteotomy. With this kept in mind, some restrictions are recommended throughout the process, especially

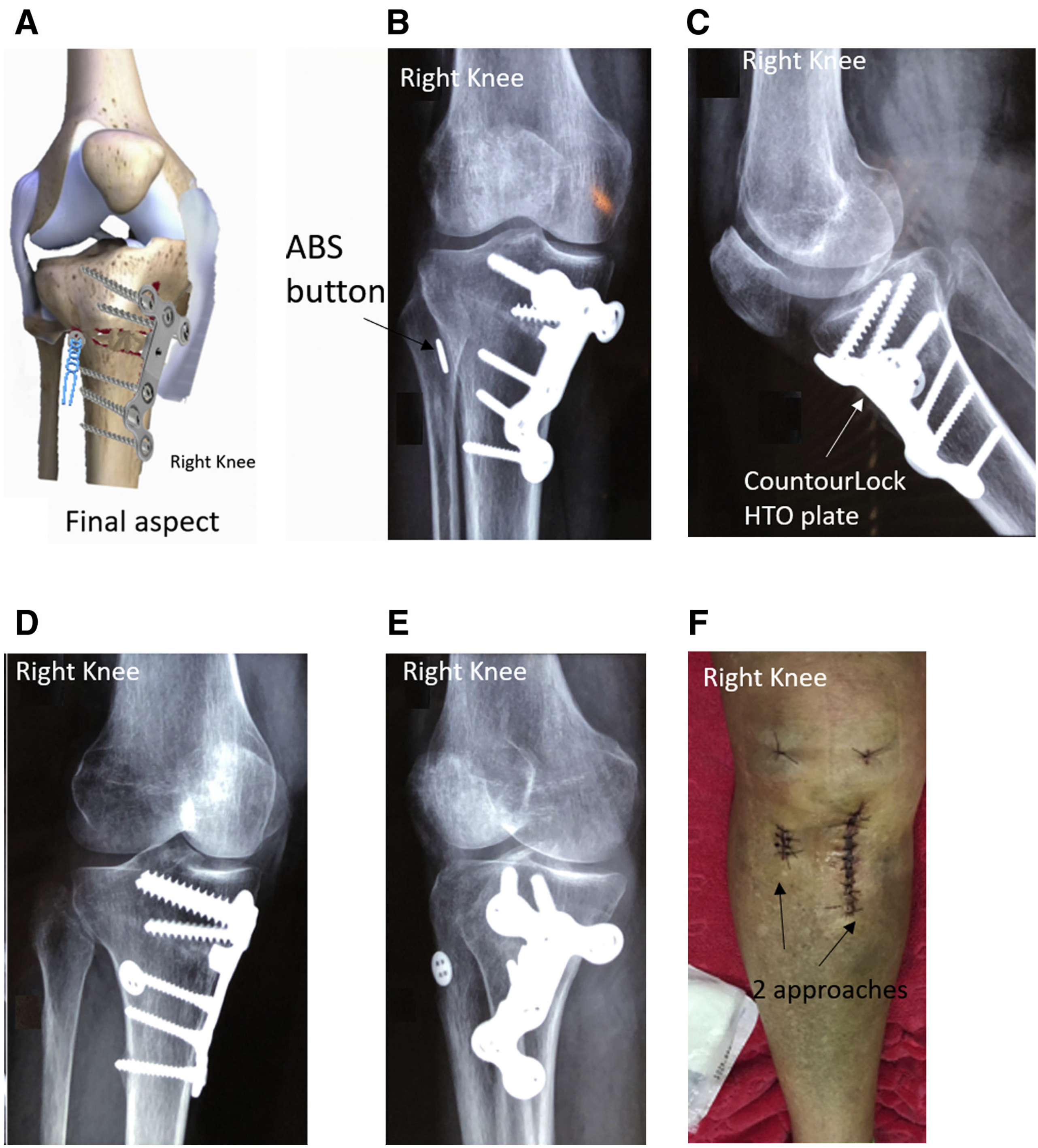

Fig 3. (A) Final schematic image of ContourLock plate positioned with 6 screws, allograft in osteotomy site, and meniscal root suture threads attached to ABS button. (B) Postoperative anteroposterior radiograph showing positioned ContourLock plate and ABS button (right knee side). (C) Postoperative lateral radiograph. (D, E) Postoperative oblique radiograph showing ContourLock plate and ABS button positioned. (F) Final aspect of surgical wound showing anteromedial and mini-lateral accesses.

non–weight bearing for 6 weeks.[5,7,13,23] If a patient does not comply with this main recommendation, there is a high risk of complications including fracture, leading to misalignment of the proximal tibia and failure of the root repair. We describe our rehabilitation protocol in Table 1.

Discussion

The great advantage of the described technique is that placing the tibial tunnel for the MMPR repair toward the lateral cortex of the tibia allows it to be positioned far from the medial osteotomy opening, reducing the chance of confluence of the tibial tunnel with the screws

Table 1. Discriminated Phases of Rehabilitation After Posterior-Medial Meniscal Root Repair Through Lateral Tibial Tunnel Combined With Medial Opening Osteotomy and Homologous Graft

Phase[11,12,23]	Rehabilitation Protocol
Phase 1: Immediate postoperative period (first week [days 1 to day 7])	• Cryotherapy is performed 6 times a day for 25 min. • Regarding care of the surgical wound, it should always be kept clean and dry with an occlusive dressing. • Pain control is achieved with analgesic medication, and edema control is achieved with limb elevation. • The patient receives a prophylactic anticoagulant (enoxaparin, 40 mg, once a day for 14 days). • Mobilization of the patella, patellar tendon, and quadriceps is performed. • Ankle pumps are performed. • A knee immobilizer is used (especially for sleeping and walking). • No weight bearing on the operated limb is allowed. • Straight leg−raising strengthening exercises are performed. • Passive flexion up to 90° is allowed, and stimulation is required to avoid joint stiffness.
Phase 2: Second and third weeks (day 7 to day 21)	• All recommendations from the previous phase are followed. • Stitches or staples are removed around the third week. • The patient performs isometric strengthening exercises for the abductor and adductor muscles.
Phase 3: Third to sixth week (day 21 to day 42)	• The knee immobilizer is no longer needed. • Passive flexion beyond 90° is allowed as tolerated by the patient. • Quadriceps, abductor, and adductor isometric exercises are performed. • Frontal and lateral radiographs of the knee are obtained to observe bone consolidation at the osteotomy site (at 6 wk).
Phase 4: Sixth to eighth week (day 42 to day 56)	• Partial weight bearing with 2 crutches is allowed (if the osteotomy shows signs of consolidation). • Active Flexion and total passive range of motion is allowed. • The patient may use a stationary bike without resistance.
Phase 5: Eighth to twelfth week (day 56 to day 84)	• The patient progresses to walking using only 1 crutch. • The focus is on gaining full active joint range of motion. • The patient begins proprioception training with support. • The patient may use a stationary bike with resistance. • The patient begins closed kinetic chain exercises with the knee flexion angle restricted to 0°-30° (always with bilateral support—leg presses and squats).
Phase 6: Twelfth to sixteenth week (day 84 to day 112)	• The use of crutches is completely withdrawn (full weight bearing). • The patient performs closed kinetic chain exercises; the range of knee motion is increased to 0°-70°. • The patient performs unilateral strengthening exercises. • Freestyle swimming, elliptical machine use, and treadmill walking are allowed to increase aerobic fitness. • At this stage, running on any surface and breaststroke kicking during swimming are still contraindicated.
Phase 7: Sixteenth week to sixth month (day 112 to day 180)	• The performs the activities contained in phase 6. • Open and closed kinetic chain exercises are maintained by increasing knee range of motion to 0°-90°. • There is a focus on quadriceps muscle strengthening and unilateral exercises, including the hip abductors and external rotators. • Freestyle swimming, elliptical use, walking on sand and grass, and treadmill use are allowed to increase fitness. • The quadriceps index is evaluated with a dynamometer (manual or isokinetic). At this stage, the quadriceps strength of the operated limb must be >80% of that of the unaffected limb.
Phase 8: >6 mo	• The patient continues muscle strengthening. • The patient is allowed to start running training on alternating surfaces (sand, grass, treadmill, and track). • The quadriceps index must be evaluated with a dynamometer (manual or isokinetic). At this stage, the quadriceps strength of the operated limb must be >90% of that of the unaffected limb. • The return to the patient's sport of choice is evaluated.

of the osteotomy plate. Furthermore, this positioning creates a more natural angle for the suture threads, reducing the "killer angle" and possibly reducing the risk of a fracture on proximal tibial plateau.

In our technique, we perform more posterior positioning of the ContourLock HTO Plate. This strategy is used to avoid the confluence of the tunnels mentioned earlier, as well as to minimize the chance of an undesired increase in the tibial slope.

A recent meta-analysis and systematic review study reported favorable results of posterior meniscal root repair compared with partial meniscectomy in patients with meniscal root injuries.[24] The findings were consistent and positive in the group undergoing repair, even among patients with degenerative lesions of the meniscal root. Fourteen studies were evaluated: 8 cohorts that evaluated the clinical outcomes of meniscal repair and 6 that evaluated the clinical outcomes of partial meniscectomy. Of the 8 studies that evaluated MMPR repair, 6 performed tibial tunnel placement anterolaterally and 2 did so anteromedially.

LaPrade et al.[25] performed a study of 49 patients who underwent posterior meniscal root reinsertion with a double tibial tunnel. Associated procedures included

Table 2. Advantages, Disadvantages, and Risks of Posterior-Medial Meniscal Root Repair Through Lateral Tibial Tunnel Combined With Medial Opening Osteotomy and Homologous Graft

Advantages
The technique allows more freedom for varying the length of the tunnel and making it longer and vertical.
It is possible to use longer screws through the plate in the holes located above the osteotomy when this technique is performed simultaneously with an opening tibial osteotomy.
Because there is no competition with the osteotomy site (medial wall of the tibia), there is no need to change the height or distance from the joint line where the osteotomy will be performed.
In this position, the root tunnel transposes the osteotomy area in a region with greater bone contact (less opening).
The tension of the meniscal sutures is applied in a more natural direction, reducing the killer angle for the threads.
Good soft-tissue coverage is achieved, given that the fixation button can be very superficial (subcutaneously) in the medial aspect of the tibia in thinner patients.
The tibial tunnel has a different direction when associated with anterior cruciate ligament reconstruction.
Disadvantages
The technique requires additional anterolateral aaproach and soft-tissue dissection.
The guide must be handled through the anterolateral portal (or accessory port) to create the tunnel for the medial posterior root.
Risks
Convergence between the tibial root tunnel and the osteotomy plate screws may occur.
Fracture of the lateral tibial plateau may occur owing to a more lateralized tibial tunnel.
Limitations
The technique can only be used in combination with a medial opening high tibial osteotomy.

anterior cruciate ligament, posterior cruciate ligament, and medial and lateral collateral ligament repair. In the authors' series, no osteotomy was performed in association with root repair. The primary objective of this Level III cohort study was to assess whether there was any difference in clinical outcomes between patients younger than 50 years and patients aged 50 years or older, with a mean follow-up period of 2 years. The authors found similar results between the 2 groups, concluding that age does not interfere with the indications for posterior meniscal root repair and the clinical results of patients.

Another Level III cohort study compared patients with posterior meniscal root injuries at 6 years' follow-up, evaluating which patients progressed to total knee arthroplasty.[26] The patients were divided into 3 groups with matching for sex, age, involved meniscus, and Kellgren-Lawrence grade: conservative treatment, meniscectomy, and root reinsertion using the pullout technique. Each group comprised 15 participants. Of the patients, 9 in the meniscectomy group and 4 in the conservative treatment group progressed to total knee arthroplasty, whereas none of the patients who underwent meniscal root reinsertion progressed to placement of a total knee prosthesis. Hence, a protective factor of meniscal root repair was observed in patients with this type of injury.

A recent study, published in 2020, retrospectively analyzed patients with asymmetrical genu varum and MMPR injury who underwent tibial osteotomy associated with meniscal root repair; these patients were submitted to second-look arthroscopy with 2-year follow-up.[21] The authors analyzed 71 patients divided into 3 groups: The first group was composed of patients who underwent isolated tibial valgus osteotomy. The second group was submitted to tibial valgus osteotomy associated with reinsertion of the posterior root of the tibial meniscus by the pullout method. The third group was composed of patients who underwent osteotomy and repair of the posterior root of the medial meniscus with 2 horizontal stitches with a Fast-Fix meniscal suture device (Smith & Nephew, Andover, MA). The authors found improvement in clinical outcomes after 2 years of follow-up in all groups, with apparent chondral regeneration of the medial compartment, with no statistically significant difference between groups. We believe that in the short term, osteotomy is the factor that generates the greatest protection for the medial compartment, and the benefits of reinsertion or repair of the meniscal root are evident only with a longer follow-up time.

Gelber et al.,[27] in a review study, also reached the conclusion that osteotomies associated with meniscal repair treatment generate a protective effect on the affected compartment, indicating the association of this technique. Rocha de Faria et al.[23] recently described a technique involving a high medial opening osteotomy of the tibia associated with repair of the posterior root of the medial meniscus; however, they indicated that the repair of the tibial tunnel of the posterior root must be performed medially. Another difference from the technique described in our article is that the authors used a conventional Puddu plate (Arthrex) for osteotomy fixation, with the use of autologous bone graft from the iliac crest. The most modern guides created to perform root repair were developed to allow the guides to be positioned in the anatomic insertion of the anatomic root insertion. These guides provide the same placement when introduced through the medial or transpatellar portal. However, we believe that less acute positioning of the lateral transtibial tunnel can increase the chances of healing of the meniscal root inside the tunnel because, in this way, we avoid the killer angle of the meniscal root; thus, using the multi-use (MU) guide or anterior cruciate ligament tibial guides to create a lateral transtibial tunnel has several potential advantages.

There is no standard placement when creating the root tunnel associated with medial tibial opening osteotomy described in the literature. The direction, entry point, angulation, length, height, and distance from the anterior tuberosity of the tibia, whether lateral or medial, are important factors that contribute to a simpler and easier performance of the surgical procedure. The advantages and disadvantages of the described technique are presented in Table 2. We hope that our technique—posterior-medial meniscal root repair through the lateral tibial tunnel associated with medial opening osteotomy—can bring ease and intraoperative safety, as well as advantages and benefits in the postoperative period.

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