Technical Note

Treatment of Distal Patellar Tendon Chronic Rupture: The X-Wave Technique

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Abstract: Injuries to the patellar tendon (PT) are associated with knee function deterioration and loss of the capacity to perform daily and sports activities. Patellar tendon injury is often misdiagnosed at emergency rooms, leading to chronic proximal retraction and a challenging clinical scenario. Proximal PT injuries are more common, while distal ones, which can involve tibial bone avulsion fractures or direct tendon avulsion, are rarer. The low incidence of distal PT rupture and the variety of injury patterns make a personal approach reasonable when based on the intraoperative findings and the surgeon's experience. Our purpose is to describe a surgical technique to restore the knee extensor mechanism after chronic distal PT rupture using two kinds of graft, one as a waveform augmentation of the native tendon and the other as reinforcement in a letter X aspect.

Injuries to the patellar tendon (PT) most commonly occur in the patellar insertion, but also in the mid-substance, and more rarely in the PT's distal insertion.[1] They are associated with knee function deterioration and loss of the capacity to perform daily and sports activities. Therefore, PT disruption needs early surgical treatment to restore knee function.[2]

Chronic injuries to the extensor mechanism are complex to treat.[3] The proximal retraction of the quadriceps tendon makes the correct distal positioning of the patella difficult.[3-6] Patellar tendon injury is not an uncommon misdiagnosis at the emergency leading to chronic proximal retraction and, hence, to a challenging clinical scenario sometimes so intense that it may require gradual trans-osseous traction and a two-stage PT reconstruction.[4] Additionally, in the cases of chronic PT rupture, different techniques involving auto or allograft augmentation, reinforcement, and combination of other varying fixation devices were described aiming to appropriately correct the patella height and restore soft tissue integrity.[7-10]

The low incidence of distal PT rupture and the variety of injury patterns turns an individual approach based on the intraoperative findings and in the surgeon's experience, reasonable. Our purpose is to describe a surgical technique to restore the knee extensor mechanism after chronic distal soft-tissue PT avulsion, using two kinds of graft, one as a waveform augmentation of the native tendon and the other as reinforcement in letter X aspect.

Surgical Technique

With the patient in the supine position and under spinal anesthesia, a longitudinal incision is made from the middle central third of the patella to the anterior tibial tuberosity (ATT). After deep layer dissection, the peritendon is incised longitudinally to identify the patellar tendon (Fig 1A). This step is followed by lateral and medial patellar retinaculum opening and

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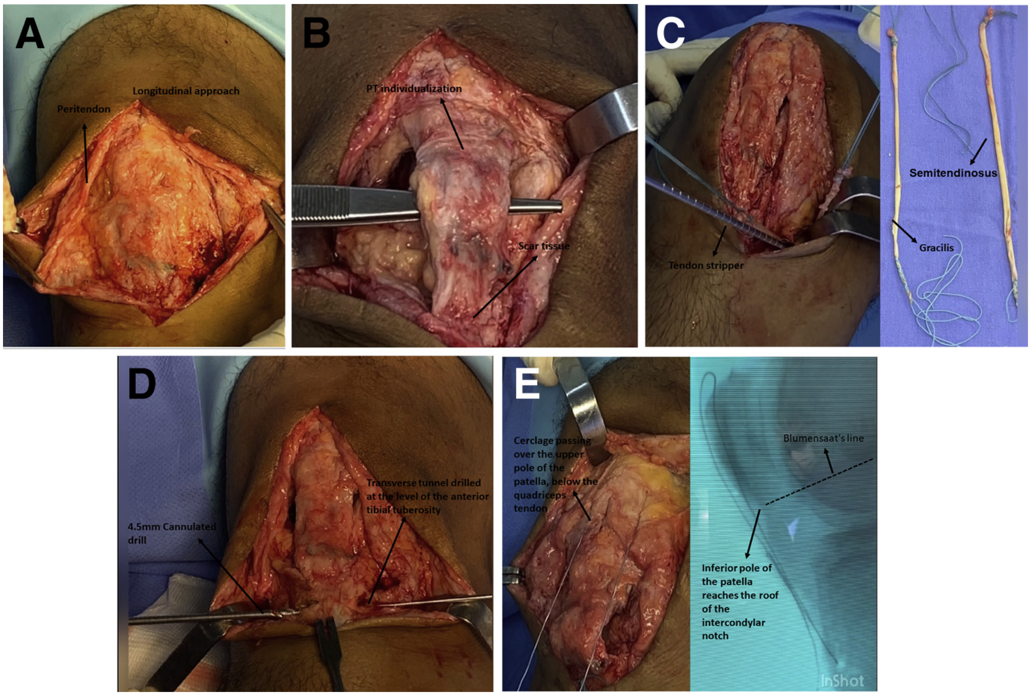

Fig 1. Identification of patellar tendon (PT) rupture, tunnel perforation, and X-shaped reinforcement. Direct view of the knee joint through the anterior longitudinal approach. (A) Longitudinal approach to the peritendon and visualization of the ruptured PT. (B) PT individualization with the medial and lateral retinaculum opening. Scar tissue at its tibial insertion can be visualized. (C) After harvesting, gracilis and semitendinosus tendons grafts are prepared with Ethibond (Ethicon, Somerville, NJ, USA) in its ends; (D) Guidewire drilling of a transverse tunnel with a 4.5-mm cannulated drill at the level of the anterior tibial tuberosity. (E) Cerclage with a 1-mm steel wire passing over the upper pole of the patella, below the quadriceps tendon and penetrating the newly made tibial tunnel. Tied with the knee at 30 degrees of flexion with fluoroscopy visualization until the inferior pole of the patella reaches the roof of the intercondylar notch (Blumensaat's line); (F) Perforation of another transverse tunnel, now in the lower pole of the patella, about 1.5 cm proximal to the distal pole, with a guidewire and a 4.5mm cannulated drill; (G) Passing the semitendinosus graft through the patellar tunnel and crossing it in an "X" shape under the patellar tendon; (H) With the aid of a needled guidewire, the graft traction threads penetrate the tibial tunnel in opposite directions; (I) Suture with simple knots of the free margins of the graft traction thread, ensuring a firm tie.

visualization of the lesion at the distal insertion of the patellar tendon in the ATT (Fig 1B).

The gracilis and semitendinosus tendon grafts are harvested with the aid of the tendon stripper, the remaining muscle is removed, and the grafts are sutured with Ethibond threads (Ethicon, Somerville, NJ, USA) using simple running stitches at the ends (Fig 1C). A guidewire is drilled transversely at the ATT level, approximately 1.5 cm deep and 2 cm long (Fig 1D). Next, a 4.5-mm drill is used to create a transverse tunnel, which will initially pass the 1.0-mm cerclage wire.

A cerclage is performed around the patella, with the steel wire being passed on supra-patellar and sub-quadricipital positions before being passed through the transverse tunnel created in the tibia (Fig 1E). The adjustment of the patellar height is made with the aid of fluoroscopy, with the knee flexed at 30°. The patella is pulled distally to the ideal height, where the lower pole is at the level of the femoral intercondylar roof.

After a guidewire is drilled transversely, 1.5 cm proximal to the distal pole of the patella, a bone tunnel is performed with a 4.5-mm drill (Fig 1F). The semitendinosus graft is then passed through the hole created in the patella and divided into two legs of equal size and then taken distally, crossing in an "X" fashion just below the patellar tendon (Fig 1G).

With the aid of a needled guidewire, the semitendinosus graft traction threads penetrate in opposite directions into the transverse tunnel created in the tibia (Fig 1H). After the traction threads are passed through the tibial orifice, the "X" figure of the semitendinosus graft can be observed. A single-knot suture of the free margins of the graft traction threads is performed to ensure tight and firm bonding to the bone (Fig 1I).

In the next step, a 4.5-mm metallic anchor (Johnson & Johnson, New Brunswick, NJ, USA) is inserted centrally in the inferior pole of the patella (Fig 2A) using fluoroscopic control, which is necessary for ideal anchor placement. Each anchor has two suture threads (Fig 2B).

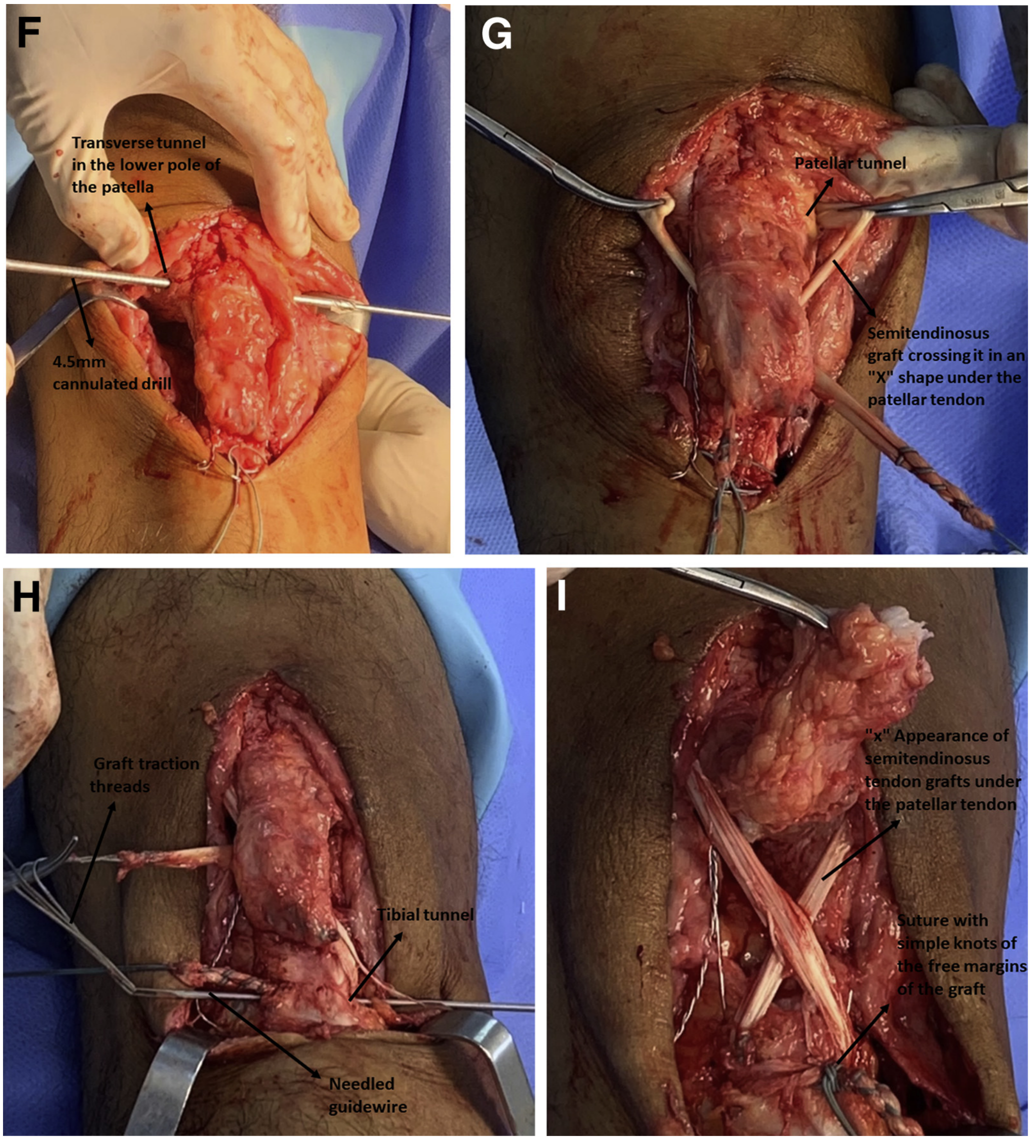

Fig 1. (*continued*).

The gracilis graft is fixed to the patella with one of the patellar anchor threads, and so it must be divided into two halves of equal size, tied with a simple knot (Fig 2C). Next three incisions are made in the remaining patellar tendon with a #11 scalpel blade, wide enough for the passage of the gracilis graft (Fig 2D). The first incision should be made just at the bottom, and the others should be spaced approximately 1.5 cm apart. With the aid of a Kelly forceps, the gracilis graft is pulled through the first proximal orifice (Fig 2E), where it shifts from the posterior region of the remaining patellar tendon, assuming an anterior position. The gracilis graft is then guided through the other two equidistant orifices in sequence. It passes from anterior to posterior in the second (Fig 2F) and from posterior to anterior in the third (and most distal) (Fig 2G). Note that the graft should be just placed on the tendon and will form the appearance of a "wave" in the lateral view (Fig 2H).

The next step is to perform multiple perforations with a 2.0-mm drill below the transverse tunnel created in the tibia, to open a bleeding bed 3-mm deep that will receive the patellar tendon distally (Fig 2I). In the bleeding site, a 4.5-mm anchor (Johnson & Johnson, New Brunswick, NJ, USA) is positioned approximately 1.5 cm distal to the transverse tibial tunnel (Fig 3A), with the aid of fluoroscopy to ensure the correct placement of the tibial anchor (Fig 3B).

With one of the remaining suture threads of the patellar anchor attached to a needle, the

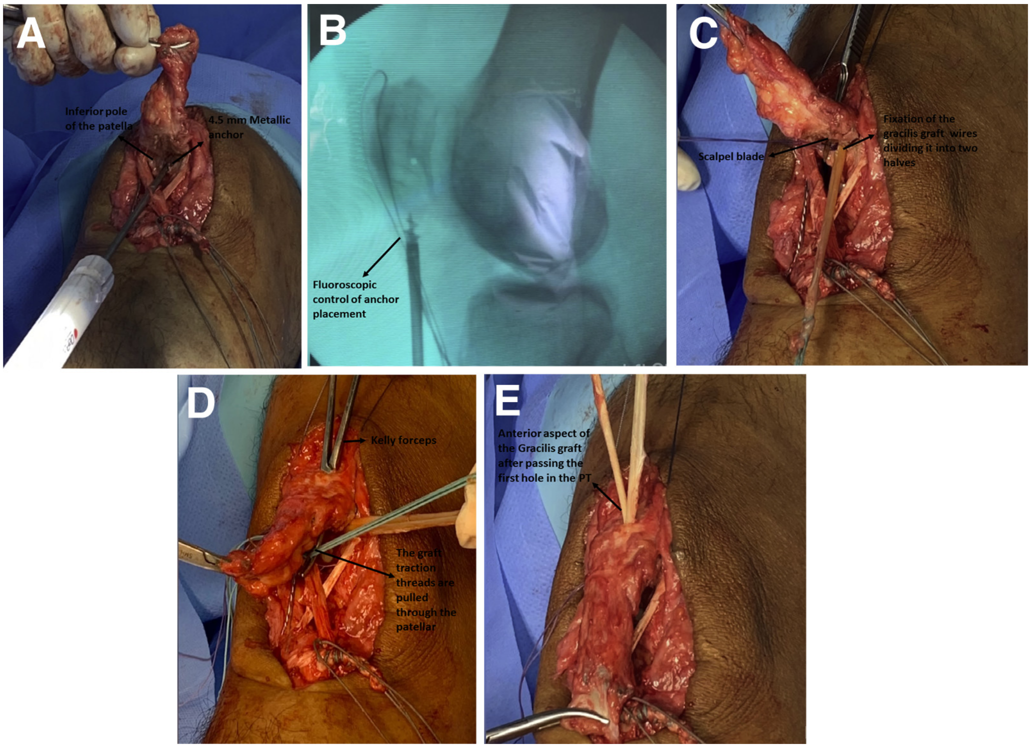

Fig 2. Patellar tendon augmentation: direct view of the knee joint through the anterior longitudinal approach. (A) Placement of a 4.5-mm metallic anchor (Johnson & Johnson, New Brunswick, NJ, USA) on the inferior pole of the patella, very central about the mediolateral plane. (B) Fluoroscopic control of anchor placement. (C) Fixation of the gracilis graft with one of the anchor wires dividing it into two halves. (D) Graft traction threads pulled through the patellar tendon with the help of a Kelly forceps, bringing the graft over the tendon close to the inferior pole of the patella. (F) The graft then perforating the tendon towards its lower surface, 1.5 cm distal to the first pass. (G) The graft brought back to the top of the tendon, 1.5 cm distal to the second pass. (H) A 2.5-mm drill used to open a bone bed just below the tunnel of the tibial tuberosity.

semitendinosus graft is sutured together with the lateral edge of the patellar tendon from proximal to distal (Fig 3C). The same step is performed with the medial borders of both the patellar tendon and the semitendinosus graft, using the other leg of the patellar anchor thread (Fig 3D).

Distal fixation of the gracilis graft has now occurred. With one of the tibial anchor threads, a Krackow-type suture is performed on both free legs of the graft so that the graft is tensioned and fixed tightly to the tibial anchor (Fig 3, E and F). With the second remaining thread of the tibial anchor, the distal part of the native patellar tendon is reinserted into the tibia (Fig 3G). Finally, the lateral and medial patellar retinaculum is sutured with the rest of the tibial anchor threads, from distal to proximal (Fig 3, H and I).

Changes in the physiological/ anatomical patterns of the knee can be observed, with the patella displaced proximally on the preoperative radiograph in lateral view and with loss of patellar tendon integrity in the sagittal view of the magnetic resonance images (Fig 4, A and B). Postoperatively, the patella returns to its physiological height about the patellar trochlea, as seen in the lateral radiographic view (Fig 4C). The entire surgical procedure can be viewed in the attached Video 1.

Rehabilitation

Early mobilization is allowed on the first postoperative day, with a range of motion according to the patient's tolerance. Exercises are guided for isometric activation of the quadriceps and active mobilization of the ankles. Loading is allowed with the aid of crutches and an immobilizer with the knee extended during gait.

Discussion

Chronic PT rupture is commonly seen after primary repair failure, or in cases of misdiagnosis at primary care assessment. It can be approached with augmentation plus reinforcement graft techniques using ipsilateral autologous hamstring tendons, allografts, and contralateral bone-patellar tendon-bone graft.[11]

Suture tape augmentation has gained popularity for knee ligament reconstruction, and it represents an option for patients with chronic or recurrent PT rupture.[12,13] It aims to permit early mobilization, thus

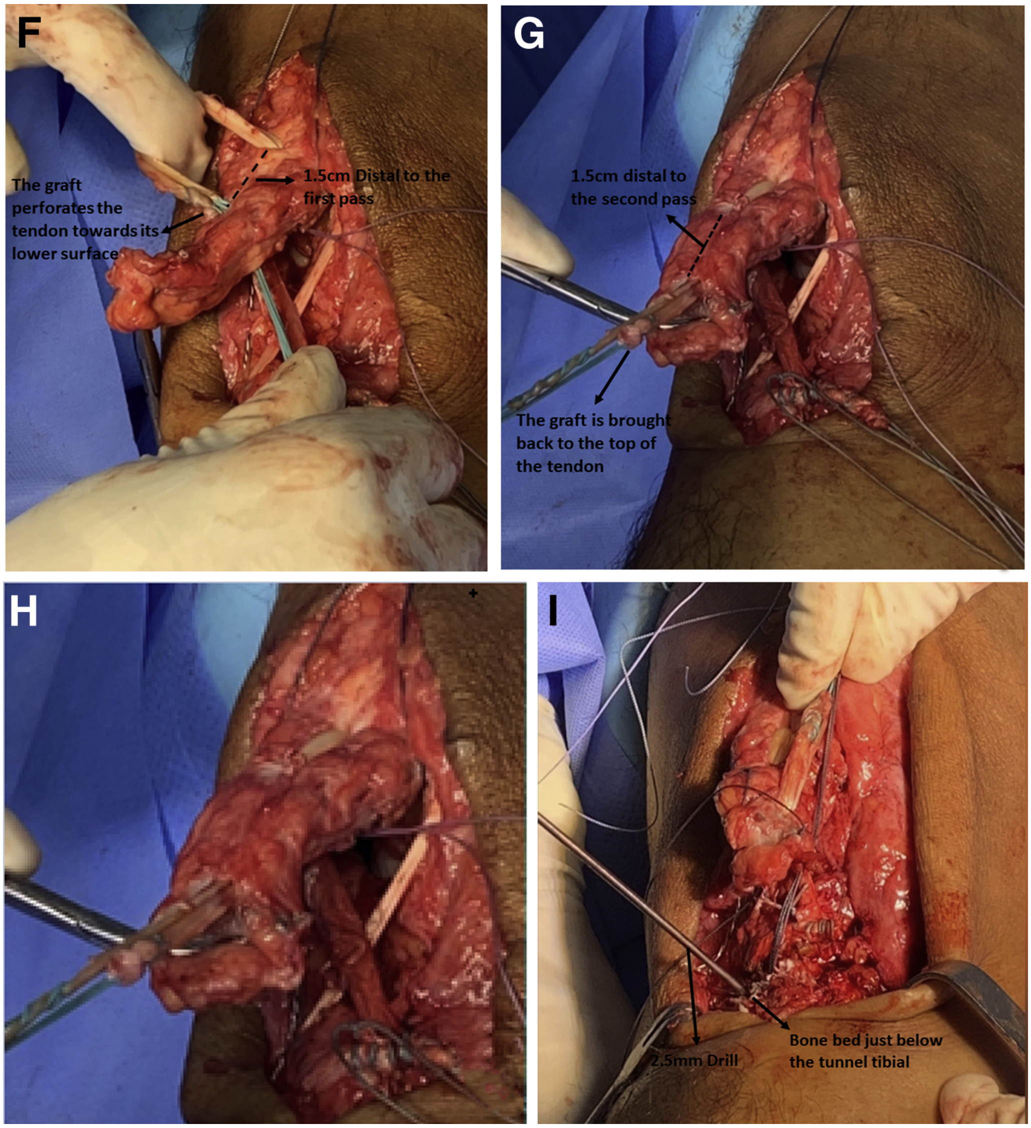

Fig 2. (*continued*).

preventing knee stiffness and quadriceps muscle atrophy (the same objective as the reinforcement techniques with biological grafts).[14]

Our group recently reported a two-stage PT reconstruction. (The ideal patella height had not been reached after manual patella traction with the patient under anesthesia.) Attention was drawn to the need to restore the correct patellar height, with its lower pole being at the level of the roof of the intercondylar notch, to properly restore the function of the knee extensor mechanism.[4]

In distal PT rupture cases, the tendon fixation to the bone at the tibial tubercle represents a substantial technical challenge. Adjustable suspensory fixation in the patella and tendon augmentation in the hamstrings were reported as giving a stable fixation for patients with chronic proximal patellar avulsion. The adjustable mechanism allows gradual graft tension, thus allowing intraoperative correction of patella height. In reinforcement and augmentation techniques, transtibial bone tunnels are usually used for distal graft fixation.[15]

In the technique reported in this paper, we seek to increase the potential for ligamentization of the gracilis graft by transversing the remaining patellar tendon like a wave, creating a primary repair of the injured tissue. We added the X-shaped reinforcement with the semitendinosus graft to protect this repair and, as regards anatomy and biology, it ends up becoming a reinforcement that would serve as a backup if the first procedure failed, hence allowing early postoperative range of motion and decreasing the chance of failure.

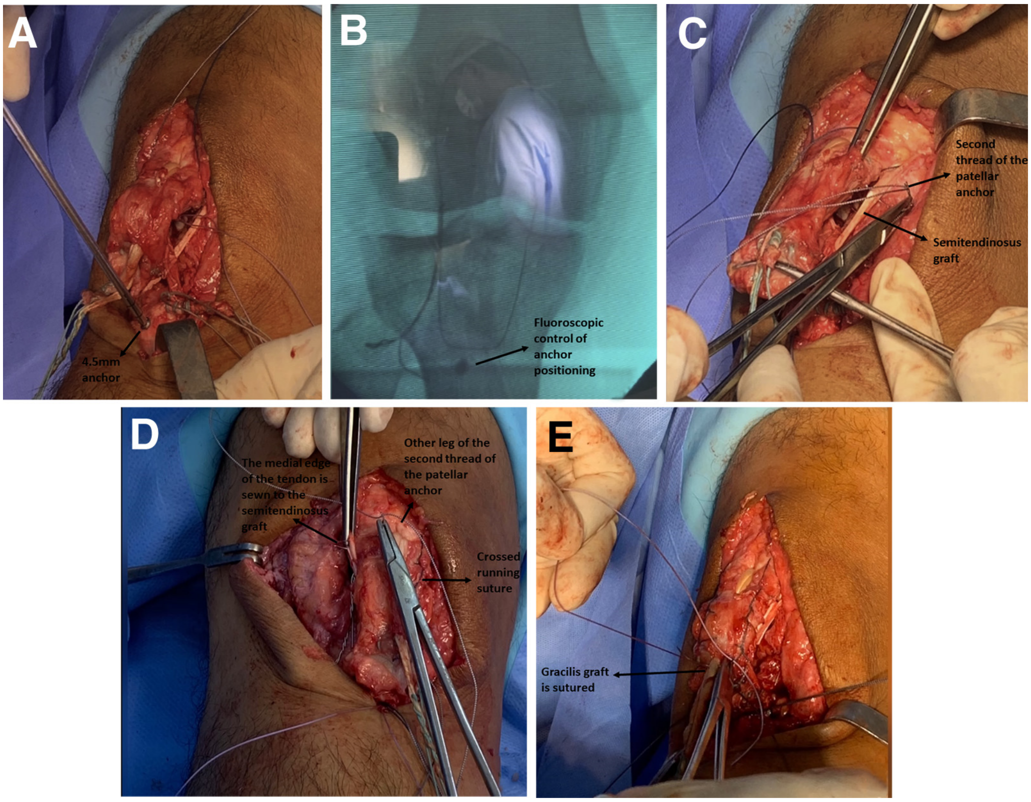

Fig 3. Patellar tendon primary repair. Direct view of the knee joint through the anterior longitudinal approach. (A) Placement of a 4.5-mm anchor (Johnson & Johnson, New Brunswick, NJ, USA) 1 cm distal to the transverse tibial tunnel, in the area previously open. (B) Fluoroscopic control of anchor positioning in anteroposterior view. (C) With one of the legs of the second thread of the patellar anchor, the lateral edge of the patellar tendon is sewn together with the semitendinosus graft using a crossed running suture. (D) The other leg of the second thread of the patellar anchor where the medial edge of the tendon is sewn to the semitendinosus graft with a crossed running suture. (E, F) One of the tibial anchors is threaded to the distal part of the gracilis graft, the graft is sutured to the anchor with Krackow stitches. (G, H) The second thread of the tibial anchor the medial and lateral retinaculum will be sewn to the medial and lateral edge of the patellar tendon with a crossed overlay suture. (I) Final aspect of repair.

We used the cerclage wire temporarily, thus ensuring the correct patellar height and freeing us throughout the surgery from the influence of flexion and extension maneuvers that could allow inadequate tensioning of the grafts. As the technique described provides double fixation, we believe it is unnecessary to keep it at the end of the surgery.

Our group reported a reproductive and low-cost reconstruction technique addressing distal patellar tendon rupture with associated soft tissue deficiency. Patients should be advised about side effects related to semitendinosus harvest graft. Alternatively, a similar reconstruction using allograft semitendinosus tissue can be performed.

We highlight the advantage of reconstructing the lost anatomy while preserving the remaining diseased tissue that is still viable, increasing the chance of healing and maintaining the anatomical patterns of healthy tissue. As we use autologous tendons in trans-osseous passages, we dispense with the use of synthetic augmentation and other fixation devices, in addition to the two metallic anchors and suture threads. Reconstruction also has the advantage of allowing early mobilization in a very safe way, thus eliminating the need for reinforcing steel wires, which usually require a second surgical procedure for their removal.

Compared to techniques that use synthetic reinforcement or isolated primary repairs, the method requires a longer surgical time to remove the tendon grafts and perforate the bone tunnels. Its advantages and disadvantages are summarized in Table 1. Care must be taken in the construction of these bone tunnels, especially regarding the depth of the perforation in reaction to the anterior, posterior, and inferior cortices of the patella and the anterior cortical of the tibia, to minimize the risk of an avulsion fracture by traction of the graft itself; hence, fluoroscopic control is critical. Care must also be taken to ensure that the reconstruction brings the patella to its average height. Before fixing the tendons, we use the temporary cerclage wire

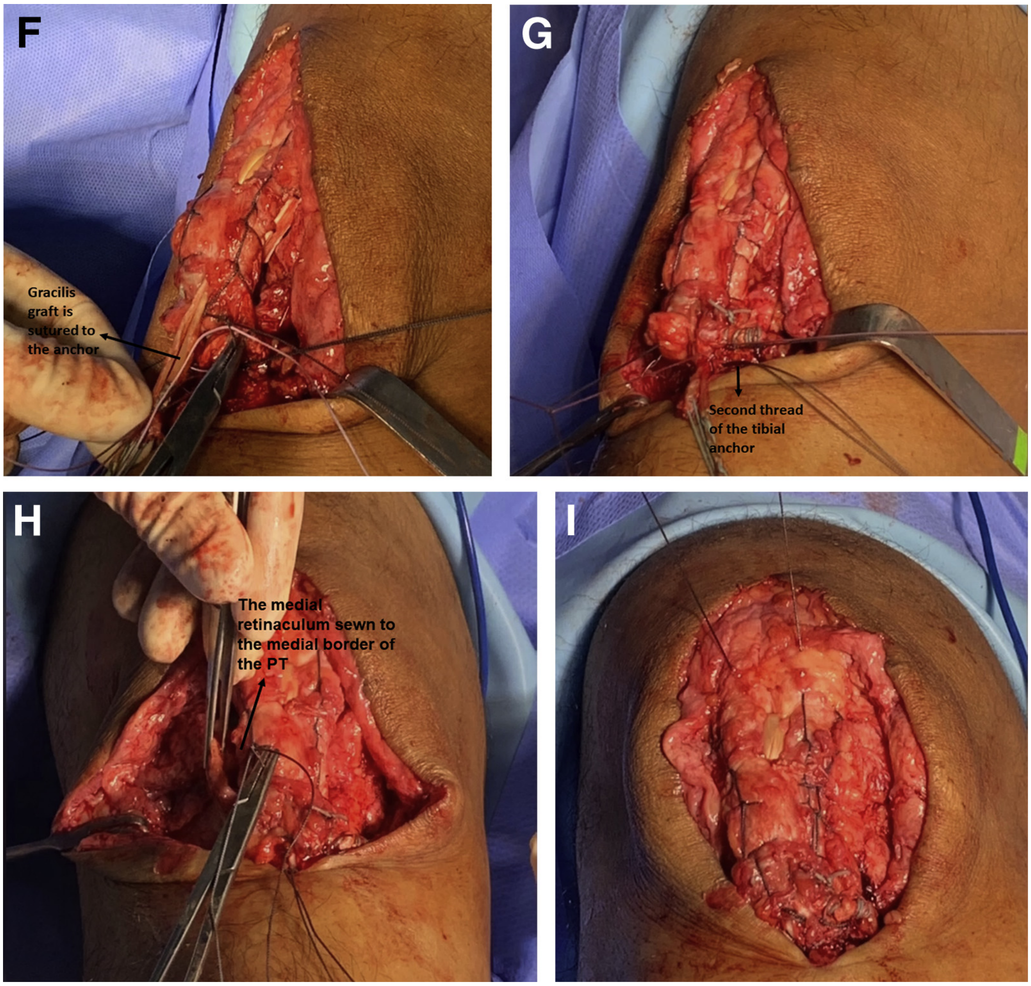

Fig 3. (*continued*).

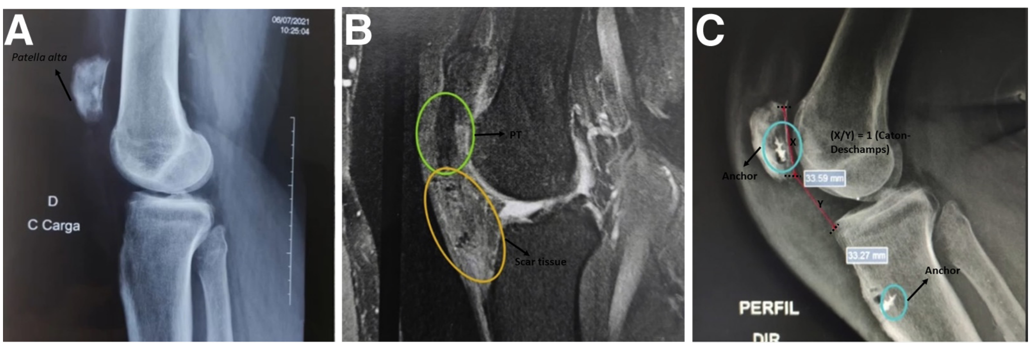

Fig 4. Pre and post-operative imaging of the knee. (A) Sagittal radiograph view showing *patella alta* due to patellar tendon (PT) injury. (B) Magnetic resonance imaging of sagittal section on T2 showing proximal retraction of the patella and remaining PT, along with injury at the level of the distal insertion: PT (*green*), scar tissue (*yellow*). (C) Sagittal radiograph view showing standard patellar height, where patellar height (X/Y) = 1 (Caton-Deschamps). Anteroposterior radiograph shows anchors' fixation on patella and tibia.

Table 1. Advantages and Disadvantages

Advantages	Disadvantages
Costs are low	Longer surgical time
Repair is biological	Morbidity in the graft donor area
Metallic cerclage requires no maintenance	
Allows early mobilization	
Ensures adequate patellar height	
Requires no synthetic augmentation	

Table 2. Pitfalls

Risk of patellar fracture
Risk of avulsion fracture at the level of the anterior cortex of the tibia

at the beginning of the procedure, the pitfalls of which are summarized in Table 2.

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