Technical Note

Quadriceps Tendon-Bone Full-Thickness Autograft: Reproducible and Easy Harvesting Technique Using Simple Surgical Tools

Konrad Malinowski, M.D., Ph.D., Jan Paszkowski, M.D., Marcin Mostowy, M.S. (medical student), Adrian Góralczyk, M.D., Robert F. LaPrade, M.D., Ph.D., and Krzysztof Hermanowicz, M.D., Ph.D.

Abstract: Autogenous quadriceps tendon-bone graft is a great choice for knee reconstruction procedures, including primary and revision reconstructions of both anterior cruciate ligament (ACL) and posterior cruciate ligament. In primary ACL reconstruction, one of the most frequently performed procedures in orthopaedic surgery, it is gaining more and more popularity owing to improved or similar biomechanical, anatomic, and histological properties than bone-patellar tendon-bone graft. The clinical outcomes of quadriceps tendon-bone graft in ACL reconstruction are similar to bone-patellar tendon-bone graft, however, lowering the inconvenience associated with donor-site morbidity and making it possible to adjust graft length and diameter. This Technical Note describes a surgical technique for harvesting a full-thickness quadriceps tendon graft with a bone block using simple surgical tools.

Although the quadriceps tendon-bone (QTB) graft was first described in 1979 by Marshall et al.,[1] it has only recently been gaining popularity. A difficult harvesting technique and extended time of the surgery caused it to be rarely used. QTB is a universal graft that can be used in primary and revision reconstructions of anterior cruciate ligament (ACL), as well as posterior cruciate ligament (PCL).[2] The length and diameter of the graft can be properly adjusted to the patient's needs and the type of planned surgery. Histologically, it has 20% more collagen fibers than a patellar tendon graft with the same cross-section. What is more, the QTB graft cross-section is almost twice as large as a bone-patellar tendon-bone (BPTB) graft, and the tensile strength and stretch are also higher in the group with QTB than in BPTB graft.[3] A QTB retains all the positive features of a bone block graft regarding bone-to-bone healing and decreases the inconveniences associated with collection sites and the nonadjustable length of a BPTB graft, forced by the individual's anatomy.

From the Artromedical Orthopaedic Clinic, Belchatow, Poland (K.M., J.P.); Orthopedic and Trauma Department, Veteran's Memorial Teaching Hospital in Lodz, Medical University of Lodz, Lodz, Poland (M.M.); ORTIM Orthopaedic Clinic, Bialystok, Poland (A.G., K.H.); and Twin Cities Orthopedics, Edina, Minnesota, U.S.A. (R.F.L.).

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Address correspondence to Konrad Malinowski, M.D., Ph.D., Artromedical Orthopaedic Clinic, Chrobrego 24, 97-400 Belchatow, Poland. E-mail: malwin8@wp.pl

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Technique

Indications

Primary and revision reconstruction of the ACL and PCL.

Contraindications

Previous history of tendinopathy or rupture of the distal quadriceps tendon.

Patient Positioning

The surgery is performed after induction of general or regional anesthesia. The patient is positioned supine. The operative leg is placed in a leg holder and then prepared and draped in a sterile fashion. A nonsterile high thigh tourniquet is used during graft harvesting.

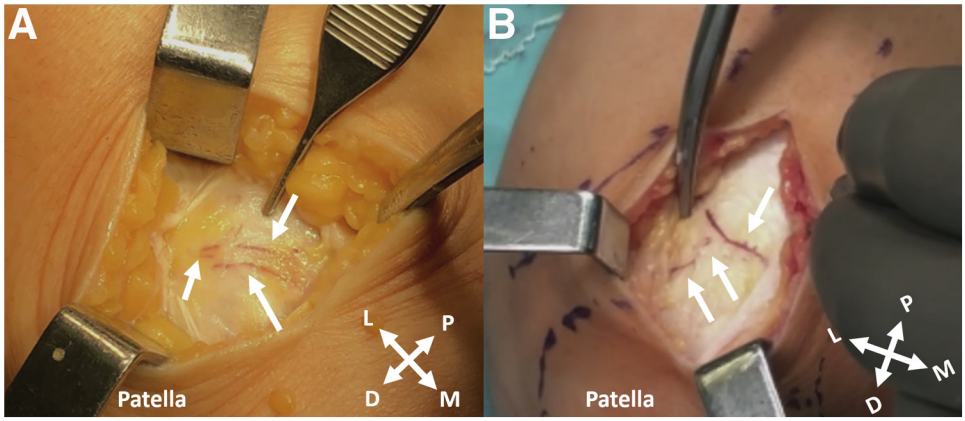

Fig 1. Visualization of 3 blood vessels perpendicular to the patellar base. (A,B) Patients are laying in supine position, suprapatellar regions are shown. Right knees are being operated on in 90° of knee flexion. To harvest quadriceps tendon-bone full-thickness autograft, 4- to 5-cm incision is made in the sagittal plane perpendicular to the superior pole of the patella, starting 4 to 5 cm proximal to the patella and directing distally up to 0.5 to 1 cm over the patellar dorsal surface. Visualization of 3 blood vessels running transversely to the cut plane just proximal to the patellar base means that we are in the right tissue layer for graft harvesting (arrows, 3 blood vessels perpendicular to the patellar base as an indicator of proper layer to start harvesting; D, distal; L, lateral; M, medial; P, proximal.)

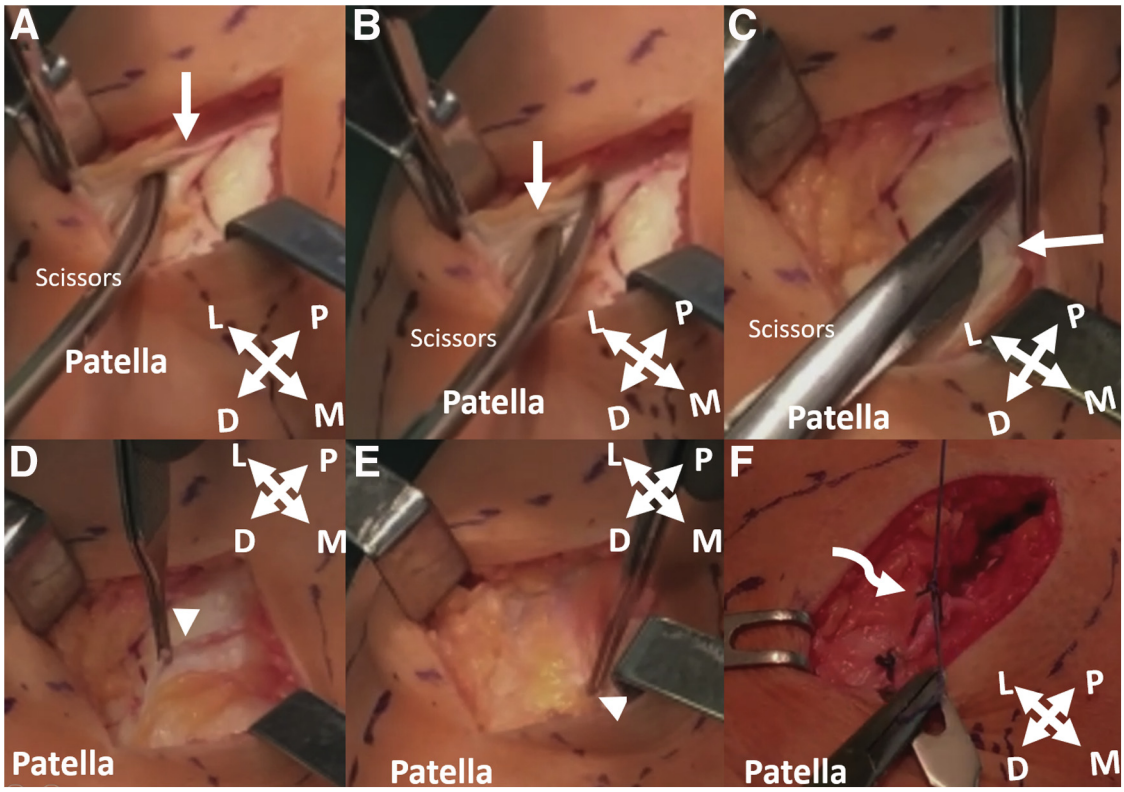

Fig 2. Paratenon mobilization and suturing. Patient is laying in supine position; right knees are being operated on in 90° of knee flexion. Suprapatellar region after incision perpendicular to the patellar base is visible. Mobilization and postharvesting suturing of paratenon covering the quadriceps tendon is shown. (A-C) Paratenon is mobilized with scissors; (D,E) it can be seen that paratenon is mobilized enough to cover the gap that will be created during harvesting the graft; (F) suturing the paratenon (straight arrows, paratenon during mobilization; arrowheads, mobilized paratenon grasped with tweezers; curved arrow, paratenon sutured after graft harvesting is finished; D-distal; L-lateral; M-medial; P-proximal.)

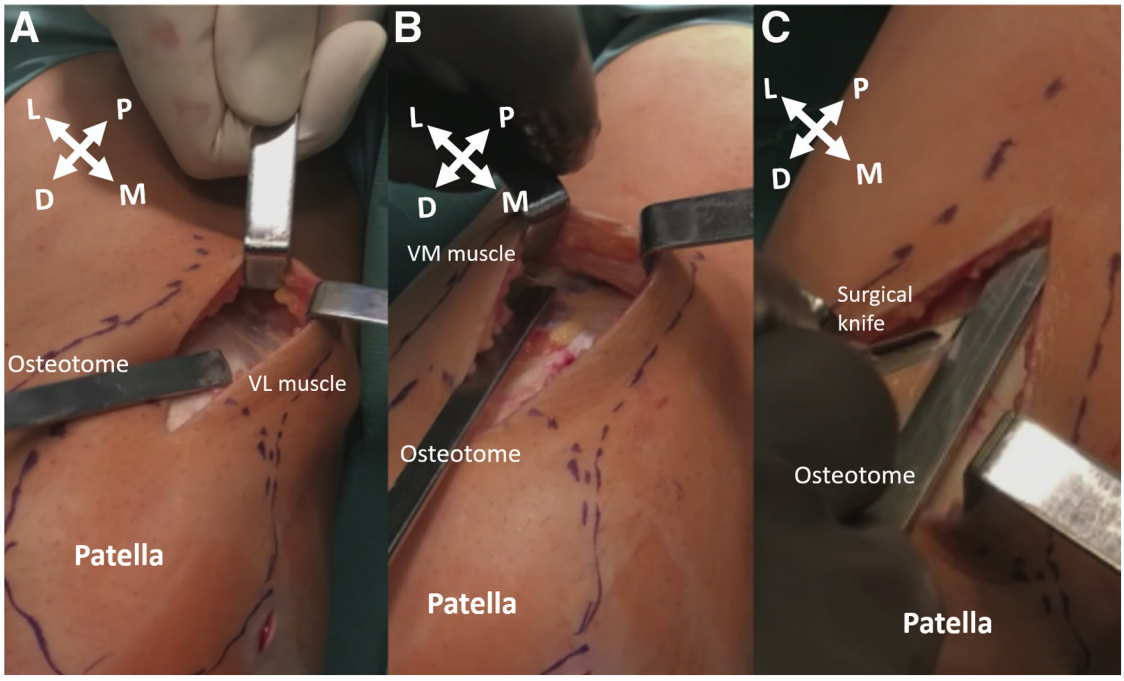

Fig 3. Using the osteotome as a guide on how to plan cuts to harvest quadriceps tendon. Patient is laying in supine position; right knees are being operated on in 90° of knee flexion. Suprapatellar region after incision perpendicular to the patellar base is visible. It is shown how to use the osteotome as a guide during harvesting quadriceps tendon-bone full-thickness autograft. (A) Visualize the vastus lateralis muscle belly; (B) visualize the vastus medialis muscle belly; (C) localize the medial border of the osteotome as close as possible to the vastus medialis muscle belly but leave approximately 3 to 4 mm of the "white" part of the tendon. This way, the osteotome will cover its thickest part (*D, distal; L, lateral; M, medial; P, proximal; VL, vastus lateralis; VM, vastus medialis.)*

Technique to Harvest Quadriceps Tendon Graft with Patellar Bone Block

A marking pen (Johnson & Johnson, New Brunswick, NJ) is used to mark the patella, vastus medialis, and vastus lateralis muscle bellies. Then, a 4- to 5-cm incision is made in the sagittal plane perpendicular to the superior pole of the patella, starting 4 to 5 cm proximal to the patella and directing distally up to 0.5 to 1 cm over the patellar dorsal

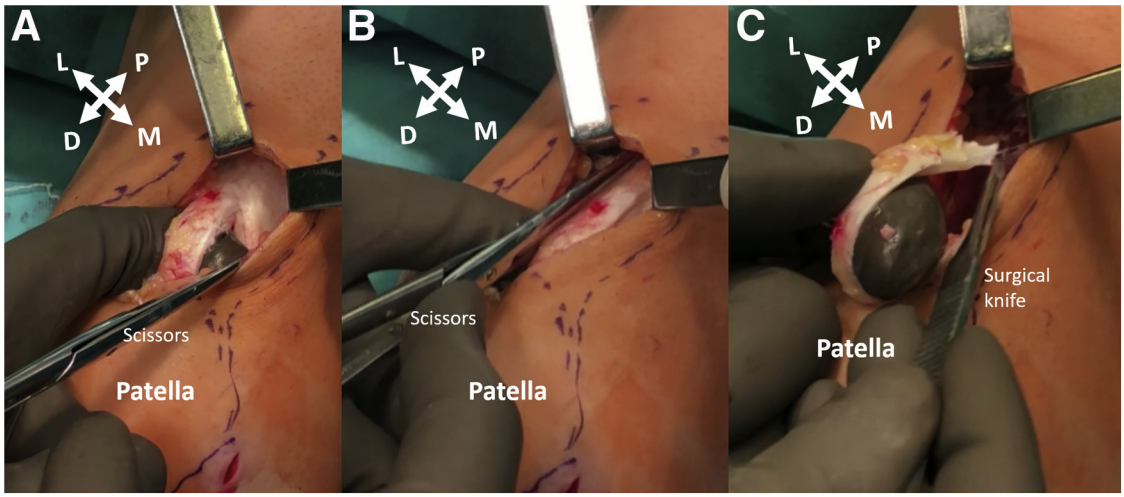

Fig 4. Tensioning the graft and performing final cuts. Patient is laying in supine position; right knees are being operated on in 90° of knee flexion. Suprapatellar region after incision perpendicular to the patellar base is visible. Tensioning the graft with the finger and performing final cuts are presented. (A) Surgeon's index finger is placed under the graft to verify that the graft has been sufficiently released; (B) while tensioning the graft, all the layers of the tendon are incised proximally with a straight scissors to a length of approximately 8 cm proximal to the patella; (C) the proximal aspect of the graft is pulled out of the wound with the index finger and cut with a knife transversely, 7 to 9 cm proximal to the superior pole of the patella (*D, distal; L, lateral; M, medial; P, proximal.*)

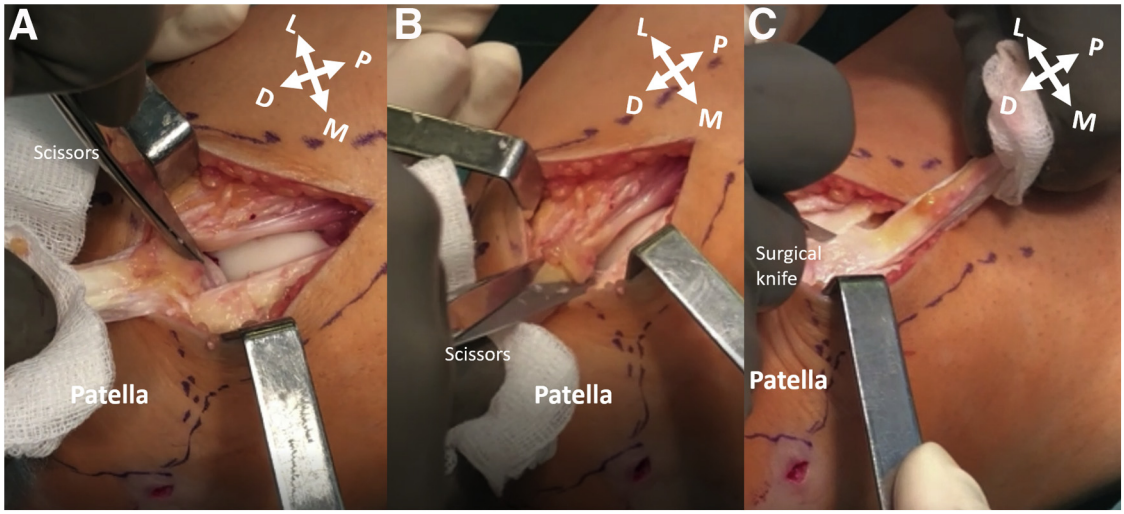

Fig 5. Attachment of the quadriceps tendon to the patella and suprapatellar fat pad. Patient is laying in supine position; right knees are being operated on in 90° of knee flexion. Suprapatellar region after incision perpendicular to the patellar base is visible. (A) The location of the attachment of the quadriceps tendon to the patella is shown, and the edge of the cartilage is shown with scissors; (B) the suprapatellar fat pad is gently cut away from the quadriceps tendon so as not to damage the graft; (C) the site of planned patellar bone plug harvest is marked with a knife, 15 to 18 mm distal to the quadriceps tendon attachment (*D, distal; L, lateral; M, medial; P, proximal.*)

surface. The subcutaneous tissues and the oblique fascia covering the quadriceps tendon is transected. Visualization of 3 blood vessels running transversely to the graft incision plane, just proximal to the patella, means that one is in the correct tissue layer for graft harvesting (Fig 1, Video 1). The paratenon over the quadriceps tendon is mobilized medially and laterally to suture its ends over the gap after harvesting the tendon (Fig 2, Video 1). The quadriceps tendon, vastus medialis, and vastus lateralis muscle bellies are visualized. Then, an 8-mm wide osteotome (Arestomed, Opole, Poland) is applied in the middle and perpendicular to the patella base, with the sharp end pointing proximal so that it anchors in soft tissues and does not move. The medial border of the osteotome has to be positioned as close as possible to the vastus medialis muscle belly and leaving approximately 3 to 4 mm of the "white" part of the tendon intact (Fig 3, Video 1). This way, the osteotome will cover the thickest part of the quadriceps tendon.[4] After proper position of the osteotome is achieved, it is used as a guide, and with a No. 15 knife blade (Swann-Morton, Sheffield, UK) all layers of the aponeurosis are incised along its fibers up to approximately 4 to 5 cm proximal to the patella. We then incise alongside both borders of the guide, ensuring that the knife blade is perpendicular to the quadriceps tendon throughout the entire cut (Fig 3, Video 1). Then, the osteotome is removed, and the final cut of the quadriceps tendon from both sides is performed. It should be possible to position an index finger under the graft to verify that the graft has been sufficiently released. In the next step, graft is tensioned using the surgeon's finger, and all the layers of the tendon are incised proximally with straight scissors (Praxies Dienst, Longuich, Germany) to a length of approximately 8 cm proximal to the patella. The proximal aspect of the graft is pulled out of the wound with the index finger and cut with a knife transversely, 7 to 9 cm proximal to the superior pole of the patella (Fig 4, Video 1). Usually a fragment of the vastus medialis muscle belly is visible from below the margin of the harvested quadriceps tendon. In Figure 5, the location of the

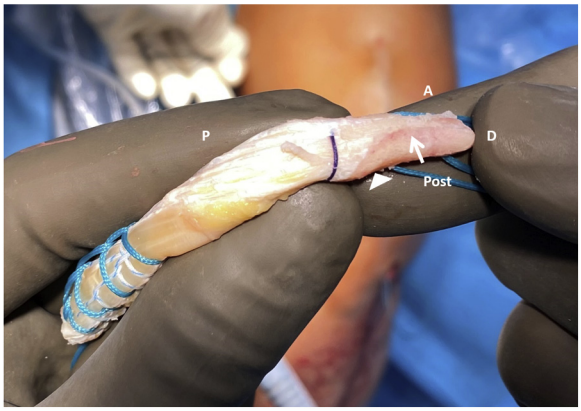

Fig 6. Attachment of quadriceps tendon to the patella. Quadriceps full-thickness tendon-bone autograft has been harvested and prepared with sutures. Morphology of attachment of quadriceps tendon to the patella is shown. Notice that the attachment is oblique in its shape. Directions were marked as if the patella was localized in anatomic position, with the following abbreviations: A, anterior; P, proximal; D, distal; Post, posterior. Anterior fibers attach more distally (arrow), whereas posterior fibers are attached more proximally (triangle).

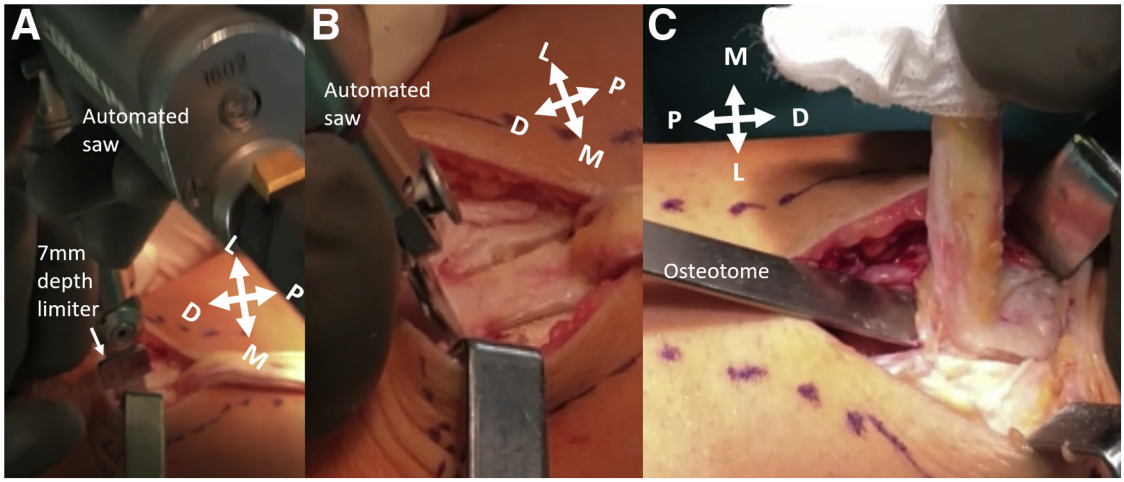

Fig 7. Using an automated saw and the osteotome to cut the bone plug from the superior pole of the patella. Patient is laying in supine position; right knees are being operated on in 90° of knee flexion. Suprapatellar region after incision perpendicular to the patellar base is visible. (A) Automated saw with 7-mm depth limiters is used to cut the superior pole of the patella sagittally within markings performed with the knife; (B) automated saw with 7-mm depth limiters is used to cut the superior pole of the patella transversely at the distal end of sagittal cuts; (C) osteotome is applied to the place previously marked with a knife on the base of the patella just below tendon attachment. It has to be positioned parallel to the dorsal patella surface (*D, distal; L, lateral; M, medial; P, proximal.*)

attachment of the quadriceps tendon to the patella is shown. The suprapatellar fat pad is gently cut away from the quadriceps tendon so as not to damage the graft and laid over the created gap to enhance gap closure. Then, the site of planned patellar bone plug harvest is marked with a knife. The desired length of harvested bone block is 20 mm, however, 15 to 18 mm are marked because attachment of the quadriceps tendon to the patella is oblique in its shape (Fig 5, Video 1). The anterior fibers attach more distally, whereas posterior fibers attach more proximally (Fig 6, Video 1).

Then an automated saw, PRO 2043, with blade No. C8804 (Conmed Linvatec Polska, Warsaw, Poland) with a 7-mm depth limiter is used to cut the patella sagittally on both sides and transversely 15 to 18 mm distal from the superior pole of the patella. Afterward, the osteotome is applied to the place previously marked with a knife on the base of the patella just below tendon

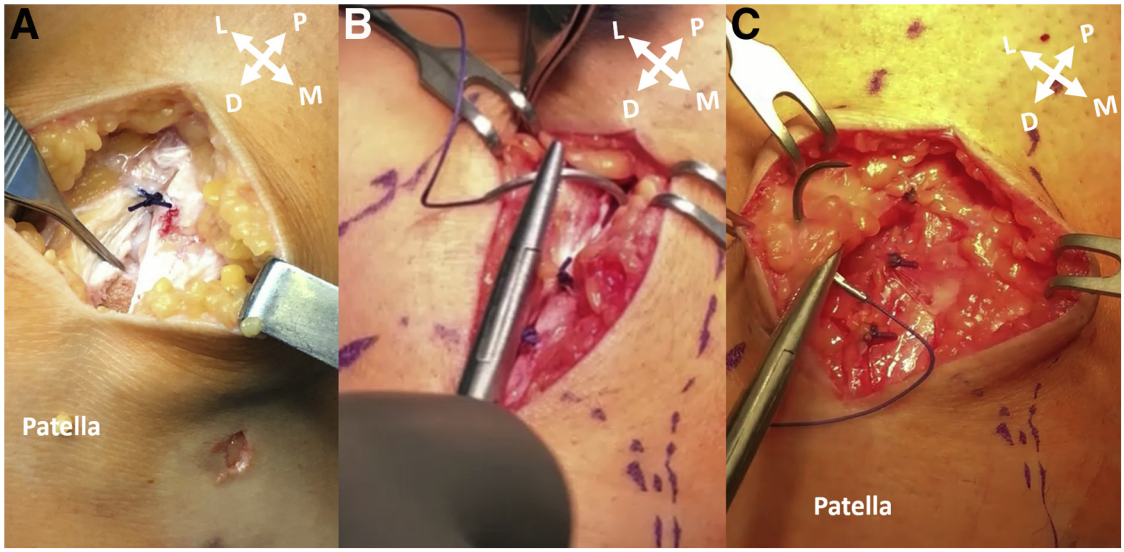

Fig 8. Suturing quadriceps tendon, paratenon, and subcutaneous tissue. Patient is laying in supine position; right knees are being operated on in 90° of knee flexion. Suprapatellar region after incision perpendicular to the patellar base is visible. (A) The first suture within quadriceps tendon is placed 15 to 20 mm proximal from the patella base to avoid excessive tension; (B) 4 to 6 absorbable sutures are placed within quadriceps tendon; (C) suturing paratenon and subcutaneous tissue (*D, distal; L, lateral; M, medial; P, proximal.*)

Table 1. Tips and Pearls of Quadriceps Tendon-Bone Full-Thickness Autograft Harvesting Technique

1) Identify the proper tissue layer using as reference point, 3 blood vessels running transversely to the cut plane just proximal to the patellar base. Leave paratenon and suprapatellar fat pad for later meticulous suturing.
2) During guiding where to cut the quadriceps tendon, the medial border of the osteotome has to be localized as close as possible to the vastus medialis muscle belly but leave approximately 3 to 4 mm of the "white" part of the tendon. This way, the osteotome will cover its thickest part.
3) When cutting the quadriceps tendon and patella, cuts need to be perpendicular to the patellar surface. Because of this, the bone-tendon junction will not be weakened, and equal diameter on all of the graft's length will be achieved.
4) Harvest full-thickness tendon. Because of the oblique shape of tendon attachment, partial-thickness harvesting may substantially weaken the bone-tendon junction, weakening the whole graft strength.
5) To avoid patellar fracture, use a 7-mm limiter on the saw. Mark the place of planned patella osteotomy with a knife so that the osteotome will not slide off the bone. Use the osteotome only to finish the patellar osteotomy, directing it from the proximal part of the patella and holding it parallel to the anterior surface of the patella.
6) Meticulous layer-by-layer suturing. As to the tendon itself, suture it to avoid penetration of intra-articular hemorrhage, but remember to lay the first suture approximately 15 to 20 mm proximally from the patellar base to avoid excessive tension.
7) In patients with short thigh, the tourniquet has to be placed as high as possible. Nevertheless, if there is not much space between the knee and the tourniquet, extra attention has to be held to set the osteotome parallel to the frontal patella surface when finishing osteotomy.

attachment. After verifying that the osteotome is positioned parallel to the dorsal patella surface, it is impacted with 2 or 3 taps to gently dislodge the bone block (Fig 7, Video 1). The next step is to sew the quadriceps tendon margins after graft harvesting. The first layer to suture is the tendon. We initially sew approximately 15 to 20 mm proximal from the patella base and put on 4 to 6 absorbable stitches (Vicryl 1; Ethicon, Somerville, NJ). Then, the paratenon and subcutaneous tissues are sutured with Vicryl 1 and 0, and skin is sutured with Ethilon (Ethicon) (Fig 8, Video 1).

The bone block is drilled in 2 places, 5 and 10 mm from the bone-tendon junction, and Ethibond 5 (Ethicon) sutures are passed through the drill holes. The soft end of the graft is sutured twice with Maxbride 2 (Zimmer Biomet Polska, Warsaw, Poland) sutures, using a Krakow suture technique. Tips and pearls for performing this technique were summarized in the Table 1.

Discussion

This article presents an effective and reproducible technique for harvesting a full-thickness autogenous quadriceps tendon graft with bone block. The most common application is for a primary ACL reconstruction, but it can also be effectively used in revision ACL and primary and revision PCL reconstructions. This technique allows to obtain a reproducible graft length of 70 to 95 mm, with additional 20-mm bone block and diameter 9 to 9.5 mm along its length. Because of this adjustability, one can choose the appropriate graft length for a given patient. In the BPTB, recognized as the gold standard, a discrepancy between bone blocks of the graft and bone tunnels (graft-tunnel mismatch) can occur, causing technical difficulties. For example, if the tendinous part of the BPTB graft is too long, then after stabilization of one bone block in the femoral tunnel, the other bone block extrudes outside from the tibial tunnel.[5,6]

After preparing the QTB graft, we obtain a bone block with a round cross-section that perfectly fits within the prepared femoral canal. Therefore small diameter stabilizing screws can be used, which is an advantage compared with grafts with hamstring tendons (HT), and this can be important for revision procedures. What is more, direct healing of the graft with the entire diameter of the bone block is achieved. Osteointegration of the bone block with the femoral bone tunnel is almost completed 8 weeks after reconstruction, whereas in the case of tendon-bone healing, as in an HT graft, it still does not fully heal until 6 months after surgery.[7,8] When harvesting a full-thickness QTB graft, the bone-tendon junction is not weakened. Another advantage of QTB is that use of bone block grafts eliminates the risk of weakening the graft at the entrance of the femoral bone tunnel, especially when using straight and antegrade drills (which result in a steep femoral angle to lateral femoral notch). To achieve this advantage, it is important not to introduce the bony part of the graft too deep into the femoral tunnel (keep equal bone to bone graft and socket surfaces).

What is more, a QTB has 20% more collagen fibers than BPTB with the same cross-section, its strength to rupture is 70% higher and to add up the remaining quadriceps tendon after harvesting graft is still 80% more resilient than intact patellar tendon.[3] An advantage of a QTB over an HT graft is that with achieving similar biomechanical graft properties, muscular agonists of the ACL are not harvested.[9] The superiority of a QTB compared with BPTB graft harvesting is the lower risk of sensory loss, anterior knee pain, donor site morbidity, and patellar ligament shortening.[10-12] Our QTB harvesting technique does not require the use of dedicated instruments, and requires only basic surgical tools, such as an osteotome, saw, and scissors.

Limitations of this technique are the extended duration of the procedure and demanding surgical technique with an inability to harvest without tourniquet. The weakest point of any bone block graft is the bone-tendon junction. In using the QTB graft technique, it is extremely important to harvest a full thickness at the

Table 2. Advantages and Disadvantages of Quadriceps Tendon-Bone Full-Thickness Autograft Harvesting Technique

Advantages:	Disadvantages:
The strongest graft option.	Joint cavity has to be opened.
20% more collagen fibers than bone-patellar tendon-bone with the same cross-section.	Quadriceps tendon-bone has to be harvested after completing all intra-articular procedures.
Use of bone block grafts eliminates the risk of weakening the graft on the edge of the femoral bone tunnel.	Possibility of occurrence and subcutaneous penetration of intra-articular hematomas when donor place is not meticulously closed.
Additional graft in multiligament reconstructions.	Postoperative transient atony of the quadriceps muscle is observed.
Adjustability of graft length for a given patient, no risk of mismatch, no need to change the tunnel angle to avoid mismatch.	Risk of patellar fracture.
Lower risk of anterior knee pain, patellar ligament shortening, and sensory loss than in bone-patellar tendon-bone.	Tourniquet has to be used.
Muscular agonists of anterior cruciate ligament are not harvested as in hamstring tendons graft.	
Big bone block, very useful in revision cases.	
Bone block with a round cross-section perfectly fitted to the prepared femoral canal allows us to use small diameter stabilizing screws.	
Direct healing of the graft with the entire diameter of the bone block.	
Osteointegration is faster than in hamstring tendons graft.	
Bone block elongates the graft for approximately 2 cm and therefore quadriceps tendon-bone is suitable for procedures where longer graft is necessary, for example, posterior cruciate ligament reconstruction.	
Only basic surgical tools are needed.	
The bone-tendon junction is not weakened.	

bone-tendon junction because of the oblique shape of its anterior and posterior fiber insertion. Thus we need to open the joint cavity, which increases pain, postoperative transient atony of the quadriceps muscle, and provides the possibility of occurrence and subcutaneous penetration of intra-articular hematomas when the donor harvest site is not meticulously closed. The need to harvest QTB graft after completing all joint procedures (as opening the joint caused swelling of the subcutaneous tissue) and possible patellar fracture[13] when using improper technique of bone block harvest have made the QTB graft a less popular reconstruction graft. Most QTB graft disadvantages are associated with its harvesting: both sophisticated instruments and procedures. Our simple technique makes it easier to harvest and use the QTB, the strongest and multipotential graft. Advantages and disadvantages of the technique are summarized in the Table 2.

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