Anterior Cruciate Ligament Reconstruction With Bone—Patellar Tendon—Bone Graft Through a Rectangular Bone Tunnel Made With a Rectangular Retro-dilator: An Operative Technique

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Abstract: Good clinical results have been reported with anatomic anterior cruciate ligament (ACL) reconstructions in which rectangular bone—patellar tendon—bone (BTB) grafts were fixed into rectangular bone tunnels made at anatomic ACL insertion sites of the femur and tibia (anatomic rectangular tunnel BTB ACL reconstruction). Notwithstanding these good results, some problems have remained unsolved, including procedural complexity and risk of damage to the femoral posterior tunnel wall, damage to nerves and blood vessels, and damage to cartilage. The purpose of this report is to present our technique of ACL reconstruction with BTB graft through a rectangular bone tunnel made with a rectangular retro-dilator. Our procedure may become a safe option for anatomic rectangular tunnel BTB ACL reconstruction because of the following advantages: (1) bone tunnels can be created more safely and accurately than in methods using transtibial and far medial portals, (2) the bone tunnel preparation procedure is less invasive than the standard outside-in method, (3) technical failure—related risks are lower because the guidewire is inserted only once, and (4) the operation time is shorter because the method is a single-bundle procedure.

The technique of anterior cruciate ligament (ACL) reconstruction has been improved in the past decade. Good clinical results have been reported with anatomic ACL reconstructions in which rectangular bone—patellar tendon—bone (BTB) graft was fixed into rectangular bone tunnels made at anatomic ACL insertion sites of the femur and tibia (anatomic rectangular tunnel [ART] BTB ACL reconstruction[1-4]). Notwithstanding these good results, some problems have remained,[5,6] including procedural complexity and risk of damage to the femoral posterior tunnel wall, damage to nerves and blood vessels, and damage to cartilage. Recently, there have been reports indicating that bone tunnels can be safely and accurately created with an outside-in method by use of retrograde drill devices during ACL reconstruction with hamstring tendon.[7,8] This article describes our technique to make rectangular bone tunnels with the Marking Hook for the RetroConstruction Drill Guide (AR-1510R; Arthrex) (Fig 1A) and a rectangular retro-dilator (Ario Medical, Osaka, Japan) (Fig 1B) for ART-BTB ACL reconstruction, and advantages and pitfalls of the procedure are presented.

Surgical Technique

The operation is performed with the patient under general anesthesia in the supine position. The lower thigh hangs over the edge of the operating table and the cushion is pinched so that the knee is positioned at a 90° angle. A 4.0-mm-diameter 30° arthroscope (TrueView II; Olympus, Tokyo, Japan) is used.

Surgical Approach and Graft Harvesting and Preparation

The BTB graft is harvested by a two—transverse incision technique[9]: through a 4- to 5-cm transverse skin incision at the lower border of the patella and through a 3- to 4-cm transverse skin incision at the level of the tibial tuberosity (Fig 2A). Arthroscopy is performed

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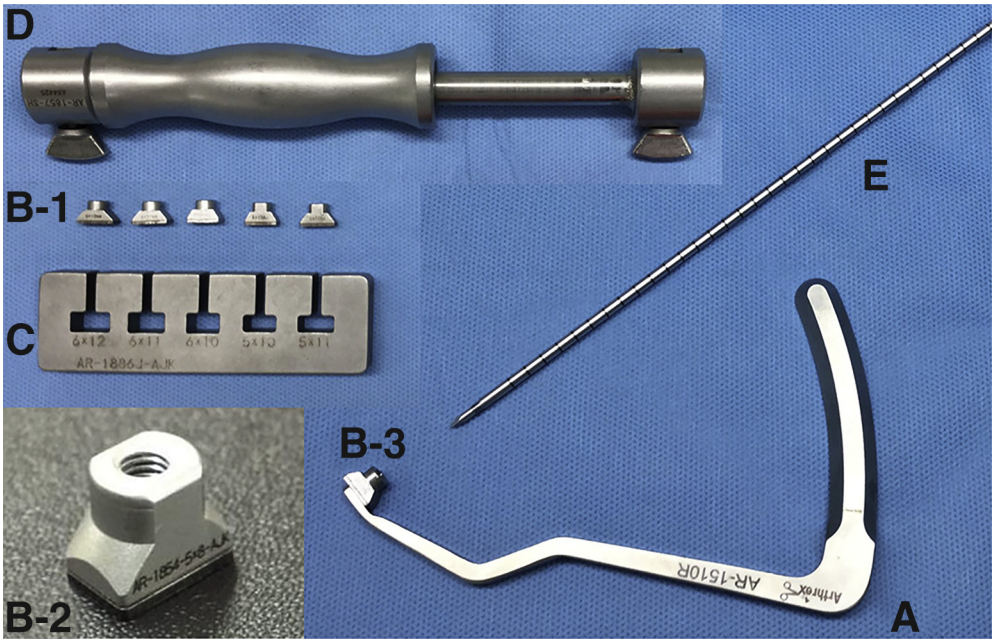

Fig 1. Surgical instruments. (A) Marking Hook for Retro-Construction Drill Guide. (B-1) In order from left to right, 5 different sizes of rectangular dilators (rectangular retro-dilator; Ario Medical) are shown: 6 × 12 mm, 6 × 11 mm, 6 × 10 mm, 5 × 10 mm, and 5 × 11 mm. (B-2) Enlarged view of dilator. (B-3) Dilator set on retrograde drill device. (C) Graft-sizing template (Ario Medical). (D) Slide hammer (Ario Medical). (E) RetroDrill Guide Pin, 3 mm, non-cannulated (AR-1250RS; Arthrex).

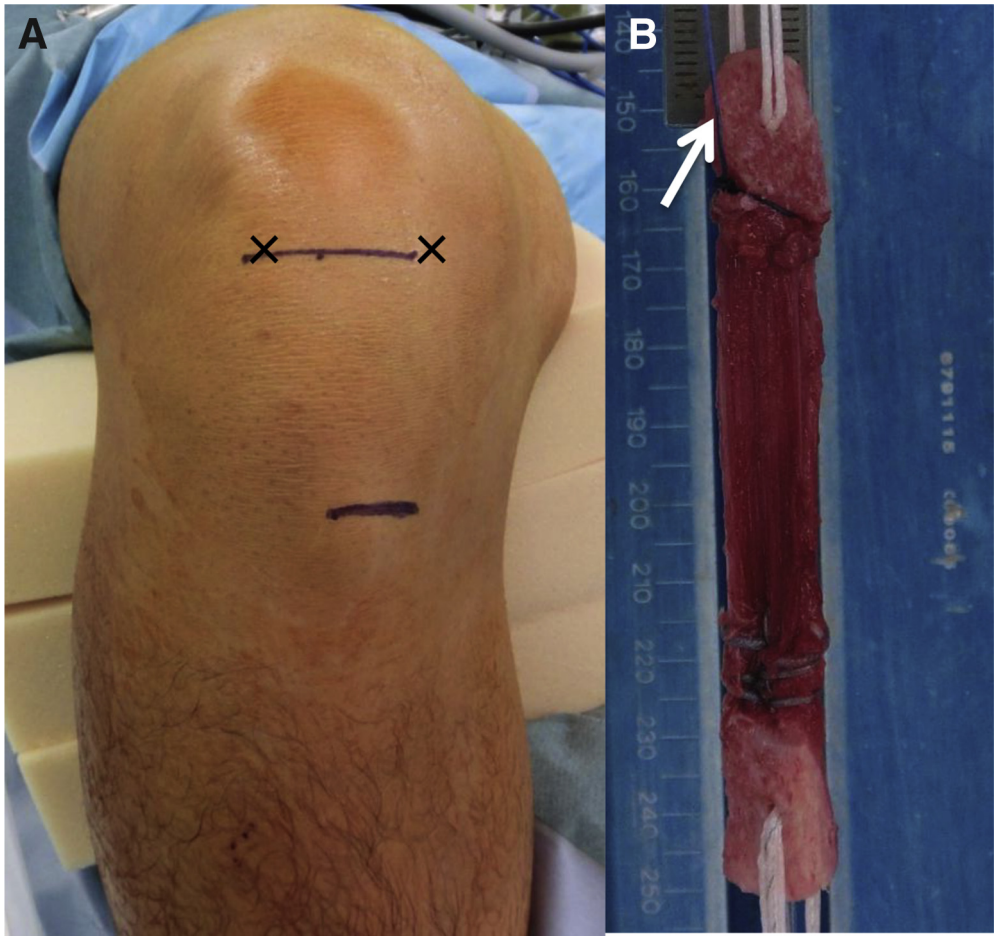

Fig 2. (A) In the supine position, the lower thigh is dropped from the operating table and the cushion is pinched so that the right knee is positioned at a 90° angle for the operation. The lines indicate the placement of the skin incisions for the right knee, and X's indicate the locations of the arthroscopy portals. Arthroscopy is performed through the usual medial and lateral infrapatellar portals. (B) Bone—patellar tendon—bone graft adjusted with bone fragment shaper into rectangular 6-mm-thick, 10-mm-wide, 15-mm-long fragments, roundly edged to facilitate easy insertion into bone tunnels. The arrow indicates an auxiliary thread.

Table 1. Surgical Steps and Technical Tips

Surgical Step	Technical Tips
Graft harvesting and preparation	Round the bone fragments to allow insertion into the bone tunnels. Add an auxiliary suture to assist the induction of the bone–patellar tendon–bone graft.
Femoral socket preparation	Insert the guide pin in the correct position. Carefully draw the dilator to the femoral bone tunnel.
Tibial tunnel preparation	Insert the guide pin in the correct position. Carefully draw the dilator to the tibial bone tunnel.
Graft passage	Note the orientation of the bone fragments. Support carefully using an auxiliary thread, probe, and mosquito forceps.
Graft fixation	Fix the graft at 20° of knee flexion.
Wound closure	Transplant the bone chips. Do not suture the patellar tendon.

through medial and lateral infrapatellar portals inserted through the aforementioned proximal skin incision (Fig 2A). An additional portal is not necessary. The distal incision is used for reaming the tibial tunnel. A 10-mm-wide BTB graft is harvested with Parallel Graft Knife Blades (AR-2285-10; Arthrex) from the central portion of the patellar tendon, and about 15-mm-long bone fragments on both ends are removed from the patellar bone and tibial tubercle with an oscillating saw and an osteotome. The bone fragment's shapes are adjusted with a bone fragment shaper into rectangular 6-mm-thick, 10-mm-wide, 15-mm-long pieces (Fig 2B). These fragments should smoothly fit the graft-sizing template (Ario Medical) (Fig 1C) before insertion into bone sockets. The bone fragments are roundly edged to facilitate easy insertion into the bone tunnels, and their direction can be adjusted with a thread (Fig 2B, Table 1).

Femoral Socket Preparation

First, the soft tissues (hematoma, synovium, remaining ACL, and so on) should be cleaned up to identify the resident ridge and the posterior articular cartilage of the lateral condyle of the femur (Video 1). Next, a 3.5-mm guide pin is inserted with a reference point at the center portion of the ACL femoral attachment; the target point is behind the resident ridge and the center of the ACL attachments (Fig 3A). A round bone tunnel (6 mm in diameter and 25 mm deep) is created in a retrograde manner by use of the Short FlipCutter II (AR-1204AS-60; Arthrex) (Fig 3B). Then, the dilator is set on the 3-mm guide pin (Arthrex) (Fig 1E) by use of the RetroConstruction Drill Guide (Fig 1A) within the knee joint (Video 1, Fig 3 C and D), and the rounded edge of the rectangular retro-dilator is inserted into the femoral bone tunnel; the dilator must fit tightly into the tunnel (Fig 3E). Finally, after the direction of the dilator has been confirmed, the dilator is inserted into the femoral bone by use of a slide hammer (Fig 1D) to about 18 mm deep; a rectangular bone socket is thus created (Fig 3 F and G).

Tibial Tunnel Preparation

First, a 3.5-mm guide pin is inserted into the center of the ACL footprint, aiming slightly medially using a reference guide (Video 1, Fig 4). Next, to prevent fracture on pulling the dilator out of the tibial bone tunnel, the cortical portion of the bone is drilled about 10 mm deep and 10 mm wide. Then, the bone is drilled with a 6-mm drill up to the joint space. Subsequently, by use of the rectangular retro-dilator, the tibial bone tunnel is prepared in the same fashion as during preparation of the femoral socket.

Graft Passage

Through the use of passing sutures, the BTB graft is passed from the tibial tunnel to the femoral socket (Video 1). At this time, because the bone tunnels are rectangular, confirmation of the bone fragments' orientation is very important. At this point, additional threads or probes are sometimes necessary to facilitate insertion because this step requires more precision than only pulling the graft as in the STG (semitendinosus and gracilis tendon) method. Insertion steps are easier to perform when the knee is in extension when the bone fragments are passed through the tibial bone tunnel and in flexion when the bone fragments are inserted into the femoral bone. Forceful insertion may damage the graft; therefore, special care must be taken during graft passage through the tunnels.

Graft Fixation

The BTB graft is fixed to the femoral bone by a BTB TightRope (AR-1588BTB; Arthrex) and to the tibial bone by an ABS Suture Button (AR-1588TB-1; Arthrex) (Fig 5A and B). Finally, the direction and tension of the reconstructed ACL are confirmed by arthroscopy (Fig 3L).

Wound Closure

The bone chips obtained at the time of bone fragment preparation for the BTB graft are transplanted into the extracted graft portion of the tibia. The periosteum over

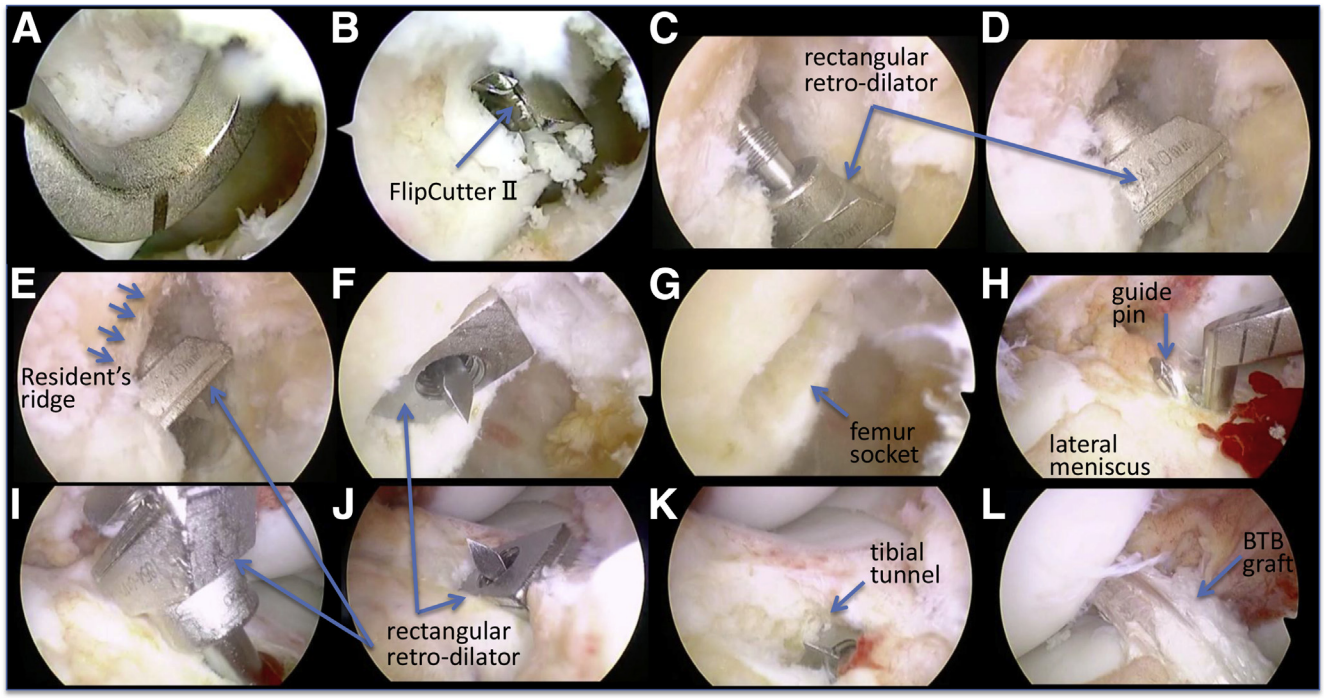

Fig 3. Arthroscopic views of right knee through anteromedial portal (A-G) and anterolateral portal (H-L). (A) A 3.5-mm guide pin is inserted with a reference point at the center portion of the anterior cruciate ligament (ACL) femoral attachment behind the resident ridge. (B) A round bone tunnel with a diameter of 6 mm is created in a retrograde manner with the Short FlipCutter II. (C, D) The dilator is set on the 3-mm RetroDrill Guide Pin using the RetroConstruction Drill Guide within the knee joint. (E) The rounded edge of the rectangular retro-dilator is inserted into the femoral bone tunnel. (F, G) After the dilator's direction is confirmed, the dilator is pulled into the femoral bone to about 18 mm deep and the rectangular bone socket is created. (H) A guide pin is inserted with the reference guide at the center portion of the ACL tibial attachment. (I) The dilator is set on the 3-mm RetroDrill Guide Pin using the RetroConstruction Drill Guide within the knee joint. (J) The rounded edge of the rectangular retro-dilator is inserted into the tibial bone tunnel. (K) After the dilator's direction is confirmed, the dilator is pulled out the tibia and the rectangular bone tunnel is created. (L) Arthroscopic view after retro-dilator anatomic rectangular tunnel bone—patellar tendon—bone (BTB) ACL reconstruction.

the extracted bone portion is then sutured; the patellar tendon tissue is left without suturing.

Discussion

Recently, good clinical results of ART-BTB ACL reconstruction have been reported.[1-4] Moreover, it has been shown that the behavior of the reconstructed knee is close to the biomechanical behavior of the normal knee as compared with the conventional round-tunnel BTB ACL reconstruction.[4]

However, the ART-BTB ACL reconstruction is particularly troublesome when making a bone tunnel on the femur. To avoid the risk of femoral posterior wall injury or nerve damage, the inside-out technique or the conventional outside-in technique (to drill from the bone cortex to the joint) is selected depending on whether knee flexion to 140° can be achieved.[3] In addition, performing the insertion of the guide pin twice raises the risk of prolonged operating time and technical error.

Several studies have indicated that bone tunnels can be safely and accurately created with an outside-in technique using retrograde drills,[7,8] namely the AI drill[10] (Aimedic MMT, Tokyo, Japan), EndoButton retro-drill[11] (Smith & Nephew, Andover, MA), or FlipCutter II[10-12] (Arthrex). Therefore, our minimally invasive ART-BTB technique uses the outside-in technique with retrograde drills, in which a rectangular pull-type dilator (Fig 1B) is used. With this method, the bone tunnel can be prepared by a single insertion of a guide pin and a rectangular pull-type dilator by the outside-in technique. In addition, it is a relatively easy and minimally invasive technique for obtaining a rectangular socket at the target position (Fig 5 C and D). Serious intraoperative complications did not occur when using this technique, and it was relatively easy to create a rectangular bone socket in the targeted position with the rectangular retro-dilator.

Our procedure has the aforementioned advantages, but there are some pitfalls (Table 2). In particular, to avoid damage to the femoral cortex due to the impact of the dilator, it is necessary to consider bone tunnel length and bone quality. That is, because the length of the bone fragment of the BTB graft is 15 mm and the

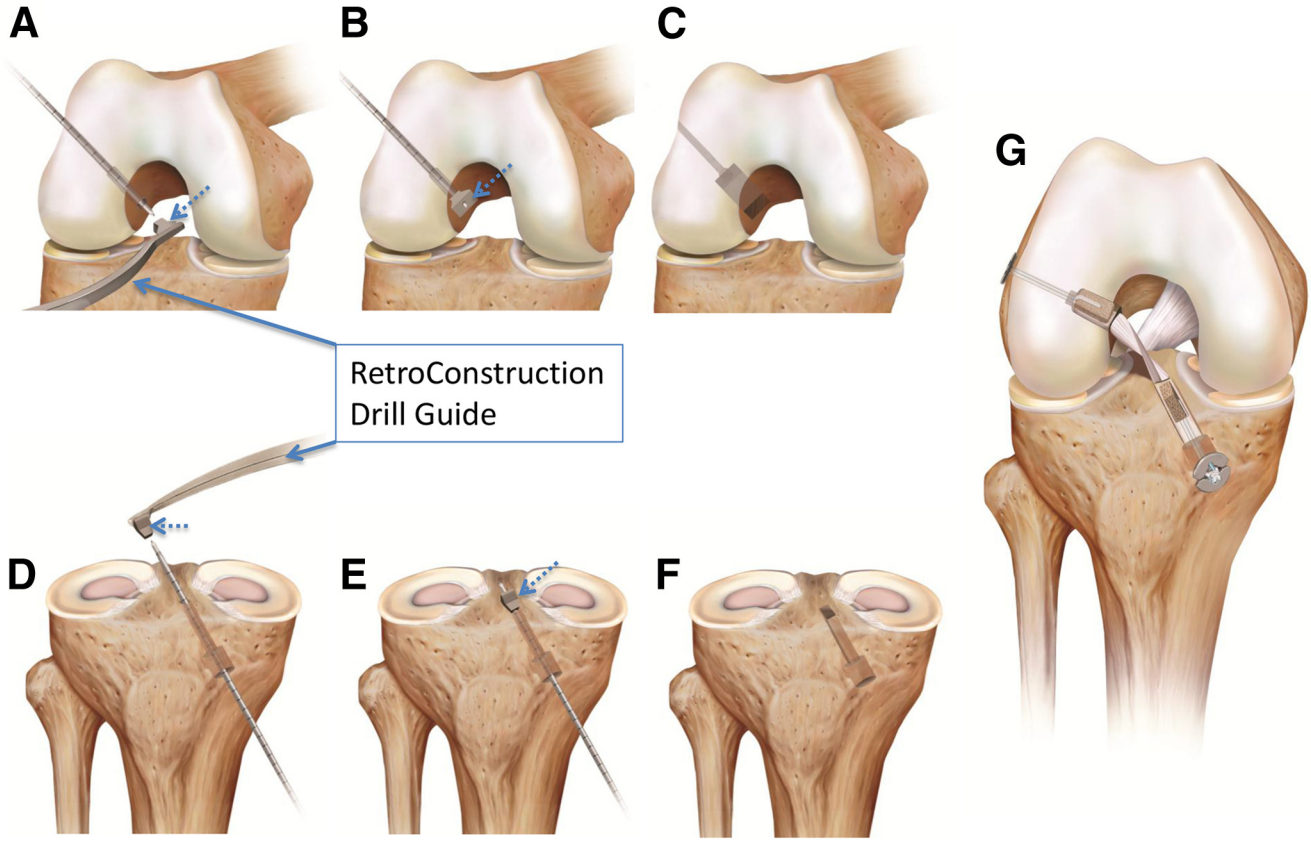

Fig 4. Femoral socket and tibial tunnel preparation of right knee. (A) After a round bone tunnel (6 mm in diameter and 25 mm deep) has been created in a retrograde fashion with the Short FlipCutter II, the dilator (arrow) is set on the 3-mm guide pin using the RetroConstruction Drill Guide within the knee joint. (B) The rounded edge of the rectangular retro-dilator (arrow) has been inserted into the femoral bone tunnel; the dilator fits tightly into the tunnel. The dilator is then inserted into the femoral bone. (C) A rectangular bone tunnel is created in the femoral bone. (D) The cortical bone is drilled with a 10-mm drill, and then the bone is drilled with a 6-mm drill up to the joint space. A rectangular pull-type dilator (arrow) is attached to the retrograde guide, mounting the dilator to the 3.0-mm guide pin within the knee joint. (E) The rectangular retro-dilator (arrow) is inserted into the tibial bone. (F) A rectangular bone tunnel is created in the tibial bone. (G) Completed retro-dilator anatomic rectangular tunnel bone–patellar tendon–bone anterior cruciate ligament reconstruction image. The twist of the ligament can be reproduced.

height of the dilator is 7 mm, the dilator is inserted 22 mm into the femur. Therefore, in cases in which the guide pin penetration length of the femur is less than 32 mm, bone preservation from the cortical bone becomes less than 10 mm. In these cases, it is more likely that the cortical bone will be damaged, and alternative

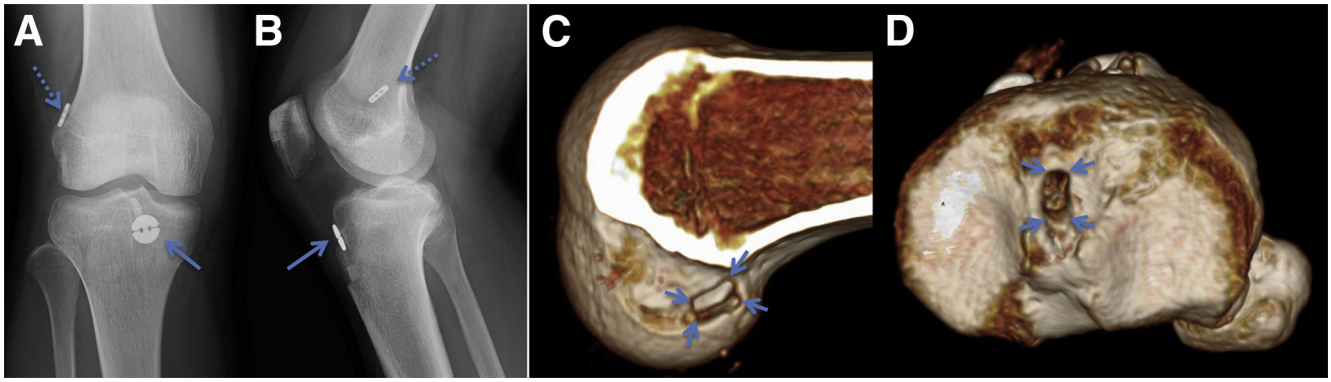

Fig 5. Radiographic postoperative findings of right knee. (A, B) Simple radiographs. The bone–patellar tendon–bone graft is fixed to the femoral bone by a BTB TightRope (dashed arrows) and to the tibial bone by an ABS Suture Button (solid arrows). (C, D) Three-dimensional computed tomography scans taken 3 weeks postoperatively. One should note the rectangular bone socket of the femur and the rectangular bone tunnel of the tibia in the attachment portions of the anterior cruciate ligament (arrows).

Table 2. Advantages and Pitfalls of Retro-dilator Anatomic Rectangular Tunnel Bone–Patellar Tendon–Bone Procedure

Advantages
Creation of bone tunnels in targeted positions safely and easily
Reduced bone loss with minimally invasive outside-in technique
Low risk of technical failure
Short surgical time
Pitfalls
Possibility of damage to bone tunnel
Possibility of bone fragment fracture
Difficult attachment of dilator in certain cases

methods may need to be considered. In addition, elderly patients may have decreased bone mineral density and bone quality, so it is necessary to be particularly careful when drawing the dilators. Therefore, this procedure may not be suitable for small elderly patients. However, as long as the aforementioned points are noted, the dilator will compress the cancellous bone to increase its strength, and cortical bone damage will not occur unless a forceful manipulation is performed. In fact, we have never experienced femoral cortical damage.

Although the procedure carries some risk of intraoperative complications, it allows for a simpler and less invasive ART-BTB ACL reconstruction, provided that the indications for surgery are carefully considered and the operative techniques are properly applied. Although the long-term clinical results cannot be assessed at this point because there are only a few cases with sufficient follow-up periods, the proposed ART-BTB method is efficient and minimally invasive. To provide further evidence, evaluation of long-term clinical results and bone tunnels for this procedure has been commenced.

We describe an easy and minimally invasive technique of ACL reconstruction with a BTB graft through rectangular bone tunnels made with a rectangular retro-dilator (i.e., retro-dilator ART-BTB ACL reconstruction). Our procedure provides an alternative but safer and easier approach for anatomic rectangular ACL reconstruction.

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