Technical Note

All-Inside Double-Bundle Anterior Cruciate Ligament Reconstruction via the Transtibial Approach With a Laser-Tip Guide System for Drilling

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Abstract: Anterior cruciate ligament reconstruction using an all-inside method to reduce bone damage caused by drill hole preparation and enhance the stability of the reconstructed ligament in the drill hole has been reported in recent years. We made a custom-designed drill guide pin and reamer, which are assembled in the joint, to create drill holes in the femur and tibia. For the transtibial method, our femoral drill hole—positioning technique, which uses a laser, is extremely convenient for accurate positioning of the drill holes. Therefore, a combination of these methods facilitates implementation of the all-inside double-bundle anterior cruciate ligament reconstruction technique.

A variety of arthroscopic procedures for anterior cruciate ligament (ACL) reconstruction have been reported to date.[1-3] These operative procedures provide stable postoperative results. The number of ACL reconstructions is increasing. However, improvements in operative procedures are needed for next-generation ACL reconstruction with even better stability and an earlier return to sports. In 1995, Morgan[4] introduced ACL reconstruction using the all-inside method with a video. Conventional methods create a tibial drill hole from the front of the tibia, resulting in voids that are not filled with reconstructed ligament. To overcome this disadvantage, a method to reduce the dead space in drill holes using a retrograde drill has been reported.[5] The creation of drill holes from inside the joint in both the tibia and femur has been reported to reduce bone damage and postoperative pain.[6,7] In addition, this technique might have other advantages such as early ligament maturation owing to reduction of the bungee phenomenon and better stability of the reconstructed ligament.[8]

We designed a method to prepare a drill hole by assembling a dedicated drill guide pin and reamer within the knee joint (Video 1). We adopted a method in which we first determine the position of the tibial drill hole at the articular surface using a drill guide. We then confirm that the femoral footprint is aligned along the drill hole path in the tibia using a laser beam with a reflective plate attached to the tip of the guide (Video 1).[9] Through a combination of these methods, all-inside ACL reconstruction via the transtibial approach is facilitated by easier and more accurate drill hole preparation.[10] Recently, some studies[6,10] have shown that a double bundle is better than a single bundle for reducing rotatory instability; therefore, we used the double-bundle technique. This article describes our operative technique.

Surgical Technique

Drilling Instruments for ACL Reconstruction

We developed the drilling instruments (Tanaka Medical Instruments, Tokyo, Japan) used for ACL reconstruction. A 30-cm-long drill guide pin has threads cut in the middle (Fig 1). It immobilizes a reamer at the level of the thread cuts. The diameter of the pin where it penetrates the femur and a tibial-side part is 2.4 mm and 3.5 mm, respectively. The pin is

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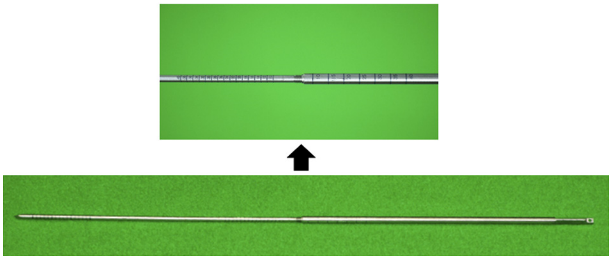

Fig 1. A 30-cm-long drill guide pin has threads cut in the middle; it immobilizes a reamer at the level of the thread cut. To measure the depth of the drill hole, scale marks in 5- and 2-mm increments are used for the femur and tibia, respectively.

inserted by sliding the reamer from the tip of the pin to stabilize it in the middle. The femoral side is immobilized owing to a difference in diameter, and the tibial side is immobilized by the screw structure of the pin and a reamer for preparing the drill hole. Consequently, a drill hole can be created by clockwise rotation in both cases. To measure the depth of the drill hole, scale marks in 5- and 2-mm increments are used for the femur and tibia, respectively. The length of the reconstructed syndesmosis is measured using scale marks in 2-mm increments at the tip of the pin.

Reamers are prepared in 0.5-mm increments between 5 and 10 mm in diameter. The harvested semitendinosus tendon is used for reconstruction. The pin and reamer are assembled and locked to each other in the joint; therefore, a hole to thread a string is made in a part of the reamer to prevent it from falling into the joint. In the unlikely event that the reamer falls into the joint, it can be removed by pulling on the string. The pin is inserted into the joint at an angle to the articular surface; therefore, the reamer gripper is shaped so that

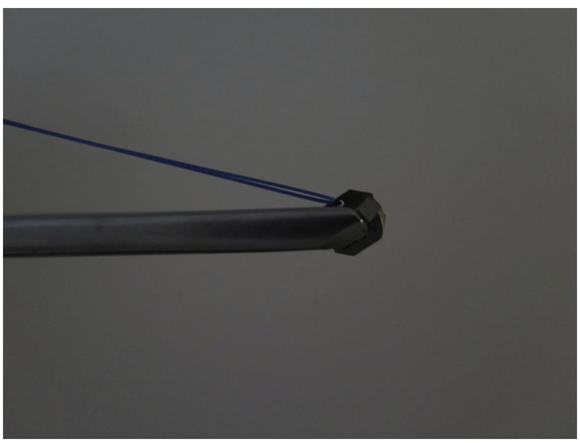

Fig 2. A hole to thread a string is made in part of the reamer to prevent it from falling into the joint. The reamer gripper is shaped so that it can grasp the reamer at an angle of 45° to the shaft for pin insertion.

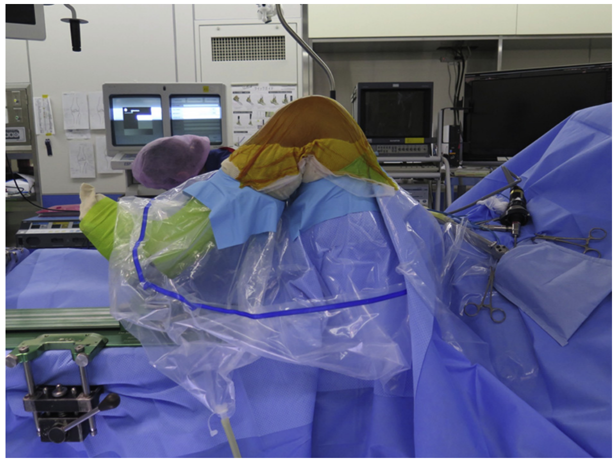

Fig 3. Leg positioning of a left knee in a flexed position using a knee positioner.

it can grasp the reamer at an angle of 45° to the shaft for pin insertion (Fig 2).

Harvesting of Semitendinosus Tendon

The semitendinosus tendon is identified through a skin incision of approximately 3 cm on the anteromedial (AM) side of the tibia. A 22-cm-long tendon is usually harvested using a tendon stripper. Two folded ligaments for reconstruction (2 ligaments of 5-6 cm and 5.5-7 cm in length for posterolateral [PL] bundle and AM bundle, respectively) are prepared using a baseball suture. The diameter of each reconstructed ligament is measured to determine the diameter of the reamer to be used.

Leg Positioning During Reconstruction

We perform reconstruction using a knee positioner (De Mayo knee positioner; Innovative Medical

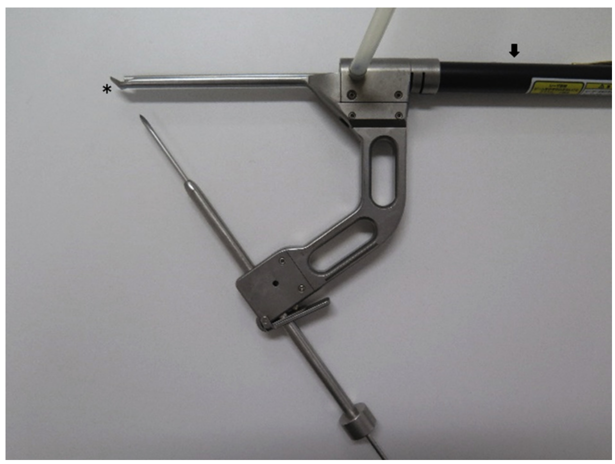

Fig 4. Laser-tip guide. Positioning of the tibial drill hole and intended femoral drill hole can be performed at the same time using the transtibial method. The laser beam is reflected by a reflector (asterisk) attached to the tip of the drill guide. The arrow indicates a laser pointer.

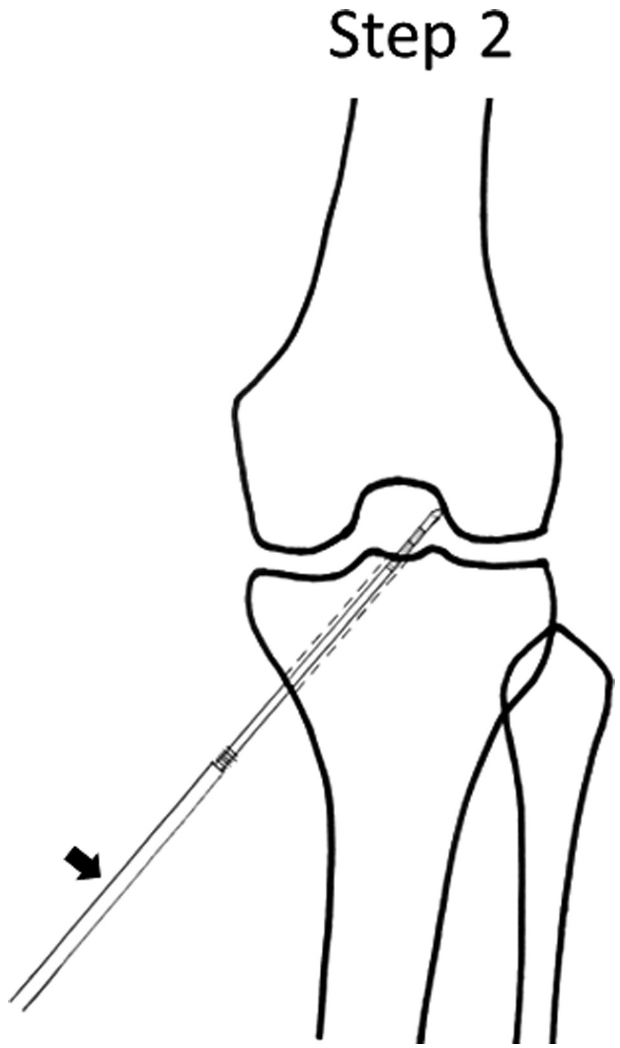

Fig 5. The drill guide pin (arrow) is inserted, and the length of the reconstructed ligament in the joint is measured.

Products, Plainville, CT) (Fig 3). The patient's knee is immobilized in a flexed position on the operating table during drill hole preparation. For the PL bundle, the procedure is performed with the knee in 90° to 100° of flexion without medial or lateral rotation of the lower leg. For the AM bundle, the procedure is performed with the knee in 120° of flexion with the lower leg being slightly externally rotated.

Positioning of Tibial Drill Hole Using Laser-Tip Drill Guide

During positioning for tibial drill hole preparation using a laser beam, the specially designed laser-tip drill guide (Tanaka Medical Instruments) can illuminate the path of the femoral drill hole (Fig 4). Therefore, positioning of the tibial drill hole and intended femoral drill hole can be performed at the same time using the transtibial method. The guide for drill hole preparation has a hole in which a laser beam can pass through the body. The straightness of the laser beam is maintained by filling it with physiological saline solution. The laser beam is reflected by a reflector attached to the tip of the drill guide; it always illuminates along the direction of tibial drilling.

In step 1, drilling is conducted from the front of the lateral femur and tibia to the articular surface by placing the tip of the drill guide pin on the tibial ACL footprint and fixing the drill guide at the position indicated by the laser for the femoral ACL footprint using a Kirschner steel wire with a diameter of 2.4 mm. In step 2, with the steel wire used as a guide, a hole with a diameter of 4.5 mm is drilled (Fig 5). Next, a drill guide pin that we developed is inserted into the hole. The length of the reconstructed ligament in the joint is measured using a scale on the tip of the drill guide pin. In step 3, a reamer is inserted into the joint from an inside portal (Fig 6). It is mounted at the tip of the drill guide pin using a sliding motion.

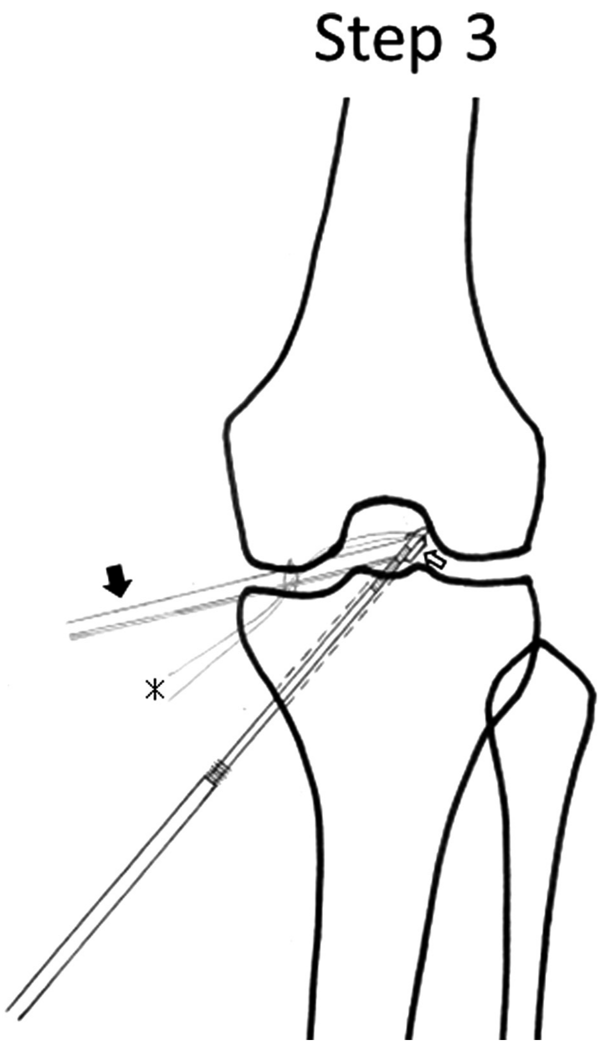

Fig 6. The reamer (white arrow) with a string (asterisk) is inserted into the joint from an inside portal using a reamer gripper (black arrow).

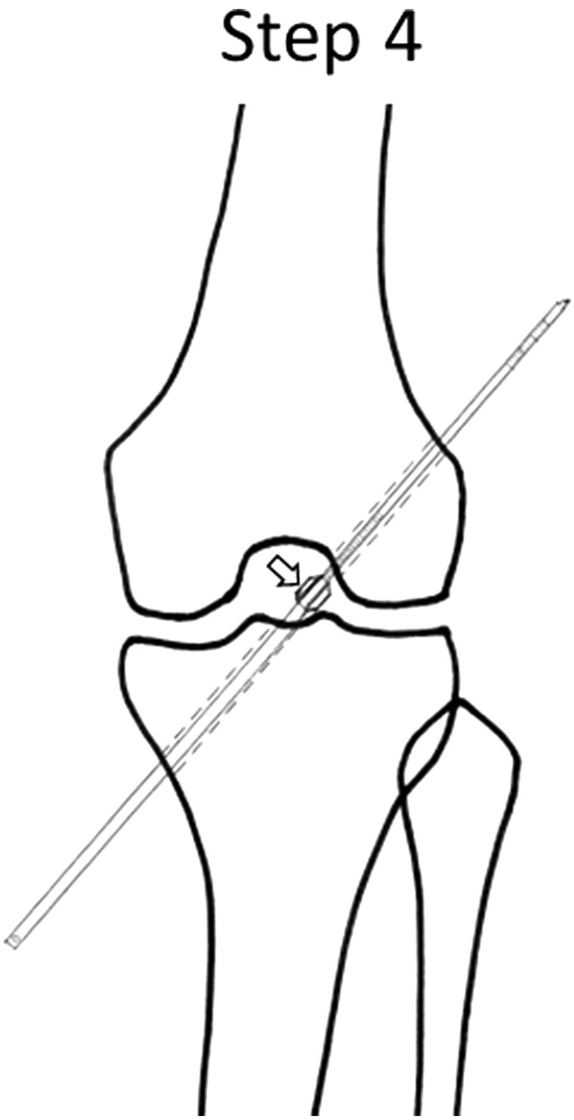

Fig 7. The reamer (arrow) is fixed in the middle of the drill guide pin when it is propelled with clockwise rotation using an electric drill.

Preparation of Femoral Drill Hole

In step 4, the reamer is fixed in the middle when it is propelled with clockwise rotation using an electric drill with the tip of the drill guide pin touching the intended footprint of the femoral insertion point (Fig 7). The reamer penetrates the femur and appears on the skin on the lateral thigh.

In step 5, reaming is performed so that the distal end of the reamer in the joint matches the bone wall of the femoral insertion (Fig 8). A depth gauge, which is used to measure the entire length of the femoral drill hole at 2-mm intervals, is inserted into the drill guide pin from the lateral thigh through the skin.

In step 6, in general, the length of the femoral drill hole is set at 25 mm, and reaming is performed in a clockwise fashion (Fig 9). We consider the inside length of the drill hole of the reconstructed ligament to be 15 mm; therefore, the entire length of the femur minus 15 mm would be the length of the ligament of the EndoButton CL-BTB device (Smith & Nephew, Andover, MA). The artificial ligament above the EndoButton is available in lengths that are multiples of 5 mm. Therefore, for example, when the entire length of the femur is 43 mm, the length of the artificial ligament would be 28 mm and an artificial ligament with the closest length of 30 mm would be used. In this case, the length of the reconstructed ligament in the femoral drill hole would be 13 mm.

Preparation of Tibial Drill Hole

The length of the tibial drill hole should be the length of the reconstructed ligament (usually 50-70 mm) and the reconstructed ligament in the femoral drill hole minus the length of the ligament in the joint. In step 7,

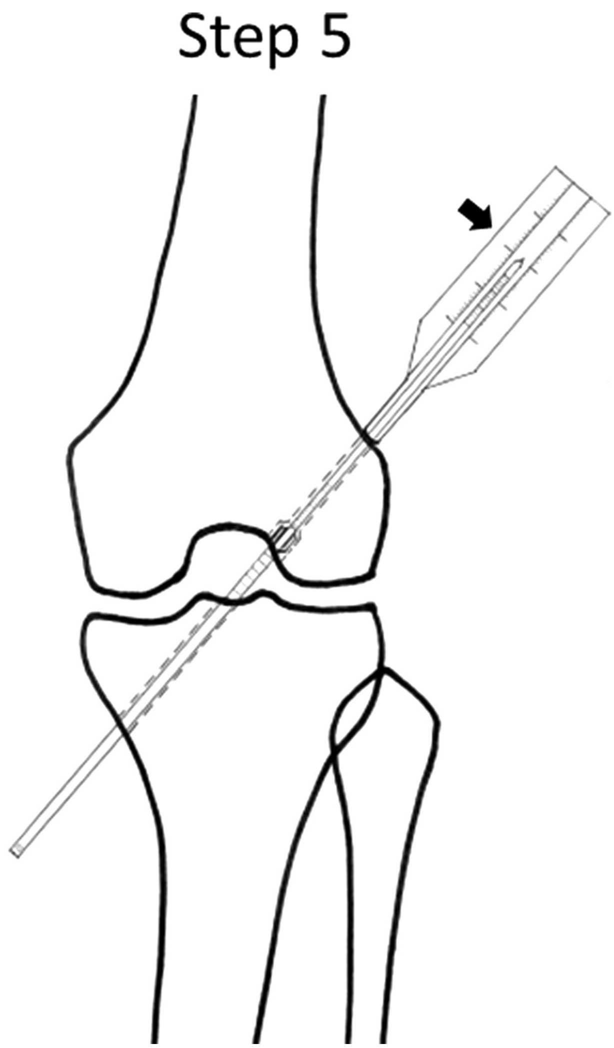

Fig 8. The distal end of the reamer in the joint matches the femoral bone wall. The entire length of the femoral drill hole is measured with a depth gauge (arrow).

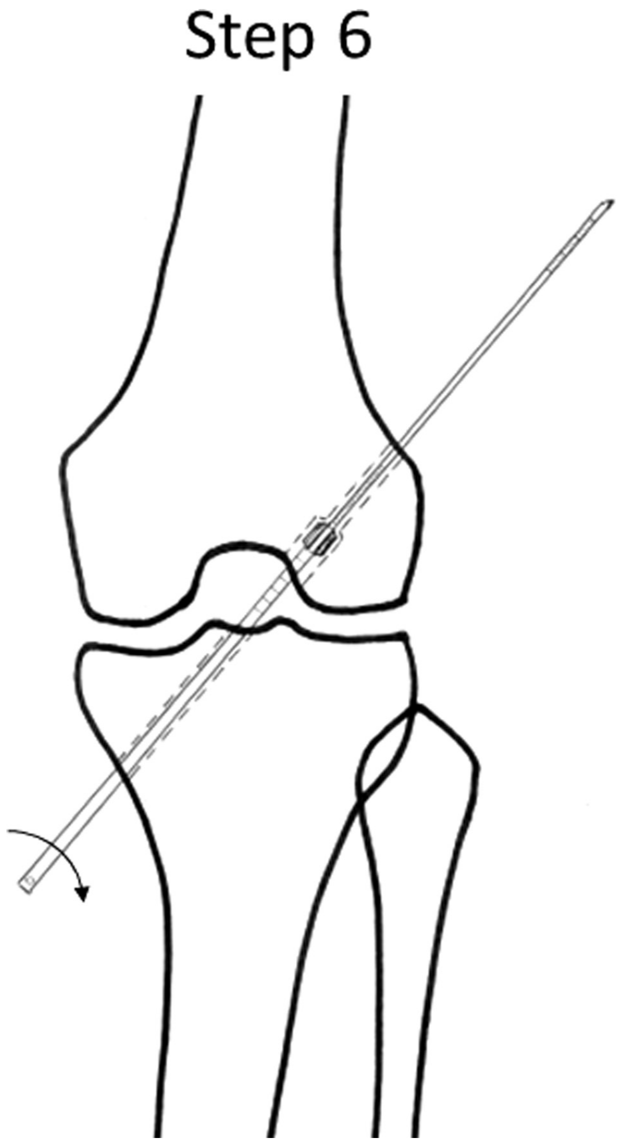

Fig 9. Reaming of the femoral drill hole is set at 25 mm, and reaming is performed in a clockwise fashion (arrow).

to safely maintain tension of the reconstructed ligament at all times, the drill guide pin is rotated in a clockwise direction up to 5 mm more than the length used to create the tibial drill hole (Fig 10). In step 8, a hole with a diameter of 4.5 mm is drilled along the drill guide pin from the lateral thigh so that the EndoButton CL-BTB device for fixation on the femoral side can be inserted from inside the joint (Fig 11).

Instrument Removal

In step 9, the drill guide pin is moved so that the reamer is positioned in the middle of the joint (Fig 12). The reamer is secured with a reamer gripper. The drill guide pin, which appears on the anterior tibia, is grasped with nippers and manually rotated counterclockwise to remove the pin and reamer together by pulling out the pin. Drill hole preparation using the all-inside method is completed in this way. The PL drill hole is created before the AM drill hole.

Fixation of Reconstructed Ligament

In step 10, during insertion of the reconstructed ligament into the joint, a passing pin is inserted from the tibial side (Fig 13). Two yarns are passed through both ends of the ring-shaped thread. The ring-shaped thread is moved to the outside of the joint under arthroscopic visualization as described by Lubowitz et al.[7]

In step 11, the EndoButton CL-BTB device on the femoral side is inserted from inside the joint and fixed outside the femur using a flip motion. Next, the tibial-side thread is drawn to the anterior tibia to fix it with the EndoButton (single item). We fix both the AM

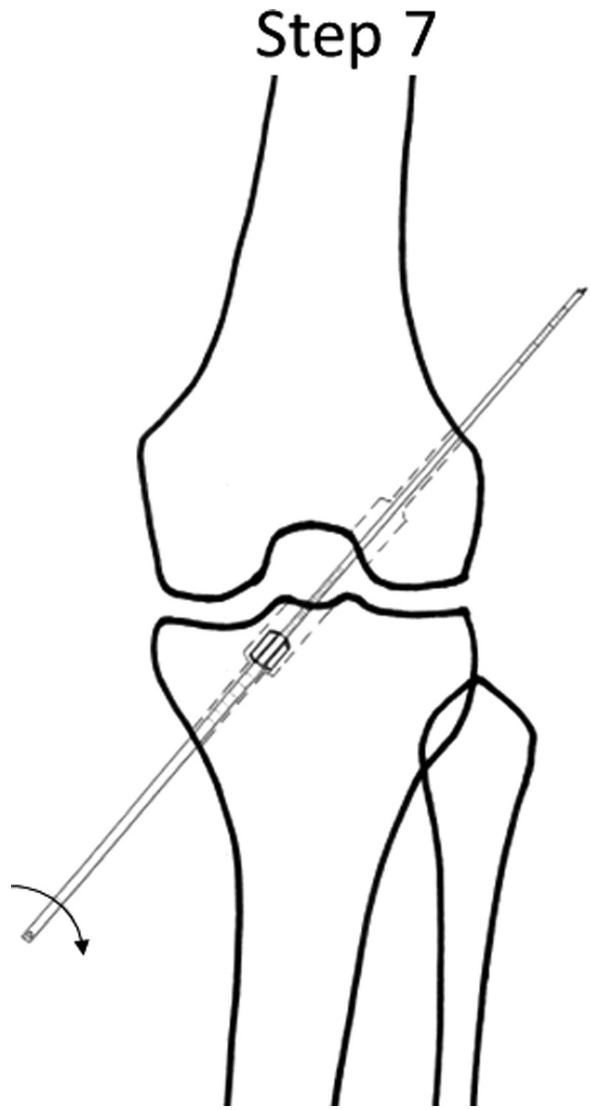

Fig 10. Reaming of the tibial drill hole is performed in a clockwise direction (arrow) up to 5 mm more than the measured length.

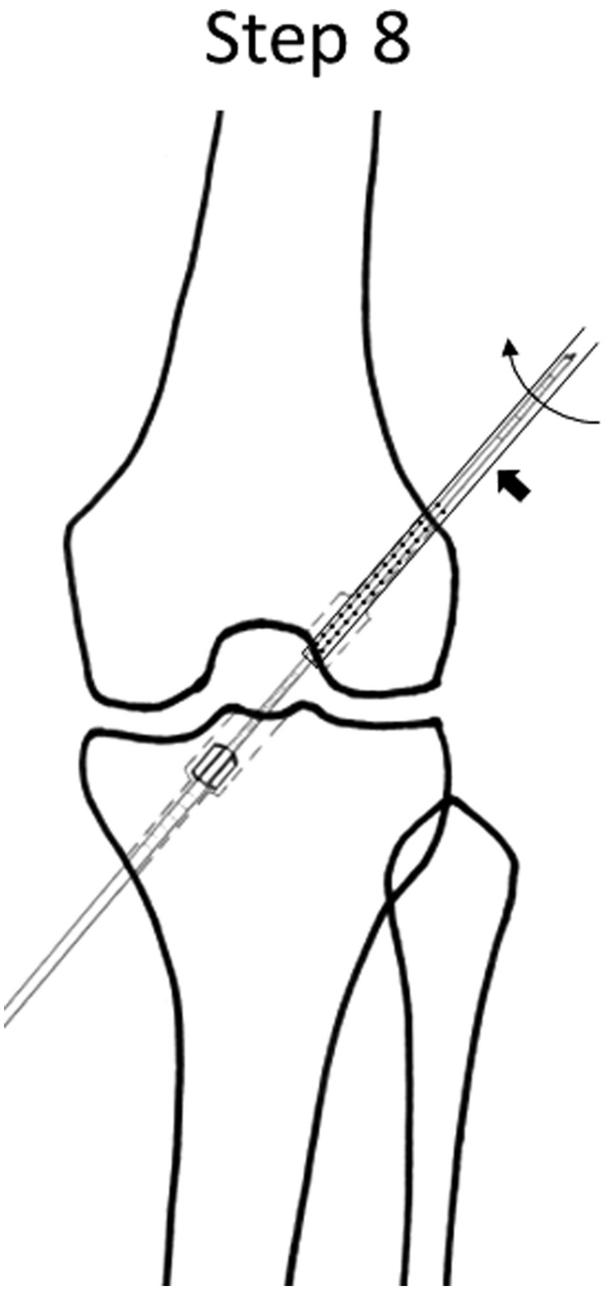

Fig 11. A hole with a diameter of 4.5 mm is drilled along the drill guide pin. The straight arrow indicates the drill with a diameter of 4.5 mm. The curved arrow indicates directionality.

and PL in extension. A drain is placed only in the joint. Immediately after surgery, the knee is fixed with a knee brace at approximately 10° of flexion.

Postoperative Care

Drains are removed the day after surgery. Joint range-of-motion training using a continuous passive motion machine is initiated 3 days after surgery. The goal of training is to achieve 90° of flexion by 2 weeks after surgery and 120° of flexion by 3 weeks after surgery. Starting 3 days after surgery, partial loading is started using an elastic brace for the ACL; an increase to full loading occurs within a range of 1 to 2 weeks after surgery.

Starting 3 months after surgery, jogging is gradually initiated with a brace. Running distance and speed are increased by 4 months. Landing after jumping and quick turns are started 6 months after surgery, and competitive sports are resumed by 6 to 9 months after surgery.

Discussion

For ACL reconstruction using the all-inside method, accurate preparation and measurement of the drill hole length in the joint are necessary to achieve the correct

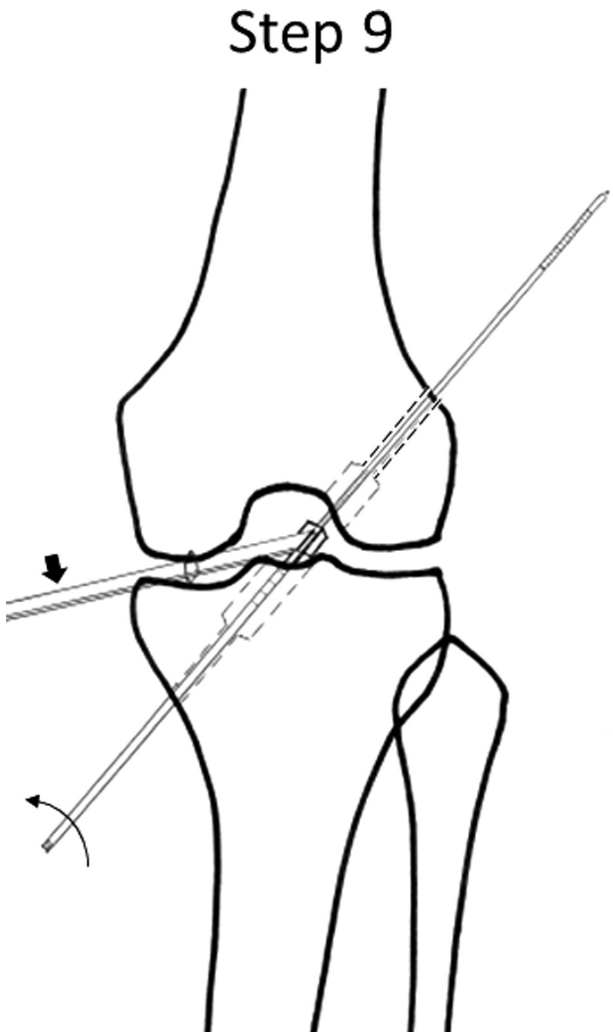

Fig 12. The reamer is secured with a reamer gripper (straight arrow). The drill guide pin, which appears on the anterior tibia, is then grasped with nippers and manually rotated counterclockwise (curved arrow) to remove the pin and reamer.

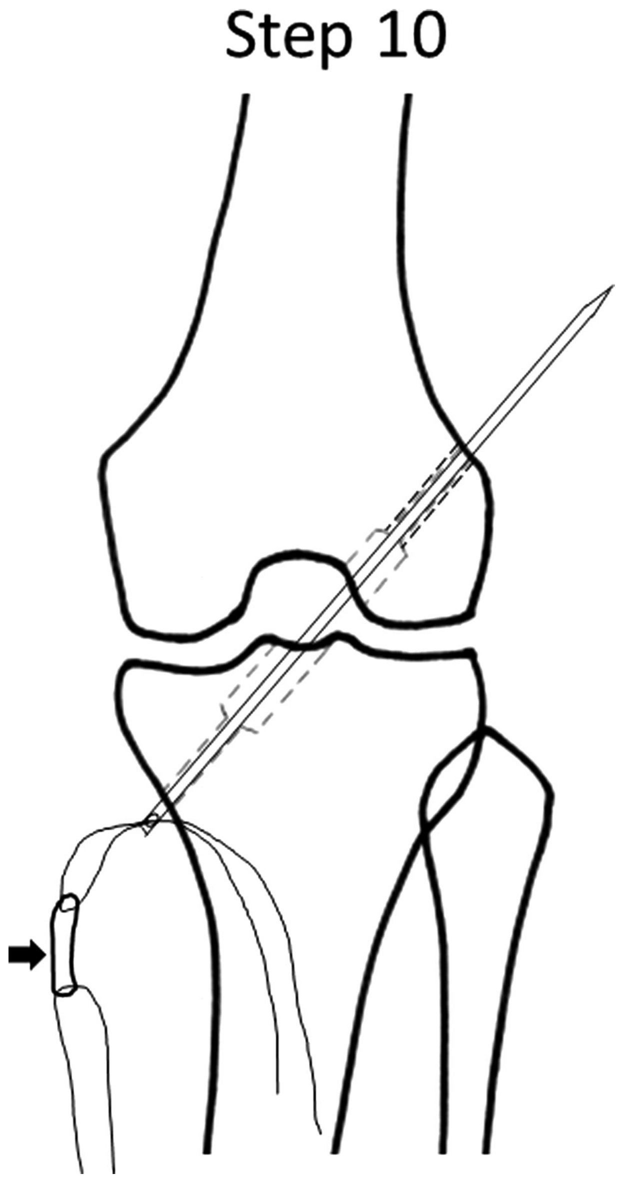

Fig 13. A passing pin is inserted from the tibial side, and 2 yarns are passed through both ends of the ring-shaped thread (arrow).

ligament length because both ends of the drill hole wall are close to the reconstructed ligament and this ligament relaxes when it is longer than the combined length of the hole in the bone and the intrajoint ligament. Our method allows for accurate measurements with a scale in increments of 2 mm and an arthroscope (Table 1). Moreover, the drill hole length on the tibial side is made 5 mm longer as a safety measure to prevent relaxation of the reconstructed ligament because the length of the joint inside the reconstructed ligament might vary by up to 5 mm, depending on the bending angle.

Our method does not involve hanging the lower leg from the operating table because the knee flexion angle can change with this positioning (Table 1). Instead, we place a drill guide as part of drill hole preparation. We insert the drill guide pin with the knee joint fixed when bone preparation has been completed because the threads in the center of the drill guide pin can be damaged during surgery if the knee joint is moved or a load that bends the pin is applied. If the pin is damaged, the reamer is grasped in the joint and removed from the joint by rotating the pin on the tibial side counterclockwise. Next, the drill hole is created again using the next drill guide pin.

Whether the performance of regular ACL reconstruction and the performance of ACL reconstruction using the all-inside method differ is a controversial topic.[5,11,12] Lubowitz et al.[7] reported that the all-inside method causes less postoperative pain. However, it has also been reported that there are no differences in postoperative stability and function.[13] Conventional ACL reconstruction requires a long period, at least 6 months, before returning to sports. Fusion of the ligament and osseous wall seems to be easier with the all-inside method than with the conventional method because both ends of the reconstructed ligament are close to the wall of the drill hole and earlier engraftment of the ligament is expected.

Therefore, it is necessary to consider whether it is possible to enable patients to resume sports in the short term with an early rehabilitation program after ACL reconstruction with the all-inside method from a clinical point of view. Although various improvements have been made so far to stabilize postoperative results, it is necessary to thoroughly examine whether reconstruction can further evolve with the all-inside method. We believe that a number of arthroscopists would be able to implement the all-inside technique more easily using the special equipment we have developed.

Table 1. Advantages and Disadvantages of Described Method

Advantages
The length of the reconstructed ligament in the joint and the lengths of the femoral and tibial drill holes can be accurately measured.
Preparation of the drill holes using the all-inside method is relatively easy.
Minimal postoperative bleeding from the tibial side occurs compared with existing techniques, which might help prevent infection.
Disadvantages
Accurate drill hole preparation needs a laser beam–guided drill guide.
Rough handling might break the drill guide pin.
A knee fixation device is required from installation of the drill guide for drill hole preparation until the completion of drill hole preparation.

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