Technical Note

One-Stage ACL Revision Using a Bone Allograft Plug for a Semianatomic Tibial Tunnel That Is Too Anterior

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Abstract: Revision of an anterior cruciate ligament (ACL) reconstruction can be performed as a one-stage or two-stage surgery. Several factors must be taken into consideration when making this choice, especially the size and position of the existing tunnels. When the tibial tunnel is semianatomic, it is difficult to make a new tunnel in the correct position without overlapping the existing tunnel. For this reason, we have developed a one-stage ACL revision surgery that uses a bone allograft plug. When it comes to choosing a reconstruction technique, we believe that combined intra-articular and extra-articular reconstruction with the iliotibial band is suitable when the hamstring tendons are not available, combined with clinical findings of translational and rotational instability. Because the existing tunnels require reorientation, a new femoral tunnel can be created by outside-in drilling to eliminate the risk of overlap, while an allograft bone plug can be used to fill the overly anterior tibial tunnel and allow us to drill the correct tibial tunnel right away. In our hands, this is a safe and effective technique, but longer follow-up is needed to validate its indications.

Introduction

The retear rate after anterior cruciate ligament (ACL) reconstruction ranges from 4% to 13%.[1-3] Revision of an ACL reconstruction is a difficult procedure that requires an accurate diagnosis and precise treatment strategy.[1-3] This revision can be done as one-stage or two-stage surgery. Several factors must be taken into consideration when making this choice, particularly the size and position of the existing tunnels.[4-6]

The existing tunnels can be divided into three categories: 1) correct anatomic position: no need to change them; 2) incorrect nonanatomic position: the position of the existing tunnel will not interfere with a new, anatomically positioned tunnel; and 3) overlapping semianatomic tunnel: the position of the existing tunnel partially overlaps the new, anatomically positioned tunnel. A one-stage revision can be done in patients whose tunnels are positioned correctly and do not have major osteolysis[7,8] or whose tunnels are nonanatomic, as the risk of overlap is small.[2,9,10]

The most challenging scenario is that of semianatomic tunnels. In this case, the tunnel is not so bad that it can be ignored, but it is not good enough to be revised in its current condition. The problem is improving the tunnel's position, while avoiding tunnel overlap. Some authors advocate for two-stage surgery: a bone graft is used to fill the existing tunnels, and then the ACL is reconstructed later on.[2,7,8] Two systematic reviews have found no differences in the clinical outcomes or retear rate between one-stage and two-stage revisions.[11-13]

One-stage surgery reduces the relative instability period and, thereby, the risk of damaging the meniscus or secondary stabilizers of the knee.[14,15] Also, the health care and social costs are lower for a one-stage procedure.[16-19] Hofbauer et al. and Vaugh et al. found better postoperative functional scores in the patients who underwent a one-stage procedure versus those who underwent a two-stage procedure.[14,15] This suggests that we should aim to do as many ACL revisions as possible as a one-stage surgery.

During one-stage surgery, outside-in drilling of the femoral tunnel prevents overlap with the existing

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The authors report the following potential conflicts of interest or sources of funding: E.C. is a paid consultant for Arthrex.Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received October 11, 2021; accepted November 16, 2021.

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2212-6287/211497

https://doi.org/10.1016/j.eats.2021.11.019

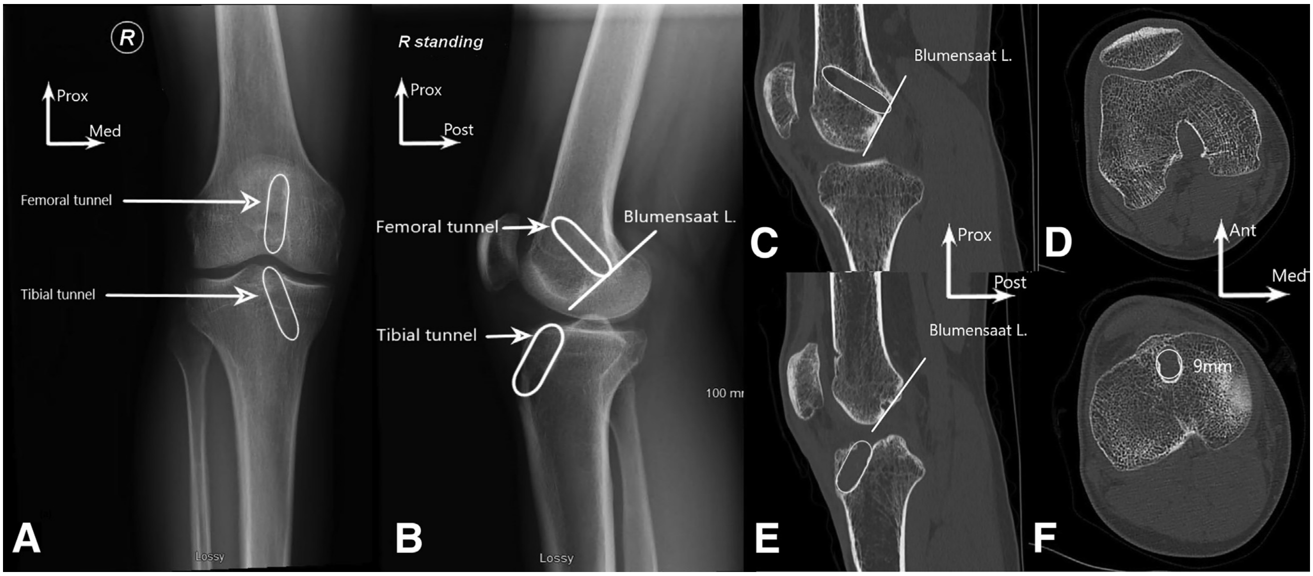

Fig 1. Preoperative evaluation. (A and B) Preoperative radiograph: anteroposterior and lateral views: Too anterior tibial tunnel. (C and D) Preoperative computed tomography (CT) scan: sagittal and axial views: Too anterior semianatomic tibial tunnel without osteolysis (diameter: 9 mm) is shown; there is a high risk of overlap, so we filled the previous tunnel with allograft bone and then drilled a new tibial tunnel in the correct position. (E and F) Preoperative CT scan: sagittal and axial views: Too anterior and vertical nonanatomic femoral tunnel without osteolysis is shown; a new correct anatomic femoral tunnel can be drilled using outside-in instrumentation.

tunnel, even if the femoral tunnel is semianatomic.[13,20,21] Conversely, when the tibial tunnel is semianatomic, it is difficult to make a new tunnel in the correct position without overlapping the existing tunnel. For this reason, we have developed a one-stage revision surgery that uses a bone allograft plug. The aim is to describe our one-stage ACL revision technique that uses allograft bone to correct a semianatomic tibial tunnel.

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Surgical Technique

See Video 1 for the complete surgical technique.

Preoperative Assessment

The assessment starts with a clinical examination that screens for a positive Lachman test and rotational instability, based on the pivot shift test. The next step is to evaluate the previous tunnels with radiographs and computed tomography (CT) scan (Fig 1): Are they in the correct position? Is there any evidence of osteolysis? Does the semianatomic position pose overlap risk? Lastly, an MRI evaluation of the meniscus, collateral ligaments and ACL graft is required (Fig 2).

Indication

Given the failure of the initial reconstruction procedure, clinical rotational instability and the fact that

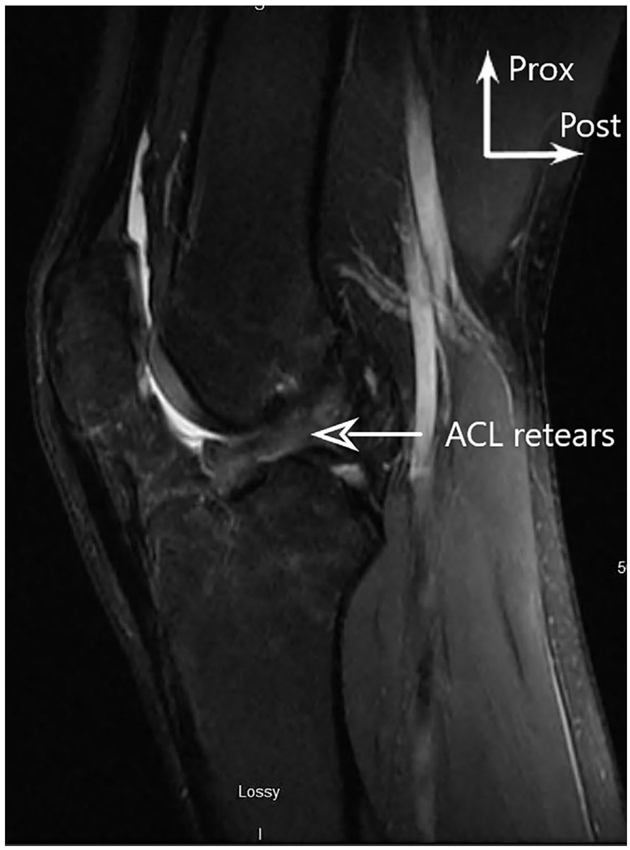

Fig 2. ACL graft retear. Preoperative magnetic resonance imaging with sagittal view. Image shows confirmation of anterior cruciate ligament graft retear without associated meniscal lesion.

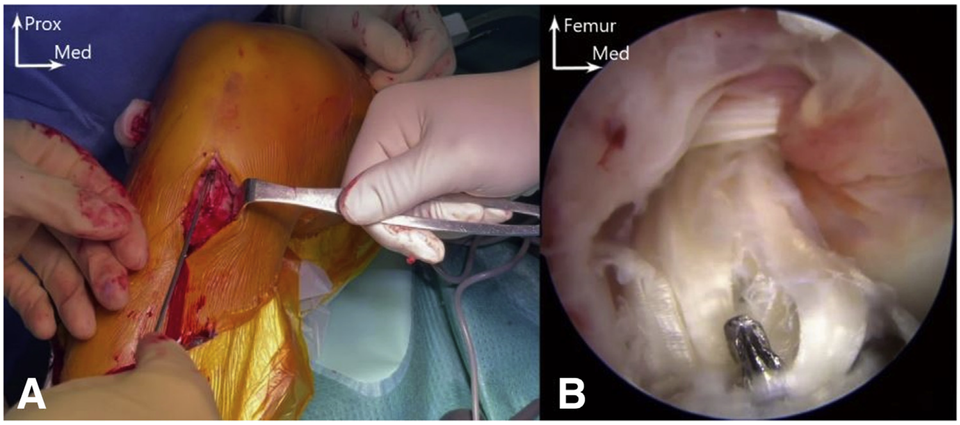

Fig 3. Identification of existing semianatomic tibial tunnel. (A) Intraoperative view showing the K-wire inserted in the existing tibial tunnel (right knee). (B) Arthroscopic view of intra-articular end of tibial tunnel with the K-wire visible.

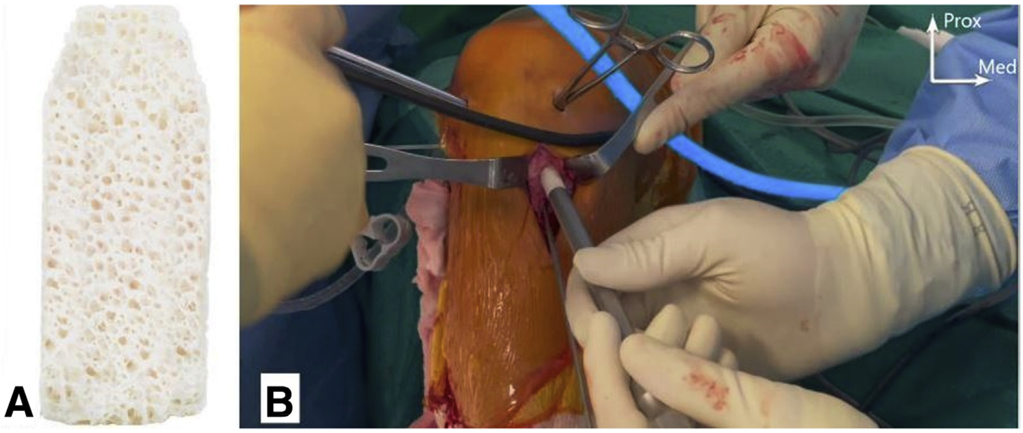

Fig 4. Allograft bone plug. (A) Frontal cut through an allograft bone plug (Biobank, Lieusaint, France). (B) Intraoperative view of allograft bone plug impaction in existing tibial tunnel along K-wire (right knee).

the ipsilateral hamstring tendons are not available, we carry out a combined intra-articular and extra-articular reconstruction with the iliotibial (IT) band.[20] The existing tunnels require reorientation. The new femoral tunnel will be created by outside-in drilling to eliminate the risk of overlap[21] while an allograft bone plug (Biobank, Lieusaint, France) will be used to fill the overly anterior tibial tunnel and allow us to drill the correct tibial tunnel right away.

Patient Positioning

The patient is placed supine with a tourniquet cuff at the base of the thigh. A lateral pad is placed against the cuff. Two L-shaped pads are used for the feet, allowing the knee to be set in 70° to 130° flexion.

Identification and Filling of Semianatomic Tibial Tunnel

Reusing the prior incision, a K-wire is inserted into the existing semianatomic tunnel to view its trajectory (Fig 3). This tunnel is bored out with a drill bit of the same diameter as the tunnel diameter measured on the preoperative CT scan (9 mm here). A cancellous bone plug of the same diameter as the existing tunnel is impacted into the tunnel, along the previously inserted K-wire (Fig 4). Arthroscopy is used to check that the allograft is flush with the articular surface and the exit of the semianatomic tibial tunnel (Fig 5). The K-wire is

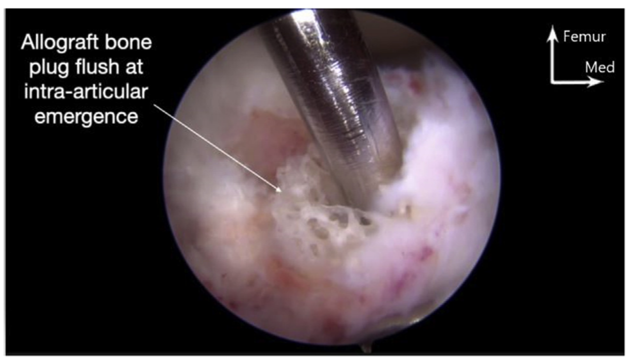

Fig 5. Intra-articular check of allograft bone plug. Arthroscopic view of right knee: Allograft bone plug is flush at intra-articular emergence of existing tibial tunnel with the K-wire.

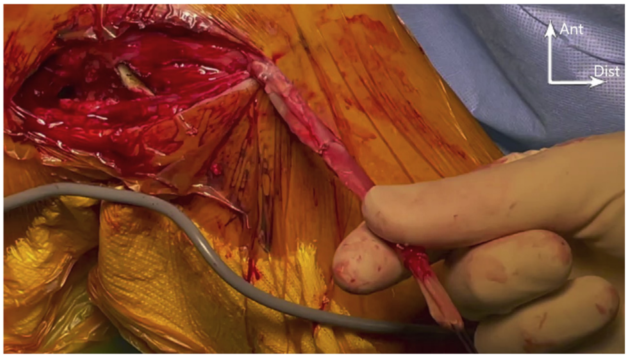

Fig 6. Final ACL graft. Intraoperative lateral view of right knee: anterior cruciate ligament graft augmentation with gracilis allograft and SutureTape (Arthrex, Naples, FL).

left in place throughout the procedure to act as a landmark for the pre-existing tunnel's position.

Graft Harvesting

To harvest the IT band graft, a 10-cm long incision is made starting 2 cm proximal to Gerdy's tubercle. A 15-cm long graft is harvested, keeping its attachment on Gerdy's tubercle intact. In this patient, the gracilis had been harvested for the first ACL reconstruction procedure. In such a case, a semitendinosus allograft is used. The IT band graft is shaped into a tube around the gracilis allograft using SutureTape (Arthrex, Naples, FL) (Fig 6). The diameter of the final graft is measured.

Correction of Existing Femoral Tunnel

The F9 isometric point of Krakow[22] is located 1 cm proximally and slightly behind the femoral condyle. Through an anterolateral approach, the outside-in femoral drill guide (Arthrex, Naples, FL) is positioned, so a K-wire can be inserted between the ACL's femoral footprint and the previously described F9 point. Next, a tunnel of the same diameter as the graft is made with a cannulated drill bit along the K-wire, ignoring the trajectory of the existing tunnel.

Drilling of Anatomic Tibial Tunnel and Graft Passage

Through the anteromedial portal and with the outside-in instrumentation, the K-wire is placed on the ACL's tibial footprint with the best trajectory chosen by the surgeon. A new anatomic tibial tunnel is drilled with a cannulated drill bit of the same diameter as the graft (Fig 7). Next, the scope is inserted in the new tibial tunnel to confirm the presence of bone around the entire tunnel to ensure good fixation (Fig 8).

Using a shuttle suture, the surgeon passes the graft from proximal to distal by the femoral tunnel and then

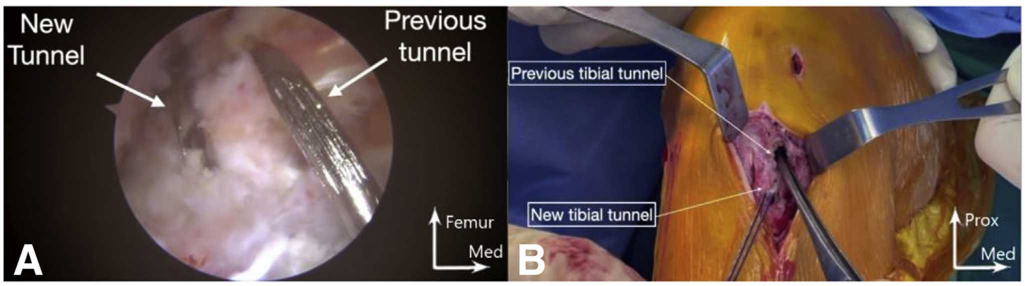

Fig 7. Identification of two tibial tunnels. Arthroscopic (A) and intraoperative (B) views of K-wires in the previous semianatomic tibial tunnel and the new anatomic tibial tunnel

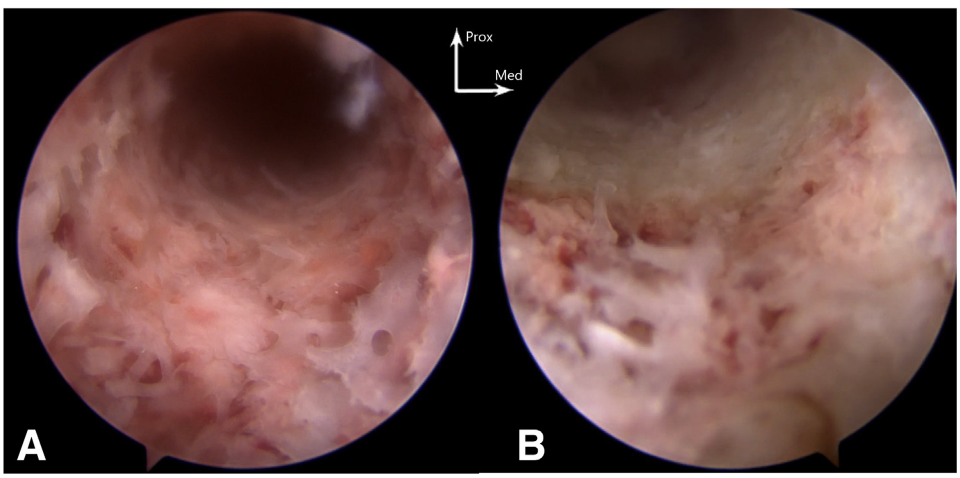

Fig 8. Arthroscopic check of new anatomic tibial tunnel. Arthroscopic views of new anatomic tibial tunnel (A, distal part, and B, proximal part) with bone all around (no overlap with previous semianatomic tibial tunnel).

Table 1. Pearls, Pitfalls, and Risks

Pearls
- Position a K-wire in the existing tibial tunnel to make it easier to drill the new tunnel in an anatomic position.
- Impact the allograft as close as possible to where the tunnel emerges inside the joint.
- The iliotibial (IT) band graft is 1 cm wide distally, 3 cm wide proximally, and is at least 15 cm long.
- If the IT band is too thin, the gracilis (if present) or an allograft tendon (gracilis or semitendinosus) can be added to it.
- The graft is shaped into a tube using SutureTape (Arthrex, Naples, FL).
- The femoral tunnel is drilled outside-in at the Krakow isometric point.
- Insert the scope into the new tibial tunnel to check that bone is present through the tunnel's circumference.
- Transect the intermuscular septum to make it easier to close the IT band by advancing the posterior fascia.

Pitfalls and Risks
- A preoperative computed tomography (CT) scan of the existing tunnels is always done to rule out the risk of severe osteolysis of the tibial tunnel, which would make it impossible to completely fill it with a bone plug and, thereby, compromise graft fixation.
- There is a risk of proximal muscle hernia when harvesting the IT band; the IT band must be closed meticulously after harvesting of graft.
- There is a risk of hematoma at lateral incision; the surgeon needs to release tourniquet at the end of procedure and perform careful hemostasis.
- Risk of iatrogenic lesion to lateral collateral ligament (LCL) when drilling femoral tunnel. This can be prevented by palpating and marking the LCL's position before starting to drill.

in the tibial tunnel. The knee is placed as close to full extension as possible to secure the graft with one interference screw (Biocomposite Interference Screws, Arthrex, Naples, FL) at the femur and then one at the tibia.

Closure

The tourniquet is released, and careful hemostasis is performed. The fascia lata is reclosed using absorbable suture (no. 2 Vicryl, Ethicon). The subcutaneous and cutaneous layers are closed with absorbable suture. The key points and pitfalls of this technique are outlined in Table 1.

Rehabilitation Protocol

All patients are operated on an outpatient basis. The patient's leg is immobilized in an articulated knee splint. If the meniscus is also damaged (bucket-handle tear, radial tear, root tear), no weight bearing is allowed for 4 to 6 weeks. Otherwise, full weight bearing is allowed, and no splint is provided.

Rehabilitation is initiated on the first postoperative day; the goals are to regain joint range of motion and quadriceps muscle function. Gradual return to sports is allowed on the basis of results of isokinetic and functional tests. Typically, straight line sports are allowed after 4 months, noncontact pivot sports are allowed after 6 months, and contact pivot sports are allowed after 9 months.

Discussion

We have described our one-stage ACL revision technique that simultaneously fills and corrects a semi-anatomic tibial tunnel. Our technique has several advantages (Table 2):

1. The existing tibial tunnel is filled completely with allograft bone, whose mechanical properties and architecture are identical to those of fresh bone.[23–25] This allows us to drill a new tibial tunnel without having to worry about overlap.
2. Since the existing tibial tunnel is filled, the revision can be carried out like a primary ACL reconstruction procedure, with no need to worry about the previous tunnel.
3. There is no need to harvest autograft bone from a healthy site, resulting in less morbidity and less pain.
4. One-stage revision requires less time and eliminates the risks, morbidity, and costs of the patient having a second procedure. This also means that a second rehabilitation program is not needed since only one surgical procedure is being done. Lastly, there is a lower risk of secondary stabilizer damage in the knee since the relative instability period between the two surgical stages is eliminated.
5. This technique broadens the indications for one-stage ACL revision to all patients who have semi-anatomic tibial tunnels that are too anterior.

One of the challenges of ACL revision is having to drill new tunnels. A widened tunnel or overlapping between the existing and new tunnel can compromise the tendon graft fixation and, thereby, require two-stage revision with a bone graft.[26] Use of outside-in instrumentation for the femoral tunnel reduces the

Table 2. Advantages and Limitations

Advantages
- Minimal donor site morbidity is achieved without touching the typical autologous bone donor sites (tibial tubercle, iliac crest).
- One-stage anterior cruciate ligament (ACL) revision is possible in all patients who do not have severe osteolysis of the tibial tunnel, which helps to reduce the risk of damage to the secondary stabilizers of the knee and the healthcare costs.
- Any ACL revision technique can be used once the existing tibial tunnel has been filled.
- Outside-in drilling of the femoral tunnel makes it easier to create an anatomic femoral tunnel without overlap, to control the entry and exit points, and to limit the risk of collapse of the posterior cortex.

Limitations
- One-stage tibial fixation is not possible if there is severe osteolysis of the existing tibial tunnel despite use of the bone plug; while this is not very likely, the maximum bone plug diameter is 14 mm.
- Use of allograft bone has increased infection risk and limited availability, and it may not be acceptable to some patients.

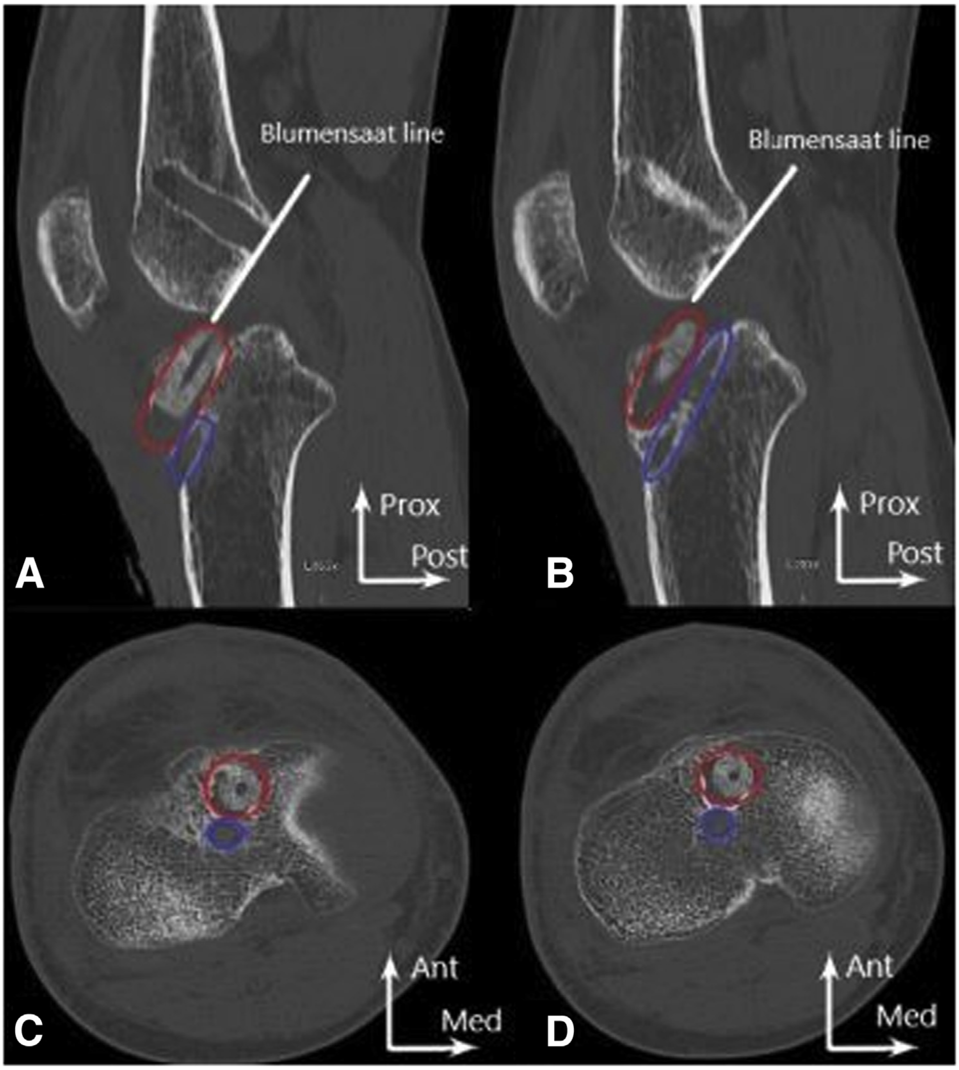

Fig 9. Postoperative computed tomography (CT) scan. (A and B) Postoperative CT scan, sagittal view. Old tibial tunnel filled by the allograft plug (red ellipse) and new anatomic tunnel with interference screw (blue ellipse). (C and D) Postoperative CT scan, axial view. Old tibial tunnel is completely filled by the allograft plug (red circle) and new anatomic tunnel with bone all around it (blue circle)

risk of overlap, helping to control the intra- and extra-articular positioning and reduces the risk of breaking the posterior cortex.[27,28]

The tibial tunnel is filled with a plug of cancellous bone allograft (Biobank, Lieusaint, France). Using their proprietary technology (Supercrit® process), this company obtains sterile[29] and virally inactivated bone grafts that have the same mechanical properties as fresh bone.[23-25,29]

All of the Biobank allograft plugs are 28-mm long cylinders and available in diameters ranging from 9 mm to 14 mm.

Filling the previous tibial tunnel with allograft that is mechanically equivalent to fresh bone eliminates the overlap risk. If the previous tunnel appears to be filled more completely proximally rather than distally as in Fig 9, it should not have any consequence on the hold of the graft. Indeed, biological fixation of an ACL graft occurs over the first few millimeters of the tunnel from the joint side.[30,31]

We have already used this technique in several patients, and we report no specific intraoperative or postoperative problems. However, we need to continue following these patients to have sufficient follow-up in order to validate the effectiveness and safety of this one-stage revision technique using bone allograft.

Conclusion

This one-stage ACL revision technique with bone allograft is useful for correcting a semianatomic tibial tunnel. In our experience, it is a safe and effective technique but requires longer follow-up to formally validate its indications.

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