Technical Note

Single-Bundle Anatomical Hardware-Free Anterior Cruciate Ligament Reconstruction

Jinzhong Zhao, M.D.

Abstract: In anterior cruciate ligament (ACL) reconstruction, fixation of the graft with hardware is a routine procedure. However, in some cases when the hardware is not intended to be used or is unavailable, ACL reconstruction with hardware-free fixation must be the treatment of choice. We introduce a single-bundle anatomical hardware-free ACL reconstruction technique in which a set of Y-shaped femoral tunnels is created for the fixation of the proximal end of the graft over the bone bridge between the 2 outer orifices, and a transtibial ridge tunnel is created to set a suture loop with a knot for the fixation of the distal end of the graft at the suture loop. We believe the introduction of this technique will provide a reasonable option for single-bundle anatomical ACL reconstruction.

In single-bundle anterior cruciate ligament (ACL) reconstruction, the graft is routinely fixed with hardware. However, various complications are related to hardware fixation.[1-3] To avoid these related complications, hardware-free fixations have been introduced in the literature, with press-fit fixation as the main method.[4,5] Here, we introduce an all-suture hardware-free fixation technique for single-bundle anatomical ACL reconstruction that we consider simpler than the press-fit fixation. This technique is indicated when ACL reconstruction is needed but hardware for graft fixation is unavailable, such as in the case of a preoperative overlooked ACL injury, to provide a salvaging method. It is also indicated when hardware fixation is not intended to be used either by the patients or the surgeons due to various reasons. Our clinical experience indicates this technique is as effective as ACL reconstruction with hardware fixation.

From the Department of Sports Medicine, Shanghai Sixth People's Hospital, Shanghai Jiao Tong University, Shanghai, China.

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Address correspondence to Jinzhong Zhao, M.D., Department of Sports Medicine, Shanghai Sixth People's Hospital, Shanghai Jiao Tong University, 600 Yishan Rd., Shanghai 200233, China. E-mail: zhaojinzhong@vip.163 or jzzhao@sjtu.edu.cn

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Surgical Technique (With Video Illustration)

The surgical steps of the current technique are like anatomical transtibial single bundle transtibial ACL reconstruction with hardware fixation.[6] The procedure is performed with the patient in the supine position. A post is placed at the lateral side of the thigh to provide support when the knee is flexed (Table 1).

Grafting Harvesting and Preparation

The semitendinosus tendon and gracilis tendon are harvested and prepared to make a 7-stranded graft by using 3 no. 2 ultra-high molecular weight polyethylene sutures (Smith & Nephew; Andover, MA) as traction and fixation sutures on the proximal end (Fig 1, Video 1). The graft is composed of a 4-stranded semitendinosus tendon and a 3-stranded gracilis tendon with a usual length of >7 cm and a usual width of 8 to 10 mm.

Locating the Tibial and the Femoral Tunnels

The inner orifices of the tibial and femoral tunnel are located respectively in the middle of ACL tibial and femoral footprints and marked with a radiofrequency probe just as in routine anatomical transtibial single-bundle ACL reconstruction. When there are no remnants at the footprints that can be used references, the tibial tunnel is located at the middle of the anterolateral slope of the medial tibial eminence, and the femoral tunnel is located at a point 5 mm anterior and proximal to the lowest point of the lateral wall of the femoral notch.[6]

Table 1. Step-by-Step Procedure of Single-Bundle Anatomical Hardware-Free ACL Reconstruction

1. The semitendinosus tendon and the gracilis tendon are harvested. A 7-stranded graft is made from these 2 tendons.
2. The inner orifices of the femoral and tibial tunnels are located and marked with a radiofrequency probe.
3. The tibial tunnel is created, angulating the sagittal plane at approximately 40° and the tibial axis at approximately 50°, with a projection point on the lateral wall of the femoral notch within 5 mm distance to the desired location of the femoral tunnel.
4. A K-wire is drilled into the marked point of the femoral tunnel though the tibial tunnel. The thick femoral socket is created.
5. The K-wire is overdrilled with a 4.5-mm cannulated drill. The straight thin part of the femoral tunnels is created.
6. A K-wire is placed to the bottom of the thick femoral socket through the far anteromedial portal and drilled through the lateral cortex at the largest angle to the straight thin part of the femoral tunnel, to create a diverging thin part femoral tunnel.
7. Guide sutures are placed through the tibial tunnel and the bifurcating femoral tunnels. The fixing sutures from the proximal end of the graft are pulled into the tunnels with the guide sutures.
8. The graft is pulled into the bottom of the femoral socket.
9. The proximal fixing sutures are exposed in the lateral gutter and tied over the bone bridge between the 2 outer orifices.
10. A transtibial ridge tunnel is created. A suture loop with a large knot is set through this tunnel.
11. The sutures from the distal graft end are tied at the suture loop.

ACL, anterior cruciate ligament.

Creating the Tibial Tunnel

A 5-mm offset point-to-hole tibial tunnel—locating device (Aesculap, Tuttlingen, Germany) is placed into the joint through the anteromedial portal. With the hook of the device placed at the correct area, the spatial position of the tunnel-locating device is adjusted to create a tibial tunnel in a plane that angulates the sagittal plane at approximately 40°. In the tibial tunnel plane, the tibial tunnel angulates the tibial axis at approximately 50°.[6]

A K-wire is drilled through the tibia to the femur to ensure that it can reach a point within 5 mm from the femoral tunnel center. Microadjustment may be needed through multiple tries. The K-wire is overdrilled to create the expected size of the tibial tunnel.[6]

Creating a Y-Shaped Femoral Tunnel

Through the tibial tunnel, a K-wire is drilled to the location of the femoral tunnel. The K-wire is first overdrilled with a drill of the same size as the graft to create a femoral socket (thick femoral tunnel part) to the expected length (which is usually 25-30 mm), and then overdrilled with a 4.5-mm drill through the outer cortex to create the straight. thin femoral tunnel part.

Then, a far anteromedial portal is created. The knee is flexed to 120°. A K-wire is placed through the far anteromedial portal to the bottom of the thick femoral tunnel part and drilled through the lateral cortex with the greatest angle to the direction of the straight thin femoral tunnel part. The K-wire is overdrilled with a 4.5-mm cannulated drill. Thus, a set of bifurcate femoral tunnel complexes, which include a large tunnel segment, a straight, thin tunnel part, and a diverging thin tunnel part, is created (Figs 2 and 3).

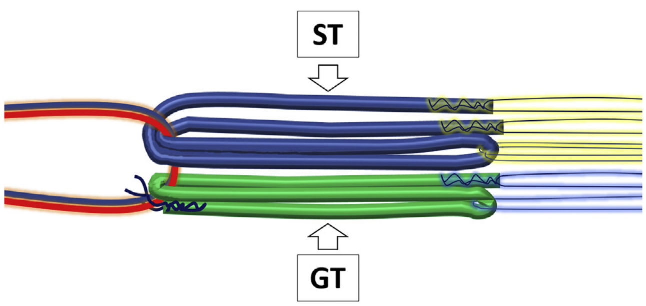

Fig 1. Illustration of the fabrication of a 7-stranded graft from the semitendinosus tendon (ST) and the gracilis tendon (GT).

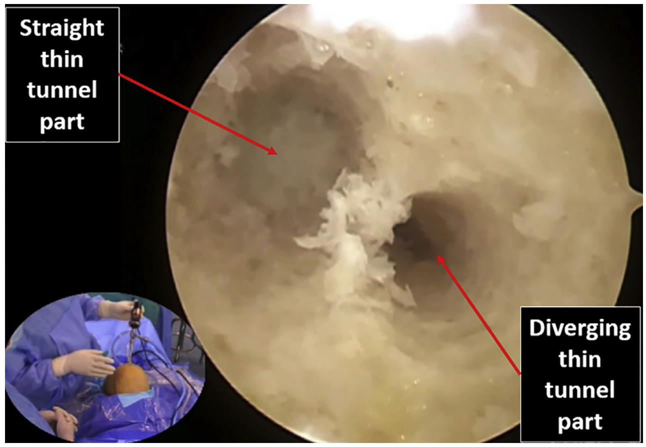

Fig 2. Arthroscopic intrafemoral tunnel view of left knee through the anteromedial portal indicating the straight and diverging thin tunnel parts.

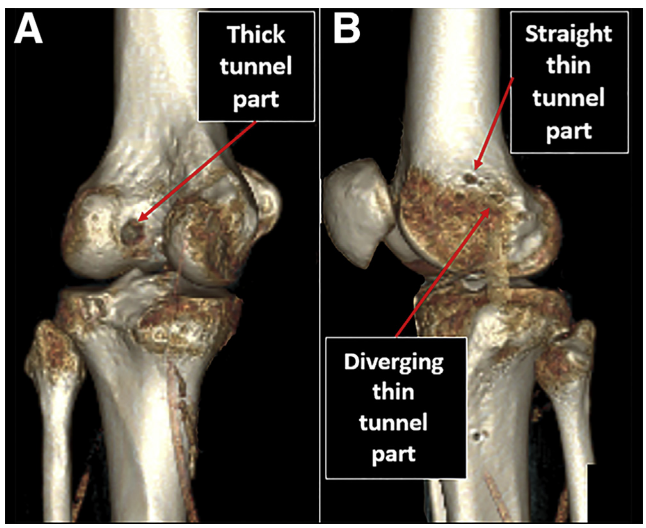

Fig 3. Postoperative computed tomography images indicating the orifice of the thick femoral tunnel part (A, posterior medial view of left knee) and the orifices of the straight and diverting thin tunnel parts (B, lateral view of the right knee).

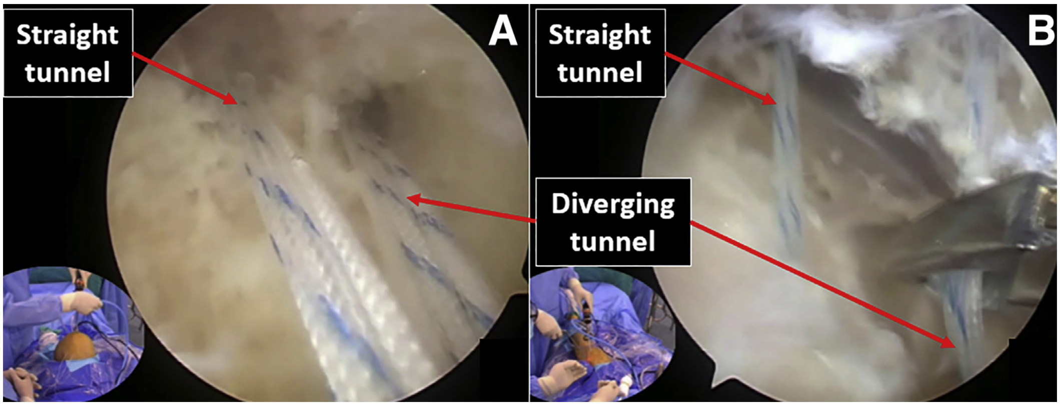

Fig 4. Passing the proximal fixing futures though the femoral tunnels (A, arthroscopic intrafemoral tunnel view of left knee through the anteromedial portal) and exposing them at the outer orifices (B, arthroscopic view of the lateral gutter of left knee through the anterolateral portal).

Graft Implantation

In hyperflexion of the knee, a guide pin is placed in through the far anteromedial portal into the thick femoral socket and through the diverging part of the femoral tunnels. Then, a guide suture is placed in with the guide pin. The distal end of this guide suture is pulled through the tibial tunnel out. The knee is set at 90° of flexion. Another guide suture is placed through the tibial tunnel, the thick femoral socket, and the straight part of the thin femoral tunnels.

Then, suture limbs at the proximal end of the graft are pulled through the tibial tunnel and the thick femoral socket, with the 2 limbs of each suture respectively through the straight and the diverging thin parts of the femoral tunnels (Fig 4A). By pulling the fixation sutures, the graft is pulled through the tibial tunnel into the end of the femoral socket.

Proximal Fixation

The knee is set in full extension. A superolateral patella portal is created approximately 2 cm from the superolateral pole of the patella. With tension of the fixation sutures, a shaver is placed in through the superolateral portal to remove the synovium in the lateral gutter to expose the outer orifices of the femoral tunnels and the fixing sutures (Fig 4B). Then, the suture limbs from the straight tunnel part are tied to their counterparts from the diverging tunnel part over the bone bridge between the 2 orifices (Fig 5). The graft is pulled back to complete proximal fixation.

Distal Fixation

A 4-cm long suture loop with a large knot is made from multistrands of a no. 2 ultra-high-molecular-weight polyethylene suture (Fig 6). A 3.0-mm transverse transtibial ridge tunnel is made with a K-wire at a site distal to the distal orifice of the tibial tunnel that accommodating the graft. The suture loop is placed through the transtibial ridge tunnel from lateral to medial side to set the knot over the lateral orifice. At full extension, the sutures from the distal end of the grafts are tied to this suture loop to complete the distal fixation of the graft (Fig 7).

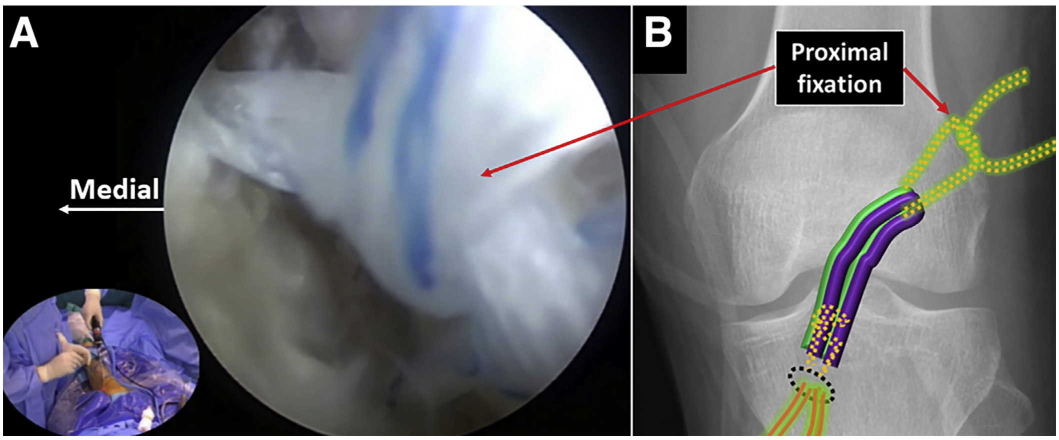

Fig 5. Proximal fixation of the graft by tying the fixing sutures over the bone bridge between the outer orifices. (A) Arthroscopic view of the lateral gutter of left knee through the anterolateral portal). (B) Illustration.

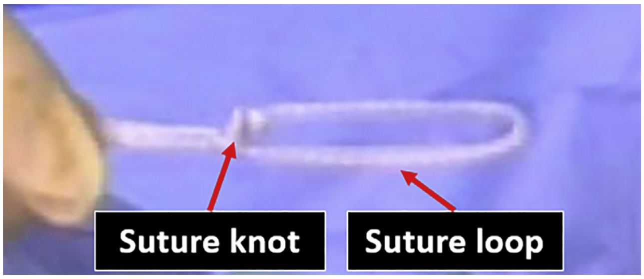

Fig 6. A suture loop with a knot is made with multistrand ultra-high-molecular-weight polyethylene sutures.

Discussion

The most critical point of this technique is fabrication of the bifurcate tunnel complex on the femoral side and obtain enough long a bone bridge between the 2 outer orifices. The current technique is suitable for single-bundle anatomical ACL reconstruction, in which the femoral tunnel is located in the anatomic center of the ACL footprint, and it is easy to create the diverging part of the femoral tunnels. It is not suitable for isometric ACL reconstruction, in which the femoral tunnel is located too deep in the femoral notch, and it is unreliable to create the diverging femoral tunnel part through the narrow femoral notch. In addition, it is suitable for ACL reconstruction with a large graft (at least 8 mm)

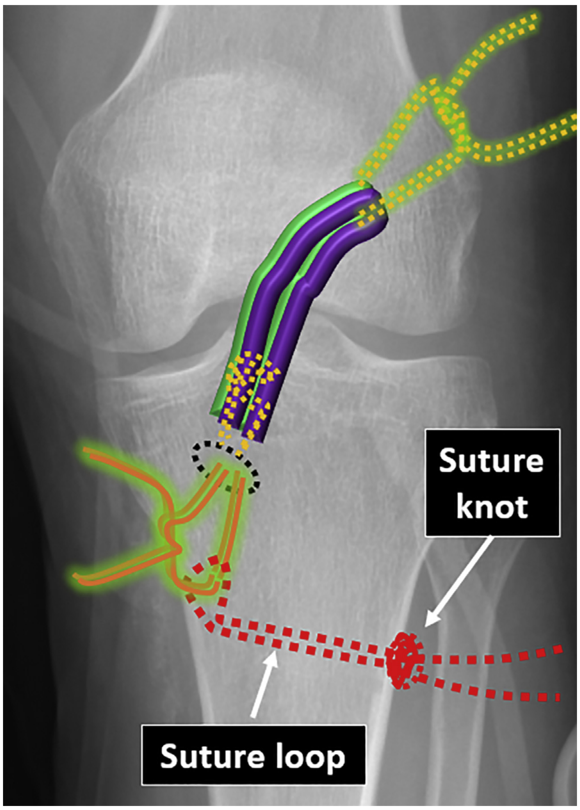

Fig 7. Illustration of distal fixation of the graft (left knee). The fixing sutures from the graft are tied to a suture loop with a knot, which is set at a transtibial ridge tunnel.

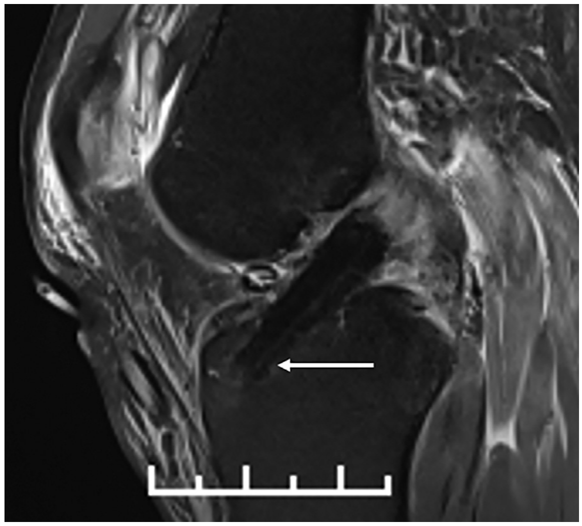

Fig 8. Postoperative magnetic resonance image indicating the thick graft going to the shallow tibial tunnel (sagittal view of left knee). Arrow indicates the shallow tibial tunnel.

Table 2. Pearls and Pitfalls of Single-Bundle Anatomical Hardware-Free ACL Reconstruction

Pearls	Pitfalls
1. Enough graft size is needed for ensure final graft strength. Thus, a graft size ≥8 mm is the best choice. When a 7-stranded semitendinosus tendon −gracilis tendon graft is still not large enough, we recommend using the anterior half of the peroneus longus tendon as a supplement.	1. During creation of the diverging femoral tunnel, the knee is flexed to 120°. Insufficient knee flexion will result in a too-posteriorly located lateral orifice.
2. During creation of the tibial tunnel, elevation of the tibial-aiming device to create a shallow tibial tunnel is the most critical step. Drilling the K-wire into the joint can help evaluate the projection of the tibial tunnel.	2. During exposing the fixing sutures with a shaver at the lateral gutter of the knee, the sutures should be kept in tensioning to prevent suctioning and cutting of the sutures by the shaver.
3. Anatomical instead of isometric femoral tunnel location is performed.	3. The knot in the suture loop should be large enough compared with the to-be-created transtibial ridge tunnel. Otherwise, the suture loop cannot be securely set at the transtibial ridge tunnel.
4. The far anteromedial portal should be medial enough to maximize the angle between the bifurcating limbs of the femoral tunnels.	4. The graft is fixed in full extension to prevent extension limitation.

ACL, anterior cruciate ligament.

Table 3. Advantages and Disadvantages of Single-Bundle Anatomical Hardware-Free ACL Reconstruction

Advantages
1. The technique can be used as salvaging or planned procedure when hardware for graft fixation is not available or is not intended to be used.
2. Anatomical single-bundle ACL reconstruction can be realized.
3. No hardware or implant is needed.
Disadvantages
1. Creation of the diverging part of the femoral tunnel may be difficult in case of femoral notch stenosis.
2. There may be suture cutting into the bone bridge at the proximal side, resulting in fixation loosening.
3. Distal fixation may fail when the transtibial ridge tunnel is too large compared with the suture knot in the suture loop.

ACL, anterior cruciate ligament.

because it is difficult to create the diverging part of the femoral tunnel when the thicker femoral socket is still too small, corresponding to too-small a graft.

The current technique is a special anatomical transtibial ACL reconstruction. To create the straight femoral tunnel part through the tibial tunnel, the projection of the tibial tunnel must be accurately set when it is created. The critical point to obtain appropriate projection of the tibial tunnel is creating a shallow tibial tunnel through the elevation of the tibial tunnel-aiming pin (Fig 8 and Table 2).

On the tibial side, the distal fixing sutures from the graft can fix to the tibial ridge directly following the creation of the transtibial ridge tunnel through wrapping the sutures around the tibial ridge. However, in this way, the suture knot is always not so securely tied, especially when the anteromedial side of the proximal tibia is not flat. Thus, we set a suture loop with a large knot at the transtibial ridge tunnel to provide an anchorage point for the fixing sutures. Our clinical experience indicates the fixing suture from the distal end of the graft can be tied to the suture loop tightly. However, the knot in the suture loop must be large enough to securely set over the lateral tunnel orifice. The pearls and pitfalls and advantages and disadvantage of the current technique are listed in Tables 2 and 3, respectively.

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