TENDON PREPARATION FOR CRUCIATE LIGAMENT RECONSTRUCTION
Using the Semitendinosus and Gracilis Tendons

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Introduction

Injuries of the anterior cruciate ligament (ACL) are among the most common injuries of the knee. They may lead to instability with secondary damage to the articular cartilage and menisci. Consequently, patients who complain of subjective instability or have already developed instability-related cartilage or meniscus damage should undergo an ACL reconstruction to stabilize the knee.

Some years ago it was very common for surgeons to reconstruct the ACL with the patellar tendon and attached bone plugs ("BTB" technique). But donor-site problems at the front of the knee have led to the increasing utilization of the semitendinosus tendon (ST tendon), which may be combined with the gracilis tendon (GR tendon) if necessary. Because the graft is composed of separate tendons, the tendons must be meticulously prepared to obtain the definitive graft (see Graft Preparation). Of course, the length and thickness of the graft will depend on the dimensions of the harvested tendons. But it is still possible to alter the graft length when necessary (e.g., in revisions) by also harvesting the GR tendon.

Every cruciate ligament reconstruction raises the problem of how to anchor the harvested graft in the bone tunnels. This must be done with great care and precision, especially with soft-tissue grafts. Hamstring tendons (the semitendinosus and gracilis) fall under the heading of soft-tissue grafts. Interference screws are one method that can be used for the fixation of these grafts. The screw is driven into the space between the graft and tunnel wall. Metal screws were widely used in the past, but most surgeons today prefer bioabsorbable screws. When screw fixation is used alone, a screw of adequate length and diameter must be used to ensure an adequate strength of graft fixation. This also means that a sufficiently long portion of the graft must be available within the bone tunnel for the screw to engage. Thus it is essential to prepare a graft of sufficient length. This makes it necessary to harvest the GR tendon as well, resulting in increased morbidity and weakening of medial structures.

One alternative is to place the fixation at the level of the cortical bone using fixation buttons, for example ("button fixation"). The main advantage of this technique is that a shorter graft can be used, eliminating the need to harvest a second tendon. This places the fixation site away from the joint line, however, which predisposes to postoperative tunnel widening and is less than optimum for tendon-to-bone healing. It is important to note that every fixation technique has specific advantages and disadvantages. To reduce the disadvantages of a given fixation technique while utilizing its advantages, more and more surgeons are performing hybrid fixations that combine interference screws with cortical buttons. Although hybrid fixation involves somewhat higher costs for fixation materials, it allows for a stronger and more controlled fixation, especially at the level of the joint line, and the "aperture fixation" creates more favorable conditions for tendon-to-bone healing.
Graft Preparation

**Instrumentation**

The harvested tendon requires preparation before it can be used as a graft for cruciate ligament reconstruction. A special instrument set is used to prepare the tendon for the desired fixation technique.

The **instrument set for graft preparation** has the following components:
- Tendon board ① with cleaning station, measuring scale, and slide rail
- Clamp fixtures ② for mounting the tendon ends
- FLIPPPTACK® holder ③
- Button slide ④
- Tensioning slide ⑤
- PLESTER Elevator ⑥

**Hamstrings**

Reconstruction of the anterior cruciate ligament requires a minimum graft length to ensure an optimum reconstruction.

The **minimum graft length** is defined as follows:
- 60 mm (standard)
- 65 mm (for patients taller than 180 cm)

Several criteria are used in determining the length of the harvested tendon. The most important considerations are the strand configuration that will be used and whether both hamstrings will have to be harvested.

When the “M” technique is used (one tendon folded to an M shape), the harvested tendon length must be at least 240 mm to provide an overall graft length of 60 mm (240 mm divided by 4 strands). Additional criteria are the thickness of the harvested tendon and the proposed fixation technique. If the harvested tendon is of very good quality and if it would be too thick in a four-stranded configuration, a three-strand technique could be used as an alternative, although this is rarely done in practice.

A longer graft length (approximately 80 mm) is recommended in cases where the graft will be fixed in the bone tunnel with interference screws alone. The longer graft is also recommended for revisions.

Grafts are distinguished based on the number of strands in the final construct. The options range from three-stranded grafts (very rare in practice) to six-stranded grafts. Four-strand grafts are most commonly used (Fig. 2).

**Overview of Strand Techniques for Semitendinosus and Gracilis Tendon Grafts**

- a Four-strand graft: M technique
- b Four-strand graft: two ST tendon loops
- c Four-strand graft: one ST tendon loop plus one GR tendon loop
- d Five-strand graft
- e Three-strand graft
- f Six-strand graft

(From Strobel and Zantop 2010, with kind permission)
Cleaning and Suturing the Grafts

The harvested tendon is placed on the cleaning station of the tendon board and is freed of adherent muscle tissue with a PLESTER Elevator (Fig. 3).

Next, unstable tendon ends are removed and the effective length of the tendon is measured on the built-in scale (Fig. 4). The quality and length of the harvested tendon will determine the rest of the preparation technique (see also Fig. 2).

Regardless of the proposed graft configuration, the tendon is mounted in the fixation clamps on the slides (Fig. 5). The slides are then positioned on the rail so that the tendon is mounted under tension. The tendon is again scrutinized for any unstable elements, which are removed.
Next the two tendon ends are whipstitched with nonabsorbable suture material (Fig. 6). Then three or four reinforcing stitches are run inward from the end of the tendon and back out again. Make sure that the reinforcing stitches are placed between the initial whipstitch sutures. They will keep the tendon from splaying open while helping to compress and secure the sutures.

If the gracilis tendon is used in addition to the semitendinosus, the lead sutures should be tagged with knots (Fig. 7) so that the sutures can be accurately paired up later for threading through the ENDOTACK®. Even when the ST tendon is used alone, knots should still be tied to mark the graft limbs.

Always follow this rule:
- Suture pair with one knot  ➔  ST tendon
- Suture pair with two knots  ➔  GR tendon

The lead sutures from the graft ends are pulled apart manually with maximum tension to seat the suture material firmly in the tendon tissue (Fig. 8). Five to 10 strong tugs should be sufficient. If the suture tears out, the tendon end can be resutured without difficulty.

If a suture does tear out, it is still easy to replace at this stage. But if a lead suture tears out after graft passage, it can be very difficult to grasp the loose tendon end and anchor it under tension. This is why great care is taken to ensure that the lead sutures are securely placed prior to graft passage.
Preparation of the Fixation Button with the FLIPPTACK® Holder

Graft fixation is accomplished with two fixation buttons. The FLIPPTACK® is used on the femoral side of the reconstruction, the ENDOTACK® on the tibial side. Both of these fixation buttons are connected to the graft with suture material. The connection between the graft and FLIPPTACK® is critically important, both for graft fixation and for controlling the graft inset depth in the femoral tunnel.

The FLIPPTACK® holder is used to mount the fixation button on the tendon board and to facilitate button preparation. It is easier to thread the sutures through the FLIPPTACK® when the device has been fitted into its holder (Fig. 9).

A fixation suture (28729 FC, KARL STORZ, Tuttlingen, Germany) is threaded through the two center holes of the FLIPPTACK® (Fig. 10a). One end of the suture is again passed through the same holes (Fig. 10b) to form an open double loop (Fig. 10c).
Next, a heavy-duty fixation suture is threaded through one of the outer holes of the FLIPPTACK® to function as the passing suture (Fig. 11a).

A No. 2 suture of a contrasting color is passed through the second outer hole to serve as the flipping suture (Fig. 11b). Make sure that the sutures in the outer holes are approximately the same length.
The prepared FLIPPTACK® in its holder is mounted on the button slide of the tendon board. The button slide is positioned at the end of the rail (Fig. 12a).

For further preparation of the tendon, a double loop is formed and secured with a suture clamp or needle holder. The double loop is placed close to the zero line on the measuring scale to simplify graft preparation (Fig. 12b).
Strand Techniques

M Strand with the Semitendinosus Tendon

This graft is created by folding one long ST tendon into an M shape. The harvested ST tendon is cleaned and its ends sutured as described (Fig. 13).

In the following pictures, a braided polyester cord was used as tendon graft substitute.

With the lead sutures placed, the folded tendon is passed through the double loop of the FLIPPTACK® mounted on the button slide (Fig. 14a).

Next, a fixation suture is passed through the tendon loop. Tension is placed on the graft, and the lengths of the graft limbs are equalized (Fig. 14b).
The lead sutures are arranged in pairs and threaded through the ENDOTACK® as shown (Fig. 16).

- One end of the white suture and one knotted lead suture are threaded through each of the holes in the ENDOTACK®. Make sure that the tubular part of the ENDOTACK® is pointing toward the graft!

After the ENDOTACK® has been mounted in place, the lead sutures are wound around the knob of the tensioning device and secured with a special clamp (Fig. 17). The clamp has special atraumatic jaws designed to prevent damage to the lead sutures.

Graft tensioning can be facilitated by having an assistant press the spring at the other end of the board to temporarily ease the tension on the graft (Fig. 18).

Now the double loop is pulled tight, and the graft diameter (see p. 21) is measured!

The lead sutures should be clamped very carefully to avoid damage and prevent later tearing of the fixation sutures. Make sure that the graft is pretensioned with the femoral end close to the zero line.
Three-Strand Graft

A three-strand graft can be used in cases where a very thick but short ST tendon has been harvested.

After the tendon has been cleaned and whipstitched, it is folded into three equal-length limbs. One limb of the graft is passed through the double loop of the FLIPPTACK® (Fig. 19).

Next, a fixation suture is passed through the free graft loop (Fig. 20). At this point one sutured end of the graft is pointing toward the FLIPPTACK®, the other sutured end of the graft and the fixation suture are pointing toward the tensioning slide, so that the overall graft has an S-shaped configuration.

One limb of the green lead suture is now threaded through the two center holes of the FLIPPTACK®, which are already occupied by the double loop (Fig. 21a).
The ends of the lead suture are now joined to form a loop, which is secured with a needle holder (Fig. 21b). Care should be taken that the sutured limb of the graft does not extend past the graft loop.

Next, one lead suture and one fixation suture from the other end of the graft are paired and passed through the ENDOTACK® (Fig. 22).

The graft is pretensioned on the tendon board with the tensioning slide (Fig. 23).

Make sure that the graft is pretensioned with the femoral end close to the zero line.
A four-strand graft consists of one ST tendon combined with a GR tendon, or one ST tendon that has been cut in half (Fig. 24).

Note the following:
- Suture pair with one knot → ST tendon
- Suture pair with two knots → GR tendon

When the ST tendon is cut in half:
- Suture pair with one knot → thick tendon
- Suture pair with two knots → thin tendon

The sutured tendons are passed through the prepared double loop and their lengths are equalized (Fig. 25). The ENDOTACK® is then threaded over the lead sutures. As noted above, the tendons are identified by knots on the lead sutures to help arrange them for threading through the ENDOTACK®. One pair of sutures with two knots and one pair with a single knot are passed through each of the holes in the ENDOTACK®.

The graft is pretensioned on the tendon board (Fig. 26).

Pretension the graft with the femoral end close to the zero line.
A five-strand graft consists of the ST tendon and the GR tendon (Fig. 27). This configuration is most often used for revision procedures and in reconstructions of the PCL. The advantage of this technique is that it provides a graft length of 80 mm or more.

The ST tendon forms three of the strands and the GR tendon forms two strands.

As in the three-strand technique, lead sutures are placed in the ends of both tendons. Two-thirds of the ST tendon is passed through the Ethibond double loop and arranged in an S shape on the tendon board (Fig. 28a).

Next, the GR tendon strand is passed through the loop (Fig. 28b).
A fixation suture is passed through the free loop of the ST tendon. The five strands of the graft are easily identified on the tendon board (Fig. 29).

The next step is to thread the lead sutures and fixation suture through the holes of the ENDOTACK® in pairs. The sutures are then secured over the knob of the tensioning device on the tensioning slide. Meanwhile the other end of the graft is held securely on the rail to maintain a uniform length of the graft limbs (Fig. 30).

Next the free lead sutures from the ST tendon are threaded through the two center holes of the FLIPPTACK® and formed into a loop (Fig. 31).

The GR tendon is now carefully placed under tension. The sutures are held in place with a needle holder (Fig. 32). The position of the button slide on the rail of the tendon board can be adjusted to help tension the graft.

Pretension the graft with the femoral end close to the zero line.
Six-Strand Graft

It is rarely necessary to prepare a six-stranded graft. This technique should be considered when the harvested tendon has an inadequate diameter and it is necessary to add the GR tendon to the graft construct.

The six-strand graft consists of a four-strand graft plus a loop of GR tendon. Thus the preparation differs from the four-strand technique only in the last two steps.

Given the bulk of the suture material, the M technique should be used for the four-strand component.

After the ST tendon has been mounted as in the M technique, the sutured GR tendon is passed through the double loop (Fig. 33). The lead sutures and fixation suture are threaded through the holes of the ENDOTACK® in pairs.

The lead sutures are then wound around the knob of the tensioning device and secured with a clamp, and the double loop is pulled tight and fixed with clamp for further preparation (Fig. 34).

Pretension the graft with the femoral end close to the zero line.
Graft Diameter

The accurate determination of femoral graft diameter is of critical importance for sizing the bone tunnels. Good graft integration can occur only if a good press fit is obtained between the graft and tunnel wall. The tibial graft diameter is also precisely determined and is usually 1 mm larger than the femoral diameter. A tendon sizing device is used to measure the diameter of the prepared graft.

With the graft construct mounted under tension, the tendon sizing device is introduced over the sutures of the double loop and is passed completely over the graft from its femoral to tibial end (Fig. 35). The diameter of the selected aperture should be read before the device is placed on the tendon graft, and the aperture with the correct reading should just fit snugly over the graft.

If the graft does not completely fill the aperture in the sizing device and leaves a visible gap (Fig. 36), the next smaller aperture should be tried.

The sizing device is scaled in 0.5-mm increments so that the diameter can be measured as accurately as possible (Fig. 37).
Graft Preparation

While the graft is being prepared, the surgeon reams the femoral bone tunnel to the 4.5-mm diameter necessary for the FLIPPTACK® and then measures the tunnel length. This parameter is of key importance for further graft preparation to ensure that the graft and FLIPPTACK® will pass snugly through the bone tunnel.

The tendon board bears length markings along the slide rail to simplify further graft preparation for passage into the femoral tunnel.

The total length of the graft can be divided into three segments designated a, b and c:

- Segment a is inside the femoral tunnel (at least 15 mm long, preferably 20 mm).
- Segment b is intra-articular (approximately 20–33 mm, depending on the size of the joint).
- Segment c is inside the tibial tunnel (at least 20 mm).

These three segments are indicated on the slide rail so that they can be quickly and easily identified.

The rail also bears a flip mark that can serve as an additional reference point for graft passage.

Measuring Scale

The tendon board has an integrated measuring scale that is of significant help during graft preparation. The scale features several important reference lines (Fig. 38a-d):

- **Zero line.** This represents the bone line. The numbers to the left of the zero line indicate graft length outside the femoral tunnel, while the numbers to the right of the zero line denote the length of the femoral tunnel.
- **Flip line.** This line is located 7 mm to the left of the zero line, placing it outside the femoral tunnel. The flip line helps to define the future inset depth of the graft and ensure that the fixation button will clear the femoral cortex.
- **Inset depth.** The standard inset depth is 20 mm. It should be reduced to 15 mm for shorter grafts and increased to 22 mm for longer grafts (>80 mm). Additional markings along the 20-mm femoral segment were placed on the measuring scale to permit rapid identification of the graft inset depth in the femoral tunnel.

After the length of the femoral tunnel has been determined, the femoral tunnel length can be set on the slide rail with the button slide (black mark = indicator for exact FLIPPTACK® position), and tendon preparation can be completed quickly and easily using the line on the measuring scale.
The button slide is positioned on the slide rail according to the measured length of the femoral bone tunnel. In the example shown, the tunnel length is 42 mm. With traction placed on the double loop of the fixation suture, the graft is pulled toward the FLIPPTACK® until the end of the graft reaches the 20-mm mark (Fig. 39). This is the segment that will be inside the femoral tunnel. If a different inset depth is required, it is easily set by using the measuring scale as a guide.

The first knot is fixed with a needle holder and then secured with a second knot tied counter to the first (Fig. 40a).

A maximum of 5 or 6 additional knots are tied (Fig. 40b).
The femoral end of the graft is additionally stabilized with circumferential sutures of absorbable USP 2-0 material. The next step is to mark the flip line on the graft. **The location of the flip line** is clearly indicated on the slide rail of the tendon board (Fig. 41a). The mark is placed 7 mm from the zero line and is therefore outside the femoral tunnel. The mark indicates how far the graft must be pulled into the femoral tunnel so that the FLIPPTACK® will emerge from the tunnel before it is flipped over the femoral cortex.

The mark is drawn all around the circumference of the graft (Fig. 41b).

At this point the graft is ready for passage into the bone tunnel (Fig. 42). The zero line can also be drawn around the graft circumference to provide an additional reference line. This line indicates how far the graft should be pulled back to seat the FLIPPTACK® against the femoral cortex.
Double Bundle: Two Strands

Graft preparation for a double-bundle reconstruction employs the same tendon board as for a single-bundle reconstruction. After the grafts have been cleaned and their lengths determined, a special double-bundle rail can be installed on the tendon board to allow for simultaneous preparation of the posterolateral (PL) and anteromedial (AM) grafts (Fig. 43). This setup makes the preparation more comfortable and practical since it is much easier to distinguish between the AM and PL bundles.

Often it is sufficient to harvest the ST tendon alone for preparation of the AM and PL grafts, provided the tendon is at least 28 cm long.

The tendon is divided into two strands 12 cm and 16 cm long (Fig. 44). Folding each strand once will yield two grafts with the following lengths:

- PL bundle = 6 cm
- AM bundle = 8 cm

The tendon ends are whipstitched as in a single-bundle reconstruction.

Use the distal, thinner portion of the tendon for the PL bundle and the proximal, thicker portion for the AM bundle!

The tendon board with the extra rail is prepared for a double-bundle setup. Both FLIPPTACKS® with their double loops are prepared and placed on the tendon board using the same technique as for a single-bundle reconstruction (Fig. 45).
Both bundles are successively passed through the double loops, and each is arranged to form a double-stranded graft (Fig. 46). A standard routine should be followed to minimize errors. The steps should always be carried out in the same sequence during preparation of the two grafts (the AM first, followed by the PL, or the PL first and then the AM). Next the lead sutures are knotted in pairs, threaded through the holes of the Mini-ENDOTACK®, and fixed on the tensioning device.

Always note the following:
- Suture pair with one knot ➔ AM bundle
- Suture pair with two knots ➔ PL bundle

The double loops are pulled tight, and the two grafts are secured under tension with a clamp (Fig. 47).

At this point the graft diameter can be determined. As in a single-bundle reconstruction, it is essential to make a very accurate measurement. A special "small" tendon sizing device is used for measuring the AM and PL grafts. Like the standard sizing device, it is introduced over the double loop sutures and passed completely over each graft. Care is taken that the diameter of the tibial portion of the graft is also accurately determined. A size difference of 0.5 or 1.0 may be found due to the bulk of the suture material (Fig. 48).

To avoid confusion, it is helpful to jot down the measured diameters of both grafts on the drape of the instrument table.

Special Tips for Reconstructing the Posterior Cruciate Ligament

Hamstring tendon grafts are also used in PCL reconstructions. Because the PCL is longer than the ACL, however, a correspondingly longer graft must be prepared. A graft length of 10 cm is desirable for a PCL reconstruction. We generally use a five-strand graft fashioned from the ST and GR tendons. The ST tendon is fashioned as a three-strand graft while the GR tendon is looped to form two strands. Graft length cannot be sacrificed in tall patients (>1.80 m). If the ST tendon is shorter than 30 cm, a four-strand graft made from the ST and GR tendons should be used. In this case, however, it is best to prepare an 11-cm-long graft to ensure that an adequate graft length is available.

Recommended Reading

Instrumentation and Implants for Graft Preparation
**Tendon Board**

![Tendon Board Image](image)

**Add-on for the Tendon Board for Double-Bundle technique**

![Add-on Image](image)

It is recommended to check the suitability of the product for the intended procedure prior to use.
Instruments

- **Thread Clip**
  - 28729 FK

- **Tissue Forceps**, 1x 2 teeth, medium, distal curved to left, length 14.5 cm
  - 28729 P

- **Raspatorium** n. PLESTER, Breite 8 mm, Länge 18 cm
  - 213008

- **PLESTER Elevator**, width 8 mm, length 18 cm
  - 213008

- **CRILE-WOOD Needle Holder**, length 15 cm
  - 515515
ENDOTACK®

28729 TT
ENDOTACK® Tibial Fixation Button

28729 MT
Mini-ENDOTACK®, tibial fixation button 8 x 12 mm, sterile
Tendon Preparation for Cruciate Ligament Reconstruction Using the Semitendinosus and Gracilis Tendons

**Tendon Thickness Tester**

- **28729 S**  
  Tendon Thickness Tester, for determination of tendon thickness size, 6 – 10 mm at intervals of 1 mm
- **28729 SA**  
  Same, 6 – 10, at intervals of 0.5 mm
- **28729 SU**  
  Same, 6.5 – 10.5 mm at intervals of 1 mm

- **28729 SD**  
  Tendon Thickness Tester, for determination of tendon thickness size, 4/4.5/5/5.5/6/6.5/7 mm

- **28729 SE**  
  Tendon Thickness Tester, for determination of tendon thickness size, 7/7.5/8/8.5/9/9.5/10/10.5/11/11.5/12 mm

**Recommended fixation thread:**

- **28729 FC**  
  Catgut Polyester-S white, 3 x 75 cm, USP 7, sterile, package of 24, for use with FLIPPTACK®, extracortical fixation button
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