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37

ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: SOFT TISSUE GRAFTS

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HISTORY OF THE TECHNIQUE

Historically, the use of a soft tissue graft such as a hamstring or tibialis tendon as a graft source for a torn anterior cruciate ligament (ACL) has been limited by the poor biomechanical properties of fixation devices and inconsistent placement of the tunnels. The fixation devices for use with soft tissue grafts were not as strong or stiff and were more prone to slippage than interference screw fixation of bone plug grafts like the bone-patella tendon-bone grafts (BPTB). Furthermore, the healing of a tendon to a bone tunnel is slower than a bone plug, which means that the fixation devices for a soft tissue graft must be better than for a bone plug graft and should allow circumferential healing of the tendon to the tunnel wall.[1,2]

Over the past decade, improvements in fixation devices have increased the use of soft tissue autografts and allografts to reconstruct the torn ACL. Biomechanical studies support the use of high strength and high stiffness fixation devices that resist slippage and allow circumferential healing of the tendon.[3–9] Newer techniques that bone graft a soft tissue ACL graft in the femoral and tibial tunnel are now in use to promote graft-bone tunnel healing, fill voids, and further improve the stiffness at the time of implantation.[9]

A fixation technique, which uses the Bone Mulch Screw in the femur and WasherLoc in the tibia (Arthrotek, Warsaw, IN), was specifically developed for use with soft tissue grafts. The Bone Mulch Screw is a rigid crosspin placed through a stab incision on the lateral femur, and the WasherLoc is a multiple spiked washer that is compressed with a screw and countersunk in a recess in the tibia to avoid hardware symptoms. Both devices provide high strength and stiffness and resistance to slippage that is superior to interference screw fixation of BPTB grafts.[6,10] Bone graft is used in conjunction with these two devices to promote circumferential tendon-tunnel healing, increase stiffness, and permit aggressive rehabilitation with soft tissue autografts and allografts.[7,8]

Over the past decade, improvements in the guidelines for placing the tibial and femoral tunnels in the sagittal and coronal plane has made the restoration of stability and motion of a knee reconstructed with a soft tissue graft better and more consistent. An error of a few millimeters in placement of the tibial and femoral tunnels causes impingement of a soft tissue graft against the roof in full extension, impingement against the posterior cruciate ligament (PCL) in flexion, and abnormal tension in the graft. Roof impingement causes extension loss and increased laxity, PCL impingement causes flexion loss and increased laxity, and abnormal graft tension overconstrains the knee. Impingement issues are more of a problem with the soft tissue grafts than with the bone plug grafts because the cross-sectional area of the soft tissue grafts is larger. Therefore, tunnel placement must be more precise with a soft tissue graft than a bone plug graft **(Fig. 37-1)**.

AUTOGRAFTS: SOFT TISSUE VERSUS BONE PLUG GRAFTS

The most commonly used soft tissue autograft is the double-looped semitendinosus and gracilis (DLSTG) graft. The DLSTG autograft has several advantages over bone plug autografts, such as the BPTB and quadriceps tendon-bone graft. The use of a DLSTG autograft avoids extensor mechanism problems such as anterior knee pain, kneeling pain, quadriceps weakness, patella tendon rupture, infrapatellar contracture syndrome, and patella fracture, which can occur with bone plug grafts. The morbidity of autogenous DLSTG graft is low with

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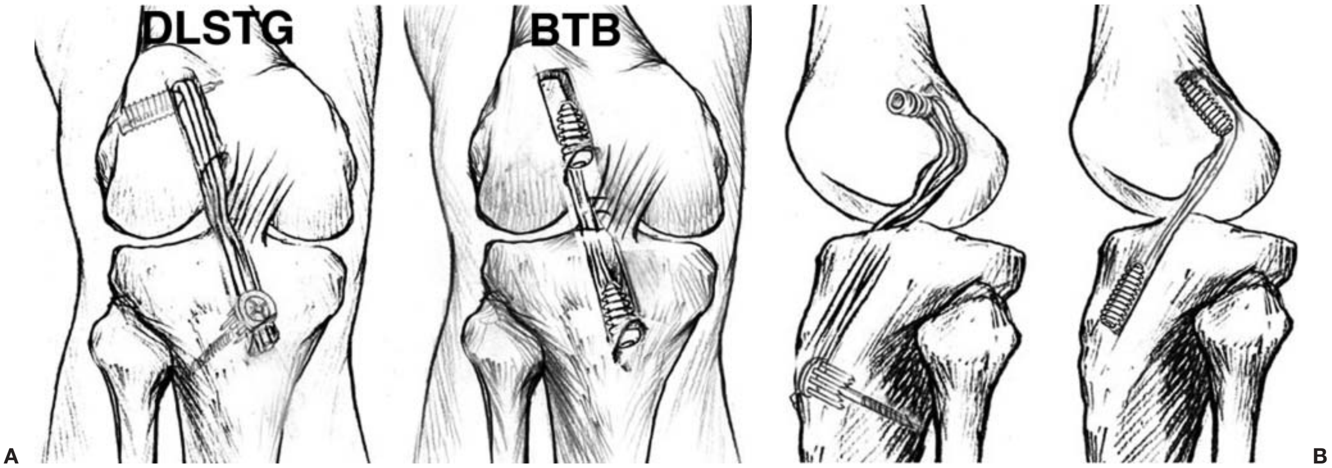

[mb8] **Fig. 37-1 A, B.** Soft tissue grafts require more precise tunnel placement to avoid impingement due to their greater intra-articular cross-sectional diameter.

complete return of flexion strength and regeneration of the tendons following hamstring harvest.[11–16] The DLSTG is stronger (4,304 to 4,590 N) and stiffer (861 to 954 N/mm) than the bone plug grafts. [17,18] In contrast to the bone plug grafts, the biomechanical properties of a DLSTG do not deteriorate with age.[19,20] Mechanically, the four strand DLSTG fixed with the Bone Mulch Screw in a single femoral socket replicates the reciprocal-tensile behavior of the native ACL, which does not occur with the single strand bone plug graft. [9,18,21] The intra-articular biologic incorporation and remodeling of an autogenous DLSTG graft is more rapid than the bone plug grafts. The autogenous DLSTG graft does not die after transplantation,[22] and viability depends on readily available synovial diffusion and not on revascularization[23]; whereas bone plug grafts undergo central necrosis and require the development of a vascular supply.[24] Finally, clinical outcome studies support the use of autogenous DLSTG graft as they are as effective as an autogenous BPTB graft for restoring stability and function in the knee with a torn ACL.[25,26]

ALLOGRAFT SOFT TISSUE GRAFTS

The most commonly used soft tissue allograft is the single loop of tibialis tendon from either the anterior or posterior tibialis tendon. Soft tissue allografts are more readily available than bone plug allografts because one cadaver provides six soft tissue allografts (i.e., two DLSTG, two anterior tibialis, two posterior tibialis) and only four bone plug allografts [mb1] (i.e., two BTB, two Achilles tendon). Soft tissue allografts are ideal for use in revision ACL surgery and in reconstruction of the knee with multiple ligament injuries. Soft tissue allografts are also useful in primary ACL reconstruction because they avoid harvest morbidity, decrease surgical time, and surgical scars.[27] An allograft without a bone plug is quicker to thaw, easier to prepare, and has less disease transmission than an allograft with a bone plug.[28] The strength and stiffness of a soft tissue allograft made from a single loop of tibialis tendon are greater than the bone plug grafts.[20]

The disadvantages of the use of soft tissue allograft center around cost, healing, and disease transmission. Soft tissue allografts generally cost a few hundred dollars less than the bone plug allografts. The added cost of the allograft may be offset to some degree by shortened operating time, less physical therapy, and quicker return to work. It is generally accepted that allografts require more time to incorporate and heal than an autograft.[29] The longer time for graft incorporation with the allograft places greater demand on the performance of fixation devices that need to provide sound fixation properties over a longer period of time. The use of allograft has an inherent possibility of transmitting an infectious disease from the donor to the recipient. Although the risk is low, HIV, hepatitis, and bacteria have been transmitted through the use of allograft tissue and there is also the theoretical possibility of transmitting slow viruses (prions).[30] Newer screening tests such as polymerase chain reaction (PCR) and nucleic acid testing (NAT) improve the detection of viral and bacterial DNA and RNA and may increase the accuracy of identifying infected donor tissue by minimizing the incidence of false-negatives and therefore the risk of disease transmission. Currently, tissue banks do not routinely perform PCR or NAT testing on allograft tissue. Irradiation of allograft tissue has been used to sterilize the tissue and lessen the risk of disease transmission. However, the high dose of irradiation (3 Mrad) required to sterilize allograft tissue also decreases the biomechanical properties of the allograft and does not prevent transmission of hepatitis when a bone plug allograft is used.[31] There are no studies showing that cryopreserved allograft performs better than a fresh-frozen allograft, which is not surprising since few donor cells survive the cryopreservation process and none survive the transplantation. The viability of a cryopreserved and fresh-frozen allograft depends solely on repopulation of the allograft with cells from the recipient.[32,33]

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Although infection is rare, surgeons must counsel their patients on the risks and benefits of the use of allograft tissue. The use of a reputable tissue bank that follows state of the art procurement, testing, and preservation guidelines should improve the safety of allograft tissue. In our practices, we consider the use of allografts in patients requiring revision ACL surgery, treatment of unstable knees with multiple ligament injuries, and in patients that request allograft for a primary ACL reconstruction because they wish to avoid the morbidity of graft harvest.

FIXATION DEVICES

A variety of fixation devices for soft tissue grafts exist for ACL reconstruction. The principles of fixing a soft tissue graft include the use of fixation devices that have high strength, high stiffness, resist slippage under cyclic load, promote biologic incorporation of the soft tissue graft at the bone tunnel interface, and safely allow aggressive rehabilitation. In the femur, we use the Bone Mulch Screw femoral crosspin because of its high strength of 1,126 N, high stiffness of 225 N/mm, and resistance to slippage.[5,9] In the tibia, we use the WasherLoc because of its high strength of 905 N, high stiffness of 248 N/mm, and resistance to slippage.[5,6,9] The use of this combination of fixation devices and a DLSTG autograft or tibialis allograft allows the use of aggressive rehabilitation and a safe return to sports at 4 months.[7,34]

When choosing a fixation device the surgeon should consider whether the device enhances or retards the healing of a soft tissue graft to the bone tunnel. Tendons heal slower to a tunnel wall than a bone plug, and the healing isn't equivalent until 6 weeks after implantation.[1] Because healing of a soft tissue graft to a bone tunnel requires more time than healing of a bone plug to a bone tunnel, the fixation devices used with a soft tissue graft must be stronger, stiffer, and work for a longer period of time.[2,9]

Several controllable factors promote healing of a soft tissue graft to bone including lengthening the tunnel,[35] avoiding the insertion of fixation devices between the soft tissue graft and tunnel wall (i.e., interference screw),[3] increasing the tightness of fit,[35] and adding biologically active tissue (i.e., periosteum, bone).[36] Lengthening the tunnel and avoiding the insertion of an interference screw requires that the fixation device be placed at the end or outside the tunnel away from the joint line. Several studies have advocated fixation of a soft tissue ACL graft at the joint line with an interference screw to shorten the graft and increase stiffness.[37–39] A disadvantage of joint line fixation is that the rate of tendon graft-to-bone healing is slower than distal fixation because the interference screw blocks healing between the ACL graft and the tunnel wall.[3,40,41] Other studies have shown that distal fixation with the Bone Mulch Screw and WasherLoc provides even greater stiffness than joint line fixation with a wide variety of metal and bioabsorbable interference screws, even though the graft is longer.[4–6,9] An advantage of distal fixation is that bone graft can be used as a supplementary fixation device. Bone graft in the form of drill reamings can be compacted into the femoral tunnel through a channel in the body of the Bone Mulch Screw, which increases stiffness 41 N/mm[9] and allows reciprocal tensile behavior in the graft.[21] A bone graft made from a dowel of cancellous bone harvested from the tibial tunnel with a coring device can be compacted back into the tibial tunnel in a space between the anterior surface of the soft tissue graft and WasherLoc and the tunnel wall, which increases stiffness 58 N/mm.[42] Tightening the fit by adding an autogenous bone graft or a biologically active tissue such as periosteum improves the rate of healing of a soft tissue graft to a bone tunnel.[35,36]

TIBIAL AND FEMORAL TUNNEL GUIDE SYSTEM

The success of a soft tissue graft with the Bone Mulch/WasherLoc technique relies on the use of a tibial and femoral guide system that consistently places the tibial and femoral tunnels in the sagittal plane and coronal plane so that roof impingement and PCL impingement is avoided and the tensile behavior in the graft matches the intact ACL. The strongest graft tissue, best fixation devices, or most carefully moderated rehabilitation protocol cannot overcome the complications from placing a tibial or femoral tunnel incorrectly in either the sagittal or coronal plane. The guideline for placing the tibial guide wire in the sagittal plane is to place the guide wire 5 mm posterior to the intercondylar roof in full extension, which avoids roof impingement. The tibial guide keys off the intercondylar roof. The guide wire is drilled with the knee in full extension, which customizes the position of the tibial tunnel in the sagittal plane for variation in knee extension and roof angle and avoids roof impingement without a roofplasty.[43–45] The guideline for placing the tibial guide wire in the coronal plane is to place the guide wire midway between the tibial spines at an angle of 65 degrees with respect to the medial joint line of the tibia, which avoids PCL impingement. An alignment rod is inserted into the handle of the tibial guide and the rod is aligned parallel to the joint line and perpendicular to the long axis of the tibia, which places the tibial tunnel at 65 degrees.[46] The tibial tunnel is used to select the placement of the femoral tunnel by inserting a femoral aimer with an offset that leaves a 1-mm thick back wall. Drilling a femoral tunnel through a tibial tunnel placed with these guidelines in the sagittal and coronal planes results in a tension pattern in the graft similar to the intact ACL and avoids roof and PCL impingement.[46]

Indication and Contraindications

We prefer to use the Bone Mulch Screw/WasherLoc ACL system in any patient requiring ACL reconstruction, including the knee with multiligament injuries. The DLSTG autograft is used in all patients who want to avoid the infectious complications of allograft tissue. The tibialis allograft is the preferred graft in patients who want to avoid the morbidity from graft harvest, in legs that are obese or large where harvesting autogenous hamstring tendons is technically challenging, and in the knee with a multiligament injury. Soft tissue grafts are preferred in the skeletally immature patient, and allografts are considered when the patient is small and the hamstring tendons are judged to be inadequate. In the patient with open physis, we recommend the use of fluoroscopy to be certain that the fixations devices do not cross the physis. In addition, bone graft is not used in the tibial and femoral tunnels in skeletally immature patients with significant growth remaining.

SURGICAL TECHNIQUE

Anesthesia

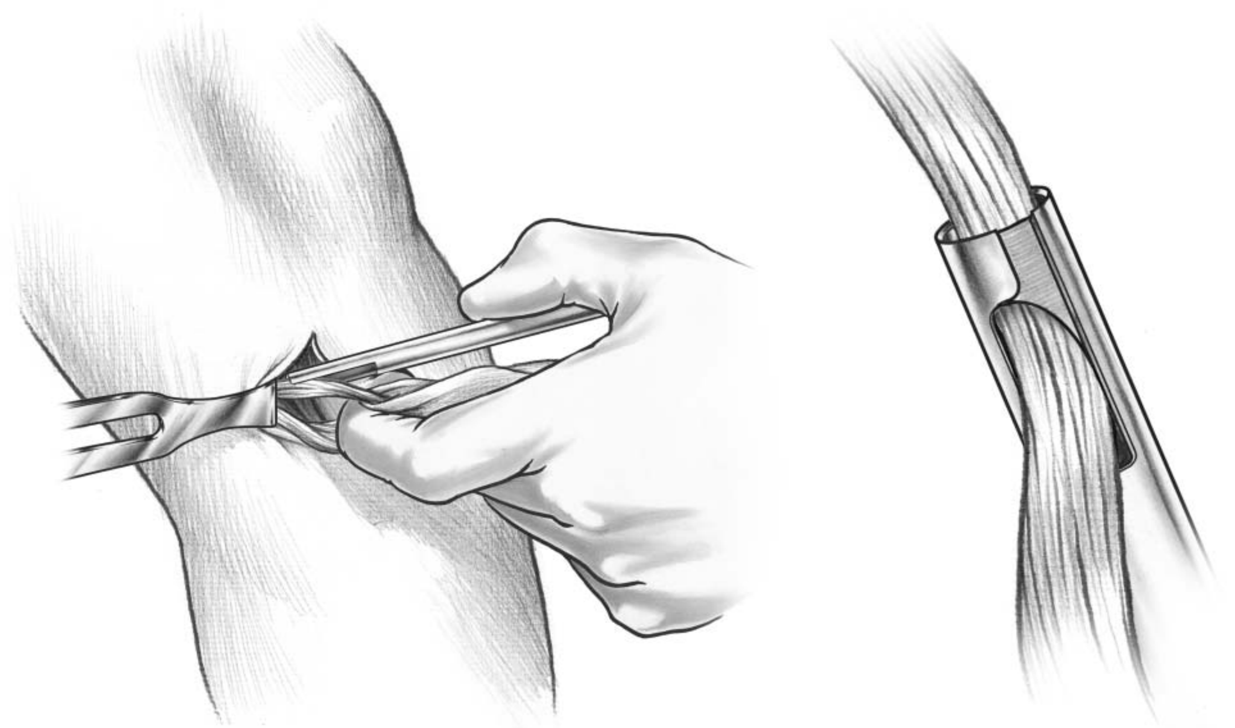
The Bone Mulch Screw/WasherLoc ACL procedure can be performed under general or regional anesthesia. We prefer general anesthesia because the duration of surgery is usually an hour or less. Acceptable regional techniques include spinal and epidural anesthesia.

Portal Placement

A modified anteromedial and anterolateral portal is used for the procedure. Position the modified anteromedial portal adjacent to and touching the medial border of the patellar tendon. Modifying the placement of the anteromedial portal so that the tibial guide touches the patellar tendon ensures that the tip of the guide can be centered inside the notch. Position the modified anterolateral portal adjacent to the lateral border of the patellar tendon at the level on the inferior pole of the patella. Alternatively, the lateral portal can be placed through the lateral one third of the patella tendon, which provides a better view of the femoral tunnel than the anterolateral portal. Use a standard superomedial portal if an outflow cannula is required so that the cannula does not interfere with the insertion of the Bone Mulch Screw on the lateral side of the knee.

Harvest the Autogenous DLSTG graft

To harvest the gracilis and semitendinosus tendons, make a 4 to 5 cm vertical or oblique incision centered three fingerbreadths below the medial joint line. Position the incision so that the index finger of the surgeon can reach *past* the posteromedial edge of the tibia and well into the popliteal space. Adjusting the location of the incision to achieve this reach enables the identification, palpation, and release of all fascial attachments of the hamstring tendons to the medial gastrocnemius. Make the skin incision and expose the sartorius fascia, which overlies the gracilis and semitendinosus tendons. Palpate the gracilis tendon through the sartorius fascia and then incise the sartorius fascia along the inferior border of the gracilis tendon. Insert a gloved finger deep to



A B

Fig. 37-2 A, B. Open-ended tendon stripper advanced along tendon while holding countertraction with finger and Penrose drain leaving the tendons attached to bone.

the sartorius fascia and bluntly dissect the gracilis tendon into the popliteal fossa. Hook the gracilis tendon with a right angle clamp and pass a 0.5 inch Penrose drain around the gracilis tendon. Use the Penrose drain to apply traction and manipulate the gracilis tendon and define any fascial attachments. Cut fascial attachments under direct view. Harvest the gracilis tendon with an open-ended tendon stripper and leave the tendon attached distally. Gently push the stripper proximally aiming toward the groin while applying a countertraction on the distal end of the tendon **(Fig. 37-2).** Identify the semitendinosus, which is distal to the gracilis tendon and in the same tissue plane. Use the right angle clamp, Penrose drain, and open-ended tendon stripper to detach the semitendinosus and leave the tendon attached distally. Scrape the remaining muscle from each tendon with a curved Mayo scissors or periosteal elevator.

Prepare and Size the DLSTG Autograft and Allograft

The same technique is used to prepare and size the DLSTG autograft and allograft except that both ends of each allograft tendon are sewn, since the allograft is not attached to the tibia. Grasp the end of each tendon with an Allis clamp. Sew the end of each tendon using a whipstitch and a 36 inch no. 1 Vicryl suture. Loop each throw of the suture around four fifths of the cross section of the tendon spacing each throw 5 to 10 mm apart until 4 to 5 cm of tendon is sewn. Create the appearance of the thongs on a "Roman sandal" by continuing the throws in the same direction up and down the tendon **(Fig. 37-3)**. Later in the procedure, when traction is applied to the whipstitch to pass the graft, a "Chinese finger trap" tapers the tip of the tendon, which aids in graft passage around the Bone Mulch Screw. Size the DLSTG graft by looping the middle on both tendons over a suture or mersilene tape. Pass a series of sizing sleeves that differ in diameter by 1 mm over the double looped graft. The diameter of the sleeve that passes freely is used to select the diameter of the tibial and femoral tunnels.

Prepare the Tibialis Allograft

The tibialis allograft should be 24 cm or greater in length and at least 7 mm in diameter. Fold the tendon over a suture or mersilene tape and pass the graft through a series of sizing sleeves. Trim the width of the tibialis tendon until it freely passes through a 9 or 10 mm sleeve. Suture each end of the tendon using the previously described whipstitch. Tubulate the remaining unsewn section of the tibialis allograft with use of a 3-0 Vicryl suture. Pull the looped end of the graft into a sizing sleeve 1 mm smaller than the sized graft. Submerge the graft folded inside in the sizing sleeve in an antibiotic-laced basin of saline. Keeping the graft inside the sizing sleeve prevents the graft from swelling, which eases the passage of the graft later in the procedure **(Fig. 37-4)**.

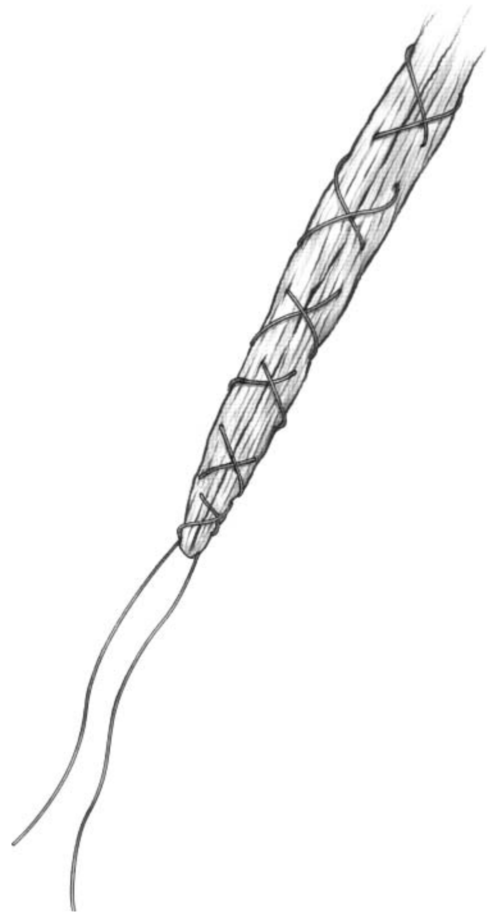


Fig. 37-3. Whip-stitch resembles a "Roman sandal" when completed. (Reprinted from Lawhorn KW, Howell SM. Scientific justification and technique for anterior cruciate ligament reconstruction using autogenous and allogeneic soft tissue grafts. Orthop Clin North Am. 2003;34:19–30. With permission from Elsevier.)

Place the Tibial Guide Wire

Excise the stump of the torn ACL. Insert the 9.5-mm wide tip of the Howell 65-degree tibial guide through the inferomedial portal. Attempt to pass the tip of the guide between the lateral femoral condyle and PCL, which is often too narrow to allow free passage of the tip of the guide. Perform a customized wallplasty with the angled osteotome and remove 2 to 3 mm of bone from the lateral femoral condyle until the tip of the guide freely passes into the notch without deforming the PCL **(Fig. 37-5)**. Widening the notch to 9.5 mm minimizes impingement of an 8-, 9-, and 10-mm wide graft against the lateral wall and PCL. Do not perform a roofplasty.

Position the tip of the tibial guide in the notch. Slowly extend the knee and arthroscopically visualize so that the tip on the guide remains inside the notch. Maintain the knee in hyperextension by placing the heel on a raised Mayo stand. Grasp the handle of the guide with the long and ring fingers and rest the hypothenar area of the hand on the patella. Seat the guide in the sagittal plane by gently

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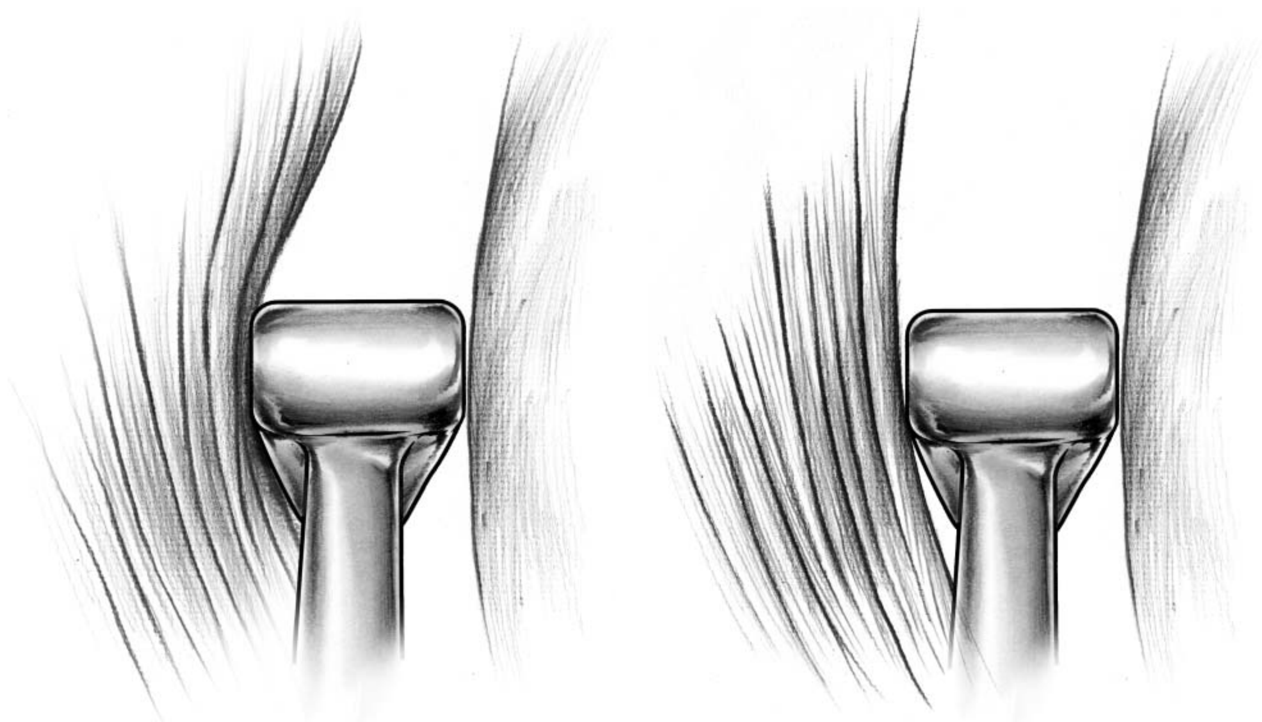
Fig. 37-4. Prepared allograft placed in sizing sleeve and stored in antibiotic saline.

lifting the handle of the guide toward the ceiling until the arm abuts the trochlear groove. Simultaneously press the patella toward the floor, hyperextending the knee. This maneuver customizes the angle and position of the guide in the sagittal plane to the roof angle and knee extension of the patient **(Fig. 37-6)**.

Adjust the angle of the tibial guide wire in the coronal plane. From the lateral side of the guide, insert the alignment rod into the proximal hole in the handle. Position the alignment rod parallel to the joint line and perpendicular to the long axis of the tibia, which angles the tibial tunnel at 65 degrees with respect to the medial joint line (Fig. 37-6). If a DLSTG autograft is being used, then insert the drill sleeve through the harvest incision until it touches the portion of the superficial medial collateral ligament that overlies the posteromedial tibia. If a soft tissue allograft is being used, then make a 4 to 5 cm transverse incision so that the drill sleeve can be positioned on bone. Drill a 2.4 mm drill tip guide wire until it stops at the broad tip of the guide.

Assess the placement of tibial guide wire. Tap the K-wire into the notch. In the coronal plane, assess the placement of the K-wire with the knee in 90 degrees of flexion. In the sagittal plane, assess the placement of the K-wire with the knee in full extension. Use a nerve hook and confirm that there is 2 mm of space between the K-wire and intercondylar roof. The correct K-wire placement is lateral to the posterior cruciate ligament, pointing down the side wall of the notch and between the medial and lateral tibial spines **(Fig. 37-7)**.

Use intraoperative radiography or fluoroscopy when there is any uncertainty about the placement of the tibial guide wire. Obtain an AP and lateral roentgenogram or fluoroscopic image with the knee in full extension with the tibial guide, alignment rod, and tibial guide wire in place. In the coronal plane, the tibial guide wire is properly placed when it is centered between the tibial spines and the tibial guide wire forms an angle of 65 ± 3 degrees with the medial joint line. In the sagittal plane, the tibial guide wire is properly placed when the K-wire is 4 to 5 mm posterior and parallel to the intercondylar roof.



A

B

Fig. 37-5. **A:** Inadequate notch width for soft tissue graft indicated by deformation of PCL when passing guide tip into notch. **B:** Adequate notch width for soft tissue graft.

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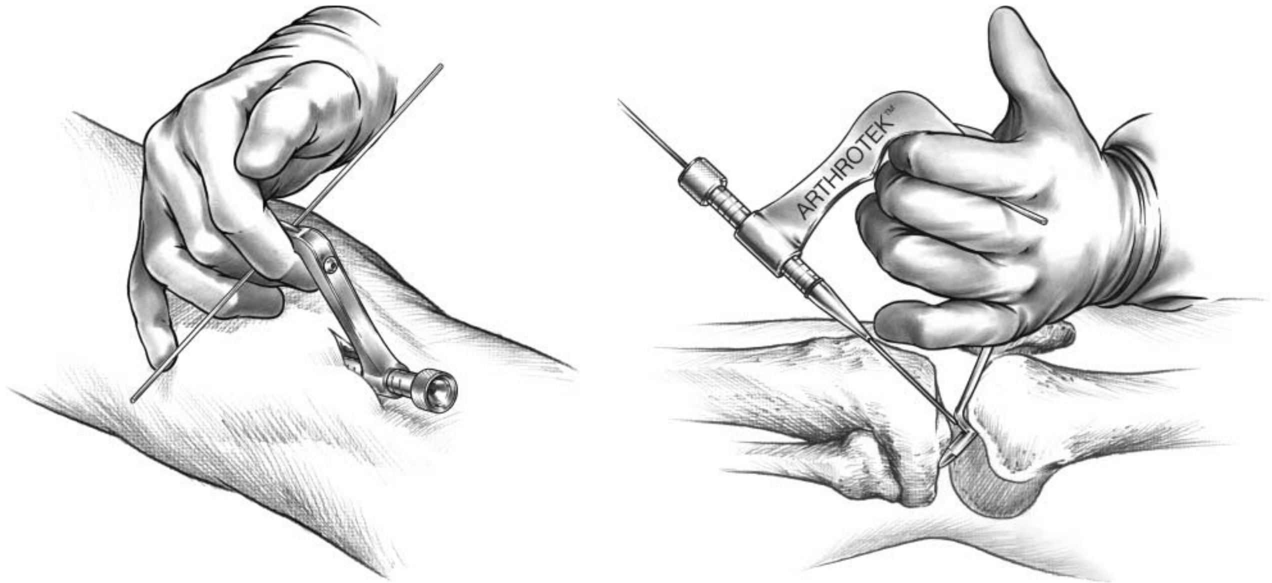

Fig. 37-6 A,B. AP and lateral views with tibial guide in place. (Reprinted from Lawhorn KW, Howell SM. Scientific justification and technique for anterior cruciate ligament reconstruction using autogenous and allogeneic soft tissue grafts. Orthop Clin North Am. 2003;34:19–30. With permission from Elsevier.)

Harvest the Bone Dowel and Drill the Tibial Tunnel

Choose a cannulated tibial reamer that matches the diameter of the soft tissue ACL graft. Drill the cannulated reamer over the guide wire a few millimeters until the distal tibial cortex is removed. Assemble the bone dowel harvester by locking an 8 mm harvester tube in the quick release handle. Insert the calibrated plunger up the harvester tube until the plunger is flush with the sharper cutting end. Impact the bone dowel harvester over the guide wire to the subchondral bone **(Fig. 37-8)**.

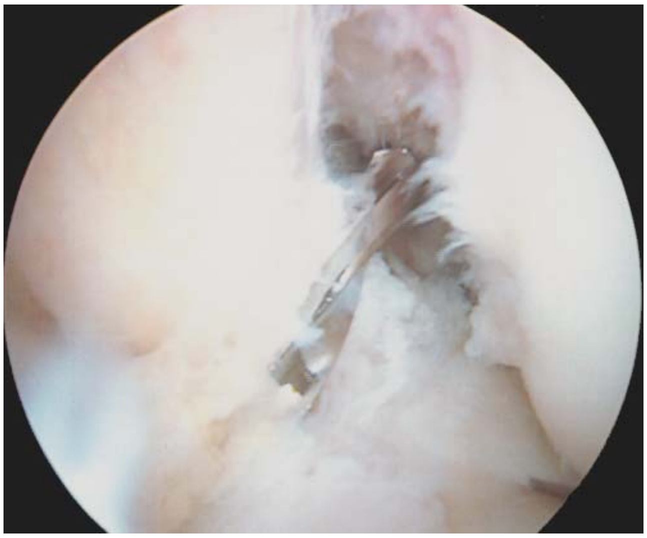

Fig. 37-7. Guide pin position should be lateral to the PCL, angle away from PCL and centered between the tibial spines.

Rotate the bone dowel harvester several times clockwise and counterclockwise to break off the cylindrical bone dowel and remove. Disengage the harvester tube from the handle. Read the calibrated plunger and determine whether the length of the bone plug is adequate (typically 25 to 35 mm) **(Fig. 37-9)**. If the tibial guide wire is removed with the harvester, then place an 8 mm femoral reamer into the tibial tunnel and reinsert the guide wire. Finish drilling the tibial tunnel.

Prepare the Counterbore for the WasherLoc

Use electrocautery and a rongeur to remove a 17 by 17 mm section of the superficial layer of the medial collateral ligament (MCL) from the cortical opening of the tibial tunnel. Because the majority of the superficial MCL fibers are retained and the deep fibers of the MCL are undisturbed, the medial stability of the knee is unaffected. Insert the counter bore guide into the tibial tunnel until the vertical sleeve is compressed against the distal end of the anterior edge of the tibial tunnel. Rotate the guide until the periscope on the counter bore is pointed toward the fibular head, which avoids damage to the posterior neurovascular structures **(Fig. 37-10)**. Impact the awl perpendicular to the back wall of the tibial tunnel through the sleeve until it is fully seated. Remove the counter bore guide and replace the awl in the pilot hole to maintain orientation. Memorize the orientation of the awl, remove it, and insert the tip of the counter bore into the pilot hole. Maintain the cutting surface of the counter bore parallel to the posterior wall of the tibial tunnel. Ream until the counter bore is flush with the posterior wall of the tibial tunnel (Fig. 37-10). Save the reamings.

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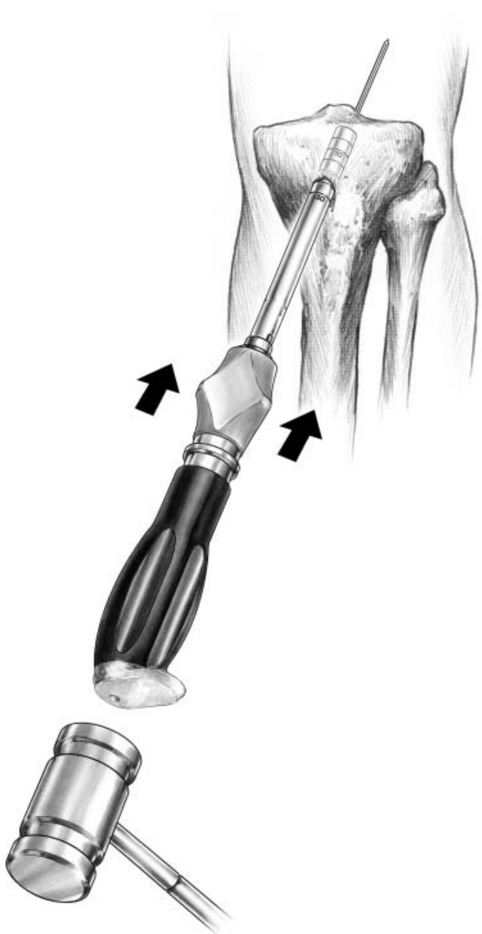

Fig. 37-8. After reaming the outer cortex of the tibia, tap the coring reamer over the guide wire until it reaches the subchondral bone.

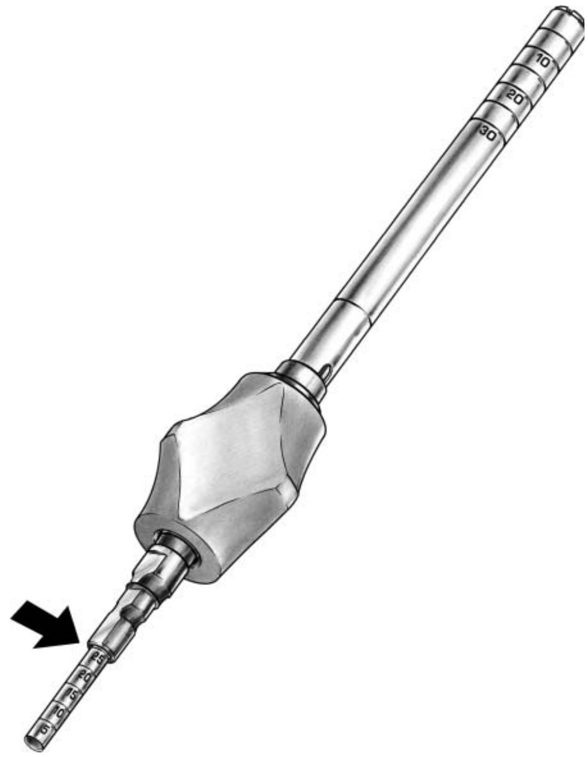

Fig. 37-9. The length of the cancellous bone dowel is indicated by calibrations on plunger.

Check for Roof Impingement and Remove the ACL Origin

Place the knee in maximum extension and insert an impingement rod the same diameter as the tibial tunnel through the tibial tunnel and into the notch. Free passage of the impingement rod indicates prevention of roof impingement **(Fig. 37-11)**. A roofplasty is rarely required with the Howell 65 degree Tibial Guide.

Insert the 70-degree angled curette through the medial portal and into the over-the-top position on the femur. Remove the remnant of the ACL origin down to bone. Removing the ACL origin allows the tip of the femoral aimer to rest on bone instead of soft tissue and prevents blowout of the posterior wall of the femoral tunnel.

Place the Femoral Tunnel

Select a femoral aimer the same diameter as the graft. Insert the femoral aimer through the tibial tunnel and hook the tip of the aimer into the over-the-top position on the femur. Allow the knee to flex until the femoral aimer locks in place. Rotate the femoral aimer a few degrees away from the PCL to minimize PCL impingement. Drill a 2.4-mm drill-tipped guide wire into the femur and then drill a 30 mm in length femoral tunnel with an acorn reamer. The placement of the femoral tunnel is controlled by the angle and placement of the tibial tunnel in the coronal and sagittal plane since the femoral tunnel is drilled through the tibial tunnel. The use of the femoral aimer through a tibial tunnel placed with the previously discussed guidelines guarantees that the placement of the femoral tunnel prevents PCL impingement and that the tension pattern in the graft replicates the intact ACL.

Insert the Bone Mulch Screw

Insert the U-guide (Arthrotek, Inc.) with a tip that corresponds to the diameter of the tunnel through the tibial until it bottoms out at the end of the 30 mm femoral tunnel. Insert the drill sleeve and rotate the guide until it points medial. Make a 10 to 12 mm incision and advance the drill sleeve until the tip touches bone. Lock the drill sleeve into place. Determine the length of the Bone Mulch Screw by reading the screw sizes of the drill sleeve from inner edge of the U-guide. When the length is between sizes (17 mm, 20 mm, 25 mm, 30 mm) use a Bone Mulch Screw of shorter length.

Drill the guide wire into the lateral femur until it strikes the tip of the U-guide in the femoral tunnel **(Fig. 37-12)**. Remove the drill sleeve and U-guide. View the femoral tunnel by inserting the scope through either the modified anterolateral or anteromedial portal. Tap the guide wire

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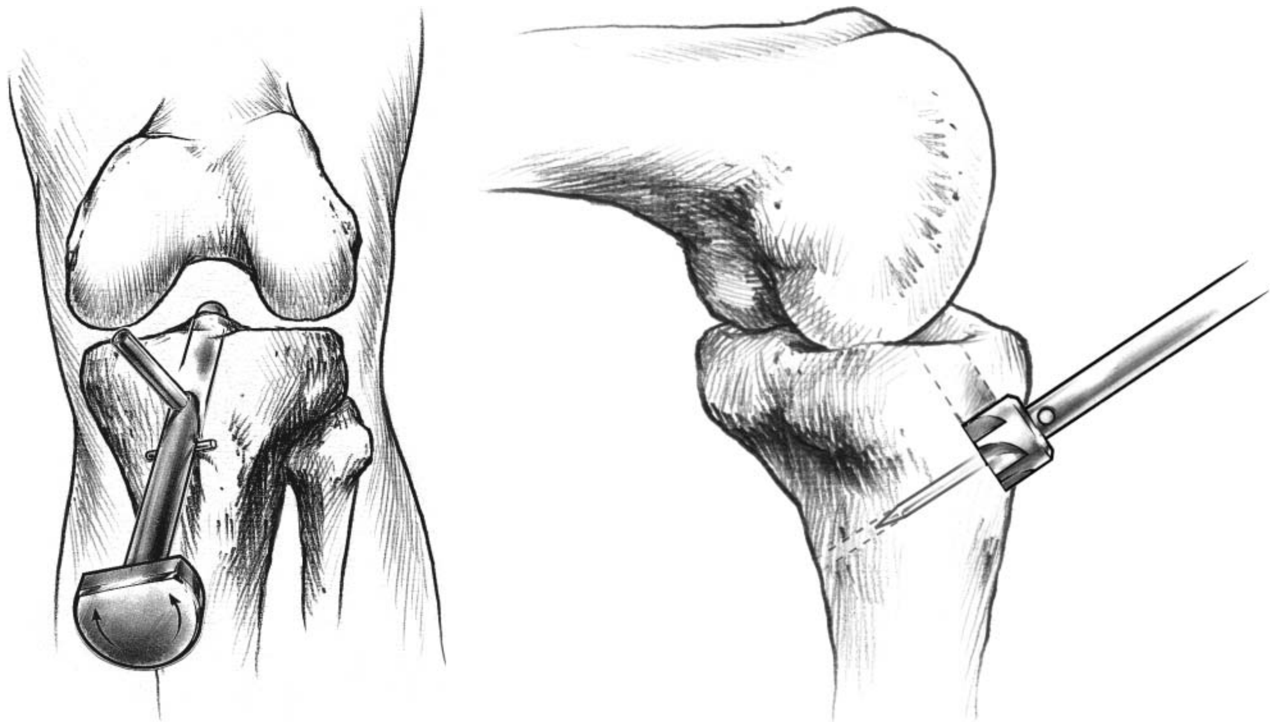

A B

Fig. 37-10. (A) Aim the counterbore awl toward the fibular head. (B) Ream the anterior wall of tibial tunnel using counterbore reamer again aiming toward the fibular head. (Reprinted from Lawhorn KW, Howell SM. Scientific justification and technique for anterior cruciate ligament reconstruction using autogenous and allogeneic soft tissue grafts. Orthop Clin North Am. 2003;34:19–30. With permission from Elsevier.)

across the femoral tunnel into the medial wall. Confirm the guide wire is centered in the femoral tunnel. Drill the guide wire into the medial wall of the femoral tunnel until the drill tip disappears. Place a sizing sleeve around the reamer and ream the transverse tunnel for the Bone Mulch Screw with a 7-mm diameter reamer in soft bone and an 8-mm diameter reamer in hard bone, stopping short of the medial wall of the femoral tunnel **(Fig. 37-13)**. Save the bone reamings. Insert the ring curette or router through the transverse tunnel and expand the femoral tunnel anteriorly and posteriorly 1 to 2 mm to make room to pass the soft tissue graft.

Insert the Bone Mulch Screw until the tip is halfway across the femoral tunnel. Use a suture passer to loop the suture over the tip of the Bone Mulch Screw **(Fig. 37-14)**. Advance the Bone Mulch Screw into the medial wall of the femoral tunnel until the tip of the screw is buried in the medial wall. Withdraw the suture passer without twisting the suture.

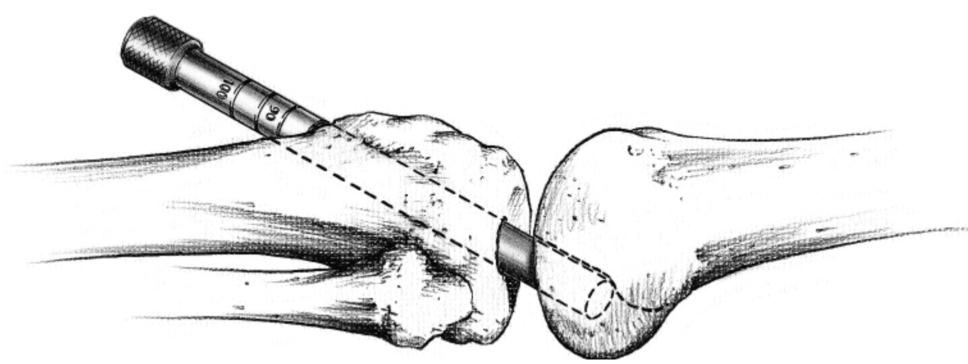

Fig. 37-11. Advance the corresponding impingement rod through the tibial tunnel into and out of the notch with the knee in full extension. Free passage of the rod confirms no roof impingement. (Reprinted from Lawhorn KW, Howell SM. Scientific justification and technique for anterior cruciate ligament reconstruction using autogenous and allogeneic soft tissue grafts. Orthop Clin North Am. 2003;34:19–30. With permission from Elsevier.)

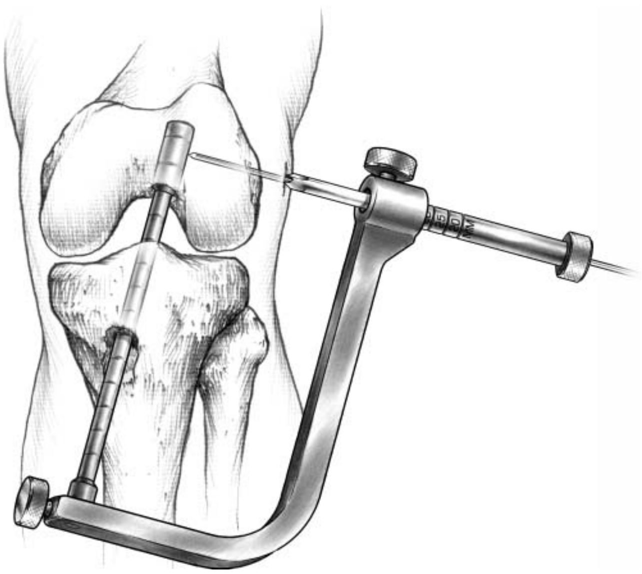

Fig. 37-12. Advance U-shaped guide through tibial tunnel and advance bullet tip guide against the bone of lateral femoral condyle. Determine Bone Mulch Screw (Arthrotek, Warsaw, IN) length and drill guide pin.

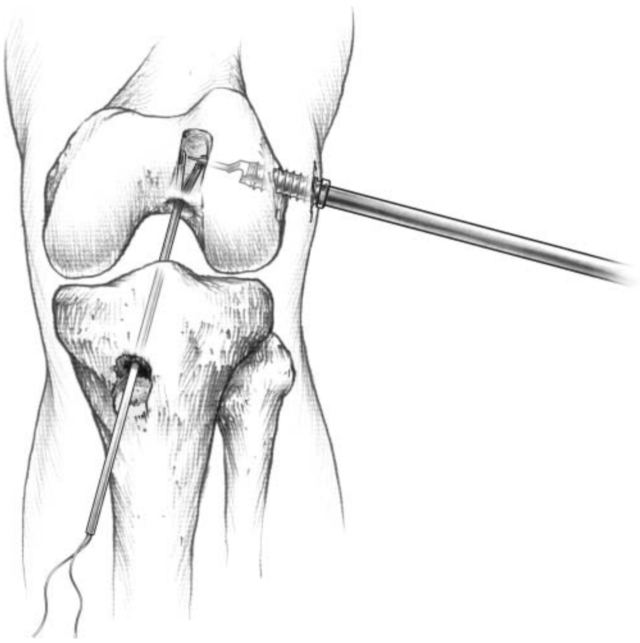

Fig. 37-14. Pass the suture loop passer with suture over the post of the Bone Mulch Screw as the screw is inserted.

Pass the Soft Tissue Graft Passage

Clamp the anterior strand of suture to the drape and tie the posterior strand of suture to the sutures sewn to the soft tissue graft. Pull the anterior strand of the passing suture, which pulls the soft tissue graft up the tunnels, around the Bone Mulch Screw, and back down the tunnels **(Fig. 37-15)**. Even the graft length and tie the graft sutures together **(Fig. 37-16)**. Precondition the graft by cycling the knee 20 to 30 times while maintaining tension on the sutures.

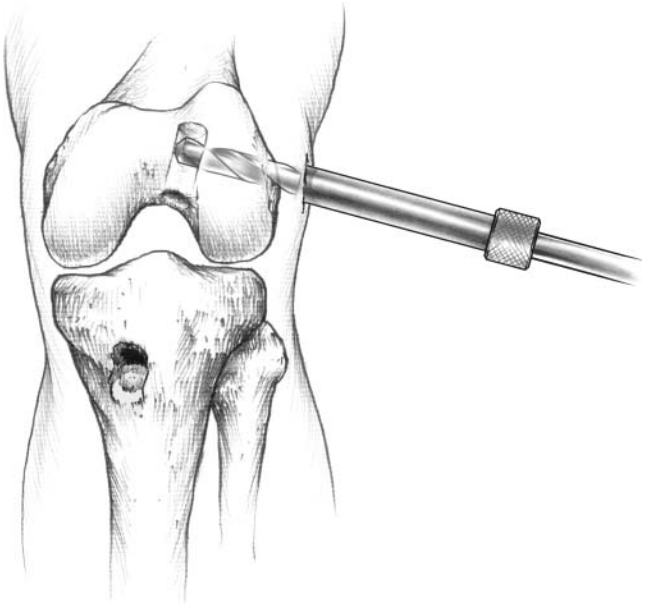

Fig. 37-13. Ream the lateral tunnel for the bone mulch screw taking care not to ream the medial wall of the tunnel. (Reprinted from Lawhorn KW, Howell SM. Scientific justification and technique for anterior cruciate ligament reconstruction using autogenous and allogeneic soft tissue grafts. Orthop Clin North Am. 2003;34:19–30. With permission from Elsevier.)

Tension and Fix the Soft Tissue Graft with the WasherLoc

Place the knee in full extension with the foot on a Mayo stand. Insert an impingement rod between the sutures and have an assistant apply tension. Select a 16 mm WasherLoc with long spikes for a graft 8 mm or smaller in diameter and an 18mm WasherLoc with long spikes for a graft 9 mm or greater in diameter. Thread the drill sleeve into the

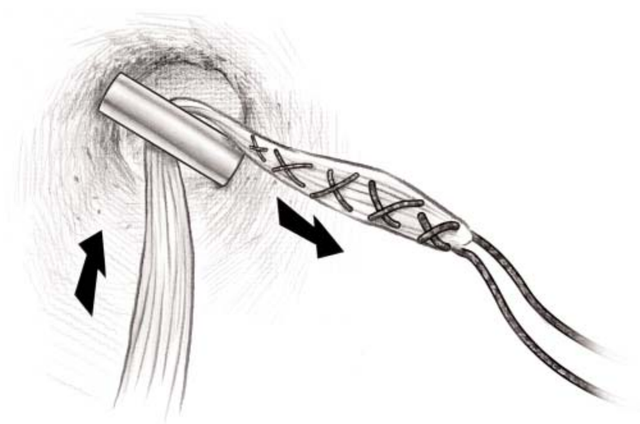

Fig. 37-15. Pass the graft over the post of the Bone Mulch Screw in a posterior to anterior direction.

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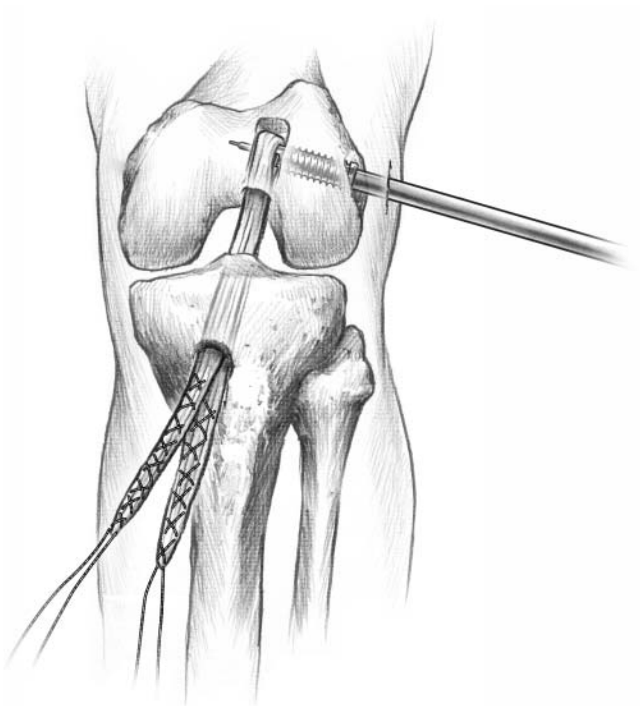

Fig. 37-16. Adjust the allograft limbs (or autograft if detached and removed from patient) so that they are equal length.

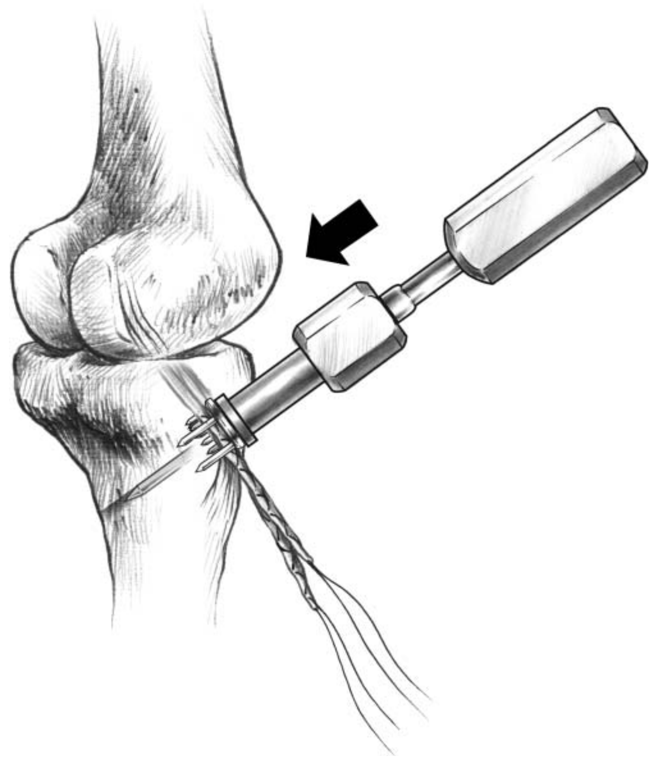

Fig. 37-17. Tension the graft limbs with knee in full extension and impact the WasherLoc into the graft and tibial tunnel while aiming towards the fibular head. (Reprinted from Lawhorn KW, Howell SM. Scientific justification and technique for anterior cruciate ligament reconstruction using autogenous and allogeneic soft tissue grafts. Orthop Clin North Am. 2003;34:19–30. With permission from Elsevier.)

WasherLoc and thread the awl into the drill sleeve. Using a right angle clamp separate the strands of each tendon on opposite sides overlying the previously made pilot hole in the distal tibial tunnel. Insert the awl in the pilot hole; aim the awl toward the fibula and perpendicular to the back wall of the tibial tunnel. Seat the WasherLoc into the graft and the tibia with a mallet **(Fig. 37-17)**. Remove the awl and use a 3.2-mm diameter drill to drill the far cortex aiming toward the fibula. Measure length of the drill hole with a depth gage. Insert a cancellous compression screw and purchase the lateral cortex of the tibia.

Assess stability by performing a manual Lachman test, and then repeat the Lachman test under arthroscopic view. Insert a nerve hook probe and palpate the graft.

Bone Graft the Femoral and Tibial Tunnels

Bone graft the femoral tunnel with bone reamings. Insert the bone compaction sleeve into the Bone Mulch Screw. Sprinkle bone reamings from the tunnels into the compaction sleeve and drive the reamings into the femoral tunnel with a compaction rod.

Bone graft the tibial tunnel with bone removed during the wallplasty and the cancellous bone dowel. Expand the space anterior to the soft tissue graft with a dilator. Insert the 8-mm diameter dilator 25 mm to the level of the joint line. Select a piece or two of the bone from the wallplasty and compact the bone graft into the tibial tunnel with the dilator. Place the plastic tip on the bone dowel harvester and drive the dowel of cancellous bone into the tibial tunnel with a mallet. Remove any excess soft tissue graft completing the reconstruction **(Fig. 37-18)**.

Wound Closure

Close the wounds and inject the joint and incisions with a local anesthetic. Apply a soft compression dressing. Because the soft tissue graft is strong, the tunnels are placed to avoid roof and PCL impingement, and if the fixation is strong, stiff, and resistant to slippage a brace is not used. The patient is instructed to weight bearing as tolerated using crutches and to perform towel extension and flexion exercises to regain full motion.

■ TECHNICAL ALTERNATIVES AND PITFALLS

Alternative fixation techniques exist for the fixation of soft tissue grafts on the femur and tibia. On the femoral side, a common technical concern of other cross pins is that they are blindly inserted into the tunnel with the soft tissue graft already in place. Blind insertion of the cross pin runs the

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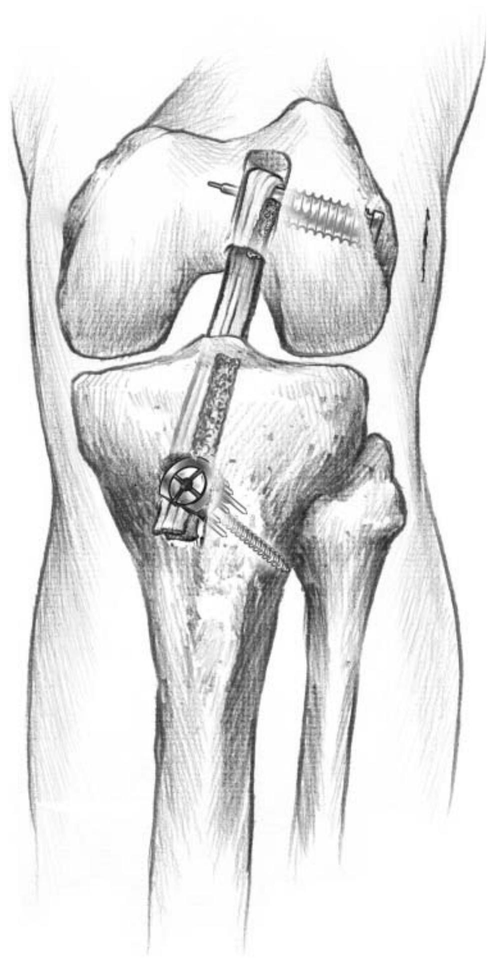

Fig. 37-18. Completed soft tissue reconstruction.

risk of leaving the head of the device proud on the lateral femur, creating hardware symptoms, or countersinking the device too deep into the femoral condyle, making revision difficult. Another technical concern of the blind insertion is that the cross pin may cut the graft or may incompletely capture the graft if the cross pin does not pass through the loop of the graft. With the Bone Mulch Screw, the surgeon directly views the loop of the graft pass over the tip of the screw. There is no chance for kinking, cutting, or incomplete graft capture or leaving the screw too proud or buried too deep. Biomechanical tests of a variety of femoral fixation devices including cross pins, interference screws, and the EndoButton showed that the Bone Mulch Screw is the strongest and stiffest femoral fixation for a soft tissue graft whether tested in animal or young human femur.[4] Unlike any other femoral fixation device for soft tissue grafts, only the Bone Mulch Screw allows compaction of bone into the femoral tunnel. Bone grafting the femoral tunnel increases the snugness of fit in the tunnel and increases stiffness of the ACL graft fixation construct by 41 N/mm in human bone.[9]

On the tibial side, the WasherLoc, soft tissue washers, interference screws, staples, and suture posts have all been tested in animal bone and some have been tested in young human tibia.[5,6] The performance of fixation devices that purchase cancellous bone such as interference screws and the Intrafix is overestimated when tested in animal bone because the density of cancellous bone in animals is greater than young humans.[6] Biomechanical tests have shown that the tibial WasherLoc or tandem soft tissue screws and washers had superior strength and stiffness compared to fixation with interference screws, bone staples, and suture posts.[6] An added benefit of the use of a fixation at the end of the tibial tunnel is that a bone dowel can be inserted to enhance biologic healing, improve stiffness 58 N/mm, and increase the snugness of fit.[36,42]

The principal pitfall associated with the Bone Mulch Screw and tibial WasherLoc system is difficulty passing the graft. Difficulty in passing the graft is avoided by following the described surgical technique for sewing the graft, sizing the graft, centering the tip of the Bone Mulch Screw in the femoral tunnel, and expanding the femoral tunnel. When in doubt drill tunnels 1 mm larger in diameter and then fill any voids with bone graft. Another pitfall with the transtibial technique is a blowout of the posterior wall of the femoral tunnel; however, a blowout does not compromise the fixation with the Bone Mulch Screw as it does with an interference screw fixation. The use of the 70-degree angled curette to clear the ACL origin and remaining soft tissue from the over-the-top position minimizes the posterior wall while allowing a thin 1 to 2 mm thick posterior wall.

REHABILITATION/RETURN TO PLAY RECOMMENDATIONS

The use of the Bone Mulch Screw and WasherLoc fixation of a soft tissue graft allows for safe brace-free rehabilitation.[7,8] The same brace-free rehabilitation protocol can be used with soft tissue allografts since the fixation devices are the weak link biomechanically. **Table 37-1** summarizes the typical rehab protocol we use with this technique and a soft tissue graft.

OUTCOMES AND FUTURE DIRECTIONS

The use of brace-free rehabilitation and return to sports at 3 to 4 months with an autogenous DLSTG graft and fixation with the Bone Mulch Screw and WasherLoc is safe and effective.[7,8] The use of brace-free rehabilitation and return to sports at 3 to 4 months with an allograft soft tissue graft has not been reported. Currently, a multicenter randomized control trial evaluating the outcome of tibialis allograft and DLSTG autograft is under way. The results of this study should provide an objective measure of the outcomes of ACL reconstruction using allograft soft tissue grafts with the Bone Mulch Screw and WasherLoc ACL system.

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[mb6] **TABLE 37-1**

Time	Activity
0–2 wk	WBAT,[a] crutches, PROM,[b] AROM,[c] hamstring curls, SAQS,[d] SLR[e]
2–8 wk	Add stationary bike when flexion >110, continue 0–2 wk activity
8–12 wk	Fast walk/backward walk on treadmill, light jogging on treadmill
[mb7] 12–16 wk	Cariocas, agility exercises, hop drills, continue strengthening
16-20 wk	Return to sports if SLH[f] for distance 85% normal side

[a]weight bearing as tolerated
[b]passive range of motion
[c]active range of motion
[d]short arc quad sets
[e]straight leg raise
[f]single-legged hop

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