Chapter 22
Mechanical Graft Tensioning in Multiple Ligament Knee Surgery

Gregory C. Fanelli

22.1 Introduction

The principles of reconstruction in the multiple ligament injured knee are to identify and treat all pathology, accurate tunnel placement, anatomic graft insertion sites, utilize strong graft materials, mechanical graft tensioning, secure graft fixation, and a deliberate postoperative rehabilitation program. This chapter will concentrate on my experience using a mechanical graft-tensioning boot, the Biomet graft-tensioning boot (Biomet Sports Medicine, Warsaw, IN), during posterior cruciate ligament and anterior cruciate ligament reconstruction in the multiple ligament injured knee. The tensioning boot, the PCL and ACL reconstruction surgical techniques, the cyclic dynamic method of graft tensioning, and the comparative results using the graft-tensioning boot will be presented in this chapter.

22.2 The Mechanical Graft-Tensioning Device

The graft-tensioning boot (Biomet Sports Medicine, Warsaw, IN) is a device used to tension posterior and anterior cruciate ligament grafts after graft preparation and prior to final fixation during the PCL and/or ACL reconstruction surgical procedure. The graft-tensioning boot consists of a frame that has a ratcheted torque wrench attached to the frame (Fig. 22.1). After completion of graft preparation, the allograft or autograft tissue is placed on the tensioning boot, and tension is gradually applied to pretension the graft tissue prior to implantation. The graft is wrapped in a damp sponge, and the tensioning boot graft assembly is protected on the back table until it is time to implant the allograft or autograft tissue (Fig. 22.2). During the surgical procedure, the sterile tensioning boot is fitted over the surgical extremity foot and shin areas, and attached to the surgical leg with a sterile bandage (Fig. 22.3). The cyclic dynamic method of graft tensioning is the intraoperative process that is used, and this method is described in detail in the surgical technique section below.

22.3 Combined PCL–ACL Reconstruction Surgical Technique Using Mechanical Graft Tensioning

My surgical technique for combined PCL–ACL medial and lateral side reconstruction is presented in Chap. 20 of this textbook. This chapter specifically addresses the surgical technique for posterior and anterior cruciate ligament reconstruction using the Biomet graft-tensioning boot.

The patient is placed on the operating room table in the supine position, and after satisfactory induction of anesthesia, the operative and nonoperative lower extremities are carefully examined [1–10]. A tourniquet is applied to the upper thigh of the operative extremity, and that extremity is prepped and draped in a sterile fashion. The well leg is supported by the fully extended operating room table which also supports the surgical leg during medial and lateral side surgery. A lateral post is used to control the surgical extremity. An arthroscopic leg holder is not used. Preoperative and postoperative antibiotics are given, and antibiotics are routinely used to help prevent infection in these time consuming, difficult, and complex cases.

G.C. Fanelli, M.D. (✉)
Geisinger Health System Orthopaedics, Danville, Pennsylvania, USA
e-mail: gfanelli@geisinger.edu

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Fig. 22.1 The graft-tensioning boot consists of a frame that has a ratcheted torque wrench attached to the frame. The device fits over the surgical foot and leg

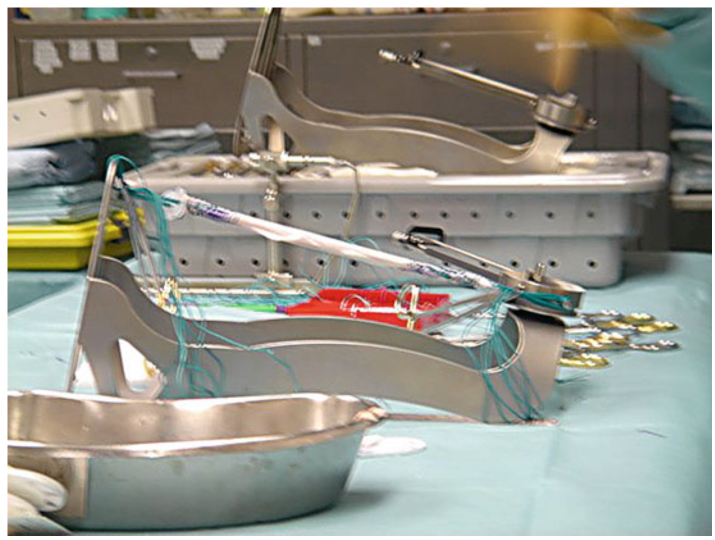

Fig. 22.2 The graft-tensioning device is used to pretension the prepared allograft or autograft tissue prior to implantation. After completion of graft preparation, the allograft or autograft tissue is placed on the tensioning boot, and tension is gradually applied to pretension the graft tissue prior to implantation. The graft is wrapped in a damp sponge, and the tensioning boot graft assembly is protected on the back table until it is time to implant the allograft or autograft tissue

Fig. 22.3 During the surgical procedure, the sterile tensioning boot is fitted over the surgical extremity foot and shin areas and attached to the surgical leg with a sterile bandage

Allograft tissue is prepared prior to bring the patient into the operating room. Autograft tissue is harvested prior to beginning the arthroscopic portion of the procedure.

The arthroscopic instruments are inserted with the inflow through the superolateral patellar portal. Instrumentation and visualization are positioned through inferomedial and inferolateral patellar portals, and can be interchanged as necessary. Additional portals are established as necessary. Exploration of the joint consists of evaluation of the patellofemoral joint, the medial and lateral compartments, medial and lateral menisci, and the intercondylar notch. The residual stumps of both the anterior and posterior cruciate ligaments are debrided; however, the posterior and anterior cruciate ligament anatomic insertion sites are preserved to serve as tunnel reference points. The notchplasty for the anterior cruciate ligament portion of the procedure is performed at this time.

An extracapsular extra-articular posteromedial safety incision is made by creating an incision approximately 1.5–2 cm long starting at the posteromedial border of the tibia approximately 1 in. below the level of the joint line and extending distally. Dissection is carried down to the crural fascia, which is incised longitudinally. An interval is developed between the medial head of the gastrocnemius muscle and the nerves and vessels posterior to the surgeon's finger and the capsule of the knee joint anterior to the surgeon's finger. The posteromedial safety incision enables the surgeon to protect the neurovascular structures, confirm the accuracy of the PCL tibial tunnel, and to facilitate the flow of the surgical procedure.

The curved over-the-top PCL instruments (Biomet Sports Medicine, Warsaw, IN) are used to sequentially lyse adhesions in the posterior aspect of the knee and elevate the capsule from the posterior tibial ridge. This will allow accurate placement of the PCL/ACL drill guide and correct placement of the tibial tunnel.

The arm of the PCL/ACL guide (Biomet Sports Medicine, Warsaw, IN) is inserted through the inferior medial patellar portal. The tip of the guide is positioned at the inferior lateral aspect of the PCL anatomic insertion site. This is below the tibial ridge posterior and in the lateral aspect of the PCL anatomic insertion site. The bullet portion of the guide contacts the anteromedial surface of the proximal tibia at a point midway between the posteromedial border of the tibia and the tibial crest anterior at or just below the level of the tibial tubercle. This will provide an angle of graft orientation such that the graft will turn two very smooth 45° angles on the posterior aspect of the tibia. The tip of the guide, in the posterior aspect of the tibia, is confirmed with the surgeon's finger through the extracapsular extra-articular posteromedial safety incision. Intraoperative AP and lateral X-ray may also be used; however, I do not routinely use intraoperative X-ray. When the PCL/ACL guide is positioned in the desired area, a blunt spade-tipped guide wire is drilled from anterior to posterior. The surgeon's finger confirms the position of the guide wire through the posterior medial safety incision.

The appropriately sized standard cannulated reamer is used to create the tibial tunnel. The surgeon's finger through the extracapsular extra-articular posteromedial incision is monitoring the position of the guide wire. When the drill is engaged in bone, the guide wire is reversed, with the blunt end pointing posterior, for additional patient safety. The drill is advanced until it comes to the posterior cortex of the tibia. The chuck is disengaged from the drill, and completion of the tibial tunnel is performed by hand.

The PCL single bundle or double bundle femoral tunnels are made from inside out using the double bundle aimers, or an endoscopic reamer can be used as an aiming device (Biomet Sports Medicine, Warsaw, IN). The appropriately sized double bundle aimer or endoscopic reamer is inserted through a low anterior lateral patellar arthroscopic portal to create the posterior cruciate ligament anterior lateral bundle femoral tunnel. The double bundle aimer or endoscopic reamer is positioned directly on the footprint of the femoral anterior lateral bundle posterior cruciate ligament insertion site. The appropriately sized guide wire is drilled through the aimer or endoscopic reamer, through the bone, and out of a small skin incision. Care is taken to prevent any compromise of the articular surface. The double bundle aimer is removed, and the endoscopic reamer is used to drill the anterior lateral posterior cruciate ligament femoral tunnel from inside to outside. When the surgeon chooses to perform a double bundle double femoral tunnel PCL reconstruction, the same process is repeated for the posterior medial bundle of the PCL. Care must be taken to ensure that there will be an adequate bone bridge (approximately 5 mm) between the two femoral tunnels prior to drilling. This is accomplished using the calibrated probe and direct arthroscopic visualization of the posterior cruciate ligament femoral anatomic insertion sites.

My preferred surgical technique of posterior cruciate ligament femoral tunnel creation from inside to outside is for two reasons. There is a greater distance and margin of safety between the posterior cruciate ligament femoral tunnels and the medial femoral condyle articular surface using the inside to outside method. Additionally, a more accurate placement of the posterior cruciate ligament femoral tunnels is possible, in my opinion, because I can place the double bundle aimer or endoscopic reamer on the anatomic footprint of the anterior lateral or posterior medial posterior cruciate ligament insertion site under direct visualization.

A Magellan suture retriever (Biomet Sports Medicine, Warsaw, IN) is introduced through the tibial tunnel into the joint and retrieved through the femoral tunnel. The traction sutures of the graft material are attached to the loop of the Magellan suture retriever, and the graft is pulled into position. The graft material is secured on the femoral side using a bioabsorbable interference screw for primary aperture opening fixation and a polyethylene ligament fixation button for backup fixation.

With the knee in approximately 90° of flexion, the anterior cruciate ligament tibial tunnel is created using a drill guide. My preferred method of anterior cruciate ligament reconstruction is the transtibial femoral tunnel endoscopic surgical technique. The arm of the drill guide enters the knee joint through the inferior medial patellar portal. The bullet of the drill guide contacts the anterior medial proximal tibia externally at a point midway between the posterior medial border of the tibia and the anterior tibial crest just above the level of the tibial tubercle. A 1 cm bone bridge or greater exists between the PCL and ACL tibial tunnels. The guide wire is drilled through the guide and positioned so that after creating the anterior cruciate ligament tibial tunnel, the graft will approximate the tibial anatomic insertion site of the anterior cruciate ligament. A standard cannulated reamer is used to create the tibial tunnel.

With the knee in approximately 90–100° of flexion, an over the top femoral aimer is introduced through the tibial tunnel and used to position a guide wire on the medial wall of the lateral femoral condyle to create a femoral tunnel approximating the anatomic insertion site of the anterior cruciate ligament. The anterior cruciate ligament graft is positioned, and fixation is achieved on the femoral side using a bioabsorbable interference screw, while cortical suspensory backup fixation is achieved with a polyethylene ligament fixation button. Additional drawings and photographs of this surgical technique are presented in Chap. 20 of this book [9].

22.4 The Cyclic Dynamic Method of Cruciate Graft Tensioning

The cyclic dynamic method of graft tensioning using the Biomet graft-tensioning boot is used to tension the posterior and anterior cruciate ligament grafts. During this surgical technique, the posterior and/or anterior cruciate ligament grafts are secured on the femoral side first with the surgeon's preferred fixation method. The technique described is a tibial sided tensioning method. I routinely use polyethylene ligament fixation buttons for cortical suspensory fixation and aperture interference fixation with bioabsorbable interference screws for femoral side posterior and anterior cruciate ligament fixation. In combined PCL–ACL reconstructions, the posterior cruciate ligament graft is tensioned first, followed by final PCL graft(s) tibial fixation. The anterior cruciate ligament graft tensioning and fixation follow those of the PCL.

With the tensioning boot applied to the foot and leg of the surgical extremity, tension is placed on the PCL graft(s) distally using the Biomet graft-tensioning boot (Biomet Sports Medicine, Warsaw, IN) (Fig. 22.4). Tension is gradually applied with the knee in zero degrees of flexion (full extension) reducing the tibia on the femur. This restores the anatomic tibial step off. Although there are numbers on the torque wrench dial, these numbers are not used to set the tension. The numbers on the torque wrench serve as a reference point during the cycling process, and readjustment process, and are not indicators of final tension in the graft. The tension is determined by reduction of the tibia on the femur in zero degrees of knee flexion (full extension), the restoration of the anatomic tibial step offs, a negative posterior drawer on intraoperative examination of the knee, and full range of motion of the knee. The knee is cycled through a full range of motion multiple times to allow

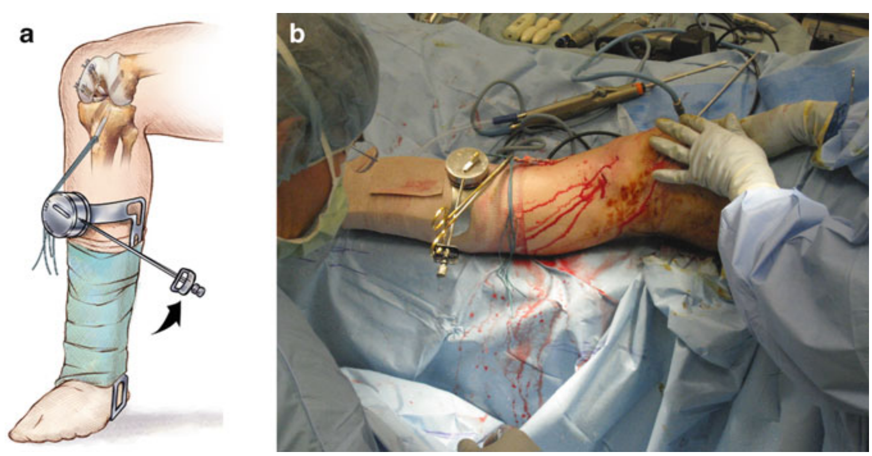

Fig. 22.4 (**a**) The graft-tensioning boot is applied to the traction sutures of the posterior cruciate ligament graft. From Ref. [1]. Reprinted with permission. (**b**) Tension is gradually applied with the knee in zero degrees of flexion (full extension) reducing the tibia on the femur. This restores the anatomic tibial step off. Although there are numbers on the torque wrench dial, these numbers are not used to set the tension. The numbers on the torque wrench serve as a reference point during the cycling process, and readjustment process, and are not indicators of final tension in the graft. The tension is determined by reduction of the tibia on the femur in zero degrees of knee flexion (full extension), the restoration of the anatomic tibial step offs, a negative posterior drawer on intraoperative examination of the knee, and full range of motion of the knee

Fig. 22.5 When the tensioning sequence described in this chapter is complete, the knee is placed in 70–90° of flexion, and fixation is achieved on the tibial side of the PCL graft with a bioabsorbable interference screw for interference fit fixation and backup cortical suspensory fixation with a bicortical screw and spiked ligament washer or polyethylene ligament fixation button

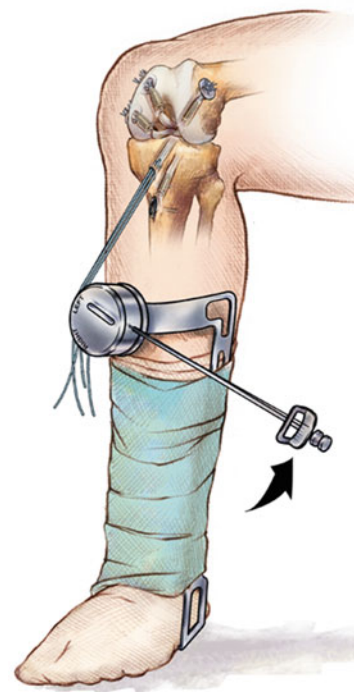

Fig. 22.6 This drawing depicts the graft-tensioning boot applied to the traction sutures of the anterior cruciate ligament graft. From Ref. [1]. Reprinted with permission

pretensioning and settling of the graft. The process is repeated until there is no further change on the torque setting on the graft tensioner with the knee at zero degrees of flexion (full extension). When there are no further changes or adjustments necessary in the tension applied to the graft, the knee is placed in 70–90° of flexion, and fixation is achieved on the tibial side of the PCL graft with a bioabsorbable interference screw for interference fit fixation, and backup cortical suspensory fixation with a bicortical screw and spiked ligament washer or polyethylene ligament fixation button (Fig. 22.5).

The cyclic dynamic method of tensioning of the anterior cruciate ligament graft is performed using the Biomet graft-tensioning boot (Biomet Sports Medicine, Warsaw, IN) after tensioning, and final fixation of the posterior cruciate ligament graft(s) has been performed (Fig. 22.6). Traction is placed on the anterior cruciate ligament graft sutures with the knee in zero degrees of flexion (full extension), and tension is gradually applied reducing the tibia on the femur. The knee is then cycled through multiple full flexion and extension cycles to allow settling of the graft. The Lachman and pivot shift tests are performed. The process is repeated until there is no further change in the torque setting on the graft tensioner at full extension (zero degrees of knee flexion), and the Lachman and pivot shift tests are negative. Although there are numbers on the torque wrench dial, these numbers are not used to set the tension. The numbers on the torque wrench serve as a reference point during

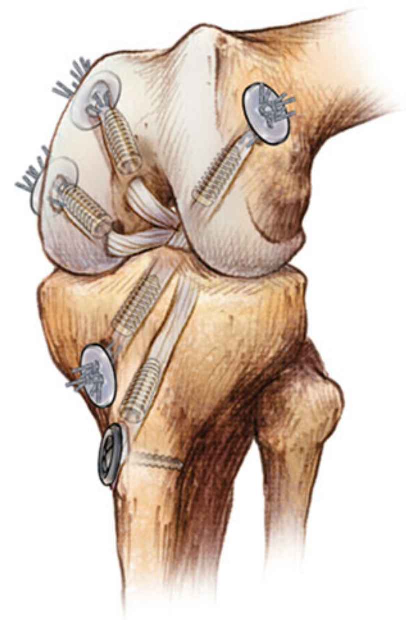

Fig. 22.7 This figure shows final fixation of the posterior and anterior cruciate ligament grafts. From Ref. [1]. Reprinted with permission

the cycling and readjustment processes but are not indicators of final tension in the graft. The final anterior cruciate ligament graft tension is determined by the Lachman and pivot shifts becoming negative and achieving full range of motion of the knee. The knee is placed in approximately 30° of flexion, and fixation is achieved on the tibial side of the anterior cruciate ligament graft with a bioabsorbable interference screw, and backup fixation with a polyethylene ligament fixation button (Fig. 22.7).

22.5 Results

Fanelli and Edson, in 2004, published the 2–10-year (24–120-month) results of 41 chronic arthroscopically assisted combined PCL/posterolateral reconstructions evaluated pre- and postoperatively using Lysholm, Tegner, and Hospital for Special Surgery knee ligament rating scales, KT1000 arthrometer testing, stress radiography, and physical examination [11, 12]. PCL reconstructions were performed using the arthroscopically assisted single femoral tunnel–single bundle transtibial tunnel posterior cruciate ligament reconstruction technique using fresh frozen Achilles tendon allografts in all 41 cases. In all 41 cases, posterolateral instability reconstruction was performed with combined biceps femoris tendon tenodesis and posterolateral capsular shift procedures. Postoperative physical examination revealed normal posterior drawer/tibial step off for the overall study group in 29/41 (70%) of knees. Normal posterior drawer and tibial step offs were achieved in 91.7% of the knees tensioned with the Biomet Sports Medicine mechanical graft tensioner. Posterolateral stability was restored to normal in 11/41 (27%) of knees and tighter than the normal knee in 29/41 (71%) of knees evaluated with the external rotation thigh–foot angle test. Thirty degree varus stress testing was normal in 40/41 (97%) of knees and grade 1 laxity in 1/41 (3%) of knees. Postoperative KT 1000 arthrometer testing mean side-to-side difference measurements were 1.80 mm (PCL screen), 2.11 mm (corrected posterior), and 0.63 mm (corrected anterior). This is a statistically significant improvement from preoperative status for the PCL screen and the corrected posterior measurements ($p=0.001$). The postoperative stress radiographic mean side-to-side difference measurement measured at 90° of knee flexion and 32 lb of posterior directed force applied to the proximal tibia using the Telos device was 2.26 mm. This is a statistically significant improvement from preoperative measurements ($p=0.001$). Postoperative Lysholm, Tegner, and Hospital for Special Surgery knee ligament rating scale mean values were 91.7, 4.92, and 88.7, respectively, demonstrating a statistically significant improvement from preoperative status ($p=0.001$). The authors concluded that chronic combined PCL/posterolateral instabilities can be successfully treated with arthroscopic posterior cruciate ligament reconstruction using fresh frozen Achilles tendon allograft combined with posterolateral corner reconstruction using biceps tendon tenodesis combined with posterolateral capsular shift procedure. Statistically significant improvement is noted ($p=0.001$) from the preoperative condition at 2–10-year follow-up using objective parameters of knee ligament rating scales, arthrometer testing, stress radiography, and physical examination.

Two- to ten-year results of combined ACL–PCL reconstructions without the Biomet Sports Medicine graft-tensioning boot have been published by Fanelli and Edson in 2002 [13]. This study presented the 2–10-year (24–120-month) results of 35 arthroscopically assisted combined ACL/PCL reconstructions evaluated pre- and postoperatively using Lysholm, Tegner, and Hospital for Special Surgery knee ligament rating scales, KT 1000 arthrometer testing, stress radiography, and physical examination.

This study population included 26 males, 9 females, and 19 acute and 16 chronic knee injuries. Ligament injuries included 19 ACL/PCL/posterolateral instabilities, 9 ACL/PCL/MCL instabilities, 6 ACL/PCL/posterolateral/MCL instabilities, and 1 ACL/PCL instability. All knees had grade III preoperative ACL/PCL laxity, and were assessed pre- and postoperatively with arthrometer testing, three different knee ligament rating scales, stress radiography, and physical examination. Arthroscopically assisted combined ACL/PCL reconstructions were performed using the single incision endoscopic ACL technique, and the single femoral tunnel–single bundle transtibial tunnel PCL technique. PCLs were reconstructed with allograft Achilles tendon (26 knees), autograft BTB (7 knees), and autograft semitendinosus/gracilis (2 knees). ACLs were reconstructed with autograft BTB (16 knees), allograft BTB (12 knees), Achilles tendon allograft (6 knees), and autograft semitendinosus/gracilis (1 knee). MCL injuries were treated with bracing or open reconstruction. Posterolateral instability was treated with biceps femoris tendon transfer, with or without primary repair, and posterolateral capsular shift procedures as indicated. No Biomet graft-tensioning boot was used in this series of patients.

Postoperative physical examination results revealed normal posterior drawer/tibial step off in 16/35 (46%) of knees and normal Lachman and pivot shift tests in 33/35 (94%) of knees. Posterolateral stability was restored to normal in 6/25 (24%) of knees, and tighter than the normal knee in 19/25 (76%) of knees evaluated with the external rotation thigh–foot angle test. Thirty degree varus stress testing was normal in 22/25 (88%) of knees and grade 1 laxity in 3/25 (1%) of knees. Thirty degree valgus stress testing was normal in 7/7 (100%) of surgically treated MCL tears and normal in 7/8 (87.5%) of brace treated knees. Postoperative KT 1000 arthrometer testing mean side-to-side difference measurements were 2.7 mm (PCL screen), 2.6 mm (corrected posterior), and 1.0 mm (corrected anterior) measurements, a statistically significant improvement from preoperative status ($p=0.001$). Postoperative stress radiographic side-to-side difference measurements measured at 90° of knee flexion and 32 lb of posteriorly directed proximal force were 0–3 mm in 11/21 (52.3%), 4–5 mm in 5/21 (23.8%), and 6–10 mm in 4/21 (19%) of knees. Postoperative Lysholm, Tegner, and HHS is Hospital for Special Surgery knee ligament rating scale mean values were 91.2, 5.3, and 86.8, respectively, demonstrating a statistically significant improvement from preoperative status ($p=0.001$). No Biomet graft-tensioning boot was used in this series of patients.

The conclusions drawn from the study were that combined ACL/PCL instabilities could be successfully treated with arthroscopic reconstruction and the appropriate collateral ligament surgery. Statistically significant improvement was noted from the preoperative condition at 2–10-year follow-up using objective parameters of knee ligament rating scales, arthrometer testing, stress radiography, and physical examination. Postoperatively, these knees are not normal, but they are functionally stable. Continuing technical improvements would most likely improve future results.

The results of allograft multiple ligament knee reconstructions using the Biomet Sports Medicine (Warsaw, IN) mechanical graft-tensioning device were published by Fanelli et al. in 2005 [12]. These data present the 2-year follow-up results of 15 arthroscopic-assisted ACL–PCL allograft reconstructions using the Biomet Sports Medicine graft-tensioning boot. This study group consists of 11 chronic and 4 acute injuries. These injury patterns included six ACL PCL PLC injuries, four ACL PCL MCL injuries, and five ACL PCL PLC MCL injuries. The Biomet Sports Medicine graft-tensioning boot was used during the procedures as in the surgical technique described above. All knees had grade III preoperative ACL/PCL laxity, and were assessed pre- and postoperatively using Lysholm, Tegner, and Hospital for Special Surgery knee ligament rating scales, KT 1000 arthrometer testing, stress radiography, and physical examination.

Arthroscopically assisted combined ACL/PCL reconstructions were performed using the single incision endoscopic ACL technique and the single femoral tunnel–single bundle transtibial tunnel PCL technique. PCLs were reconstructed with allograft Achilles tendon in all 15 knees. ACLs were reconstructed with Achilles tendon allograft in all 15 knees. MCL injuries were treated surgically using primary repair, posteromedial capsular shift, and allograft augmentation as indicated. Posterolateral instability was treated with allograft semitendinosus free graft, with or without primary repair, and posterolateral capsular shift procedures as indicated. The Biomet Sports Medicine graft-tensioning boot was used in this series of patients.

Post-reconstruction physical examination results revealed normal posterior drawer/tibial step off in 13/15 (86.6%) of knees, normal Lachman test in 13/15 (86.6%) of knees, and normal pivot shift tests in 14/15 (93.3%) of knees. Posterolateral stability was restored to normal in all knees. When evaluated with the external rotation thigh–foot angle test, nine knees were equal to the normal knee and two knees were tighter than the normal knee. Thirty degree varus stress testing was restored to normal in all 11 knees with posterolateral lateral instability. Thirty and zero degree valgus stress testing was restored to normal in all 9 knees with medial side laxity. Postoperative KT 1000 arthrometer testing mean side-to-side difference measurements were 1.6 mm (range 3–7 mm) for the PCL screen, 1.6 mm (range 4.5–9 mm) for the corrected posterior, and 0.5 mm (range 2.5–6 mm) for the corrected anterior measurements, a significant improvement from preoperative status. Postoperative stress radiographic side-to-side difference measurements measured at 90° of knee flexion, and 32 lb of posteriorly directed proximal force using the Telos stress radiography device were 0–3 mm in 10/15 knees (66.7%), 4 mm in 4/15 knees (26.7%), and 7 mm in 1/15 knees (6.67%). Postoperative Lysholm, Tegner, and HSS knee ligament rating scale mean values were 86.7 (range 69–95), 4.5 (range 2–7), and 85.3 (range 65–93), respectively, demonstrating a significant improvement from preoperative status.

The authors concluded that the study group demonstrates the efficacy and success of using allograft tissue and a mechanical graft-tensioning device (Biomet Sports Medicine graft-tensioning boot) in single bundle single femoral tunnel arthroscopic posterior cruciate ligament reconstruction in the multiple ligament injured knee. Without the tensioning boot, there were 46% normal posterior drawer and tibial step off examinations, and with the graft-tensioning boot, the normal tibial step off and posterior drawer examinations improved to 86.6% of the PCL reconstructions in the study group.

22.6 Summary and Conclusions

The principles of reconstruction in the multiple ligament injured knee are to identify and treat all pathology, accurate tunnel placement, anatomic graft insertion sites, utilize strong graft material, mechanical graft tensioning, secure graft fixation, and a deliberate postoperative rehabilitation program. This chapter has presented my experience using a mechanical graft-tensioning boot during posterior cruciate ligament and anterior cruciate ligament reconstruction in the multiple ligament injured knee. The cyclic dynamic method of posterior and anterior cruciate ligament graft tensioning pretensions the grafts, allows graft settling, and confirms knee range of motion and knee stability before the final fixation of posterior and anterior cruciate ligament reconstruction. Our results demonstrate the efficacy and success of using allograft tissue and a mechanical graft-tensioning device (Biomet Sports Medicine graft-tensioning boot) in single bundle single femoral tunnel arthroscopic posterior cruciate ligament reconstruction in the multiple ligament injured knee. We have also found the graft-tensioning boot to be equally effective in double bundle posterior cruciate ligament reconstructions in the multiple ligament injured knee [2, 3, 14].

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