A Review Paper

Applying Military Strategy to Complex Knee Reconstruction: Tips for Planning and Executing Advanced Surgery

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Abstract

Complex knee restoration for injured soldiers follows a similar paradigm as for high-end civilian athletes. The military healthcare paradigm often involves the added logistics of transporting the service member to the correct military treatment facility at the correct time and ensuring the patient's work-up is complete before he or she arrives for the complex knee restoration. Such cases require significant rehabilitation and time away from family and work, so anything that reduces the morbidity of the surgical undertaking and the overall "morbidity footprint" of time away and that helps the patient return to normal function are value-added and worthy of our attention and diligence in developing an efficient system for managing complex cases.

The globally integrated military healthcare system that is in place has matured over the past decades to allow for the significant majority of the necessary preoperative work-up to be performed at a soldier's current duty station, wherever in the world that may be, under the guidance of local healthcare providers with specific inputs from the knee restoration surgeon who eventually receives the patient for the planned surgical intervention. Efficient preoperative workup and cutting edge knee restoration procedures that are often combined to limit overall morbidity along with managed physical therapy are the keys to success.

Complex combined knee restoration surgery can be safely performed in an outpatient setting. The term *complex knee restoration* is used to describe management of knee injuries that are more involved—that is, there is damage to the menisci, cartilage, ligaments, and bones. Management entails not only determining the best treatment options but navigating the more complex logistics of making sure all necessary grafts (fresh and frozen allografts and autografts), implants, and instrumentation are readily available as these cases come to fruition.

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Algorithm for Knee Restoration Planning

Alignment Issues

The first task is to confirm the realignment indication. Realignment may be performed with a proximal opening-wedge medial tibial osteotomy (OWMTO), a distal opening-wedge lateral femoral osteotomy (OWLFO), or a tibial tubercle osteotomy (TTO).[1] Given the reproducible clinical improvement achieved and the robust nature of the fixation, these osteotomies are often the first surgical step in complex knee restorations.[2] The final determination, made by the surgeon in consultation with the patient, is whether to perform the indicated osteotomy alone or in combination with the rest of the planned restoration surgery. In the vast majority of cases I have managed over the past 2 decades, I have performed the entire knee restoration in a single operation.[3] Within the past 5 years, combining the procedures has become even more feasible with the important progress made in multimodal pain management and with the close collaboration of anesthesiologists.[4]

Meniscus and Cartilage Status

The integration status of meniscus and cartilage within the medial and lateral tibiofemoral compartments is crucial to the comprehensive restoration plan. In fact, the success of the restoration can be said to be dependent on the functional status and health of meniscus and cartilage—which either succeed together or fail apart.

Important covariables are age, prior surgical interventions, activity level expected or allowed after surgery, and size, location, and depth of cartilage injury.[5] Whether a cartilage injury is monopolar or bipolar is determined with advanced imaging (magnetic resonance imaging [MRI], computed tomography [CT], weight-bearing radiography) along with analysis of a thorough history (including a review of prior operative reports and arthroscopic images) and a knee examination. Bipolar injuries that involve the condyle and juxtaposed plateau often bode poorly for good clinical outcomes—compared with unipolar lesions, which usually involve the condylar surfaces in isolation. The same thinking regarding the patellofemoral compartment is appropriate. Cartilage lesions that involve the juxtaposed surfaces of the patellar and trochlear groove do poorer than isolated lesions, which are more amenable to cartilage restoration options. The literature on potential cartilage restoration options for the patella and trochlea is expanding. I use the 3-dimensional cartilage restoration option of a fresh patellar osteochondral allograft (OCA) for high-grade cartilage lesions thought to be clinically significant. Other options, such as microfracture, cell-based cartilage restoration, and Osteochondral Autograft Transfer System (Arthrex) procedures (from the thinner condylar cartilage), have varied in their outcomes for patellar lesions. According to more recent literature and a review of my clinical results, fresh patellar OCAs are a good option for patellar lesions.[6] Similarly, trochlear lesions can be managed with microfracture, cell-based therapies, or fresh OCAs, depending on surgeon preference.

Functional total or subtotal meniscectomies are often best managed with meniscal allograft transplantation (MAT). An intact or replaced medial or lateral meniscus works synergistically with any planned anterior cruciate ligament (ACL) reconstruction. Again, the adage that meniscus and cartilage succeed together or fail apart is appropriate when planning complex knee restoration. Signs of extrusion or joint-space narrowing and root avulsion or significant loss of meniscal tissue, visualized on MRI or on prior surgical images, often help substantiate a MAT plan. MAT has had the best long-term results when performed in compartments with cartilage damage limited to grade I and grade II changes, in stable knees, and in knees that can be concurrently stabilized.[5] Technological advances have increased the value of MAT by limiting the morbidity of the operation and thus allowing for other surgery to be performed concomitantly and safely as part of comprehensive knee restoration. Over the past 20 years, I have arthroscopically performed MAT with bone plugs for medial and lateral procedures, and my results with active-duty soldiers have been promising, paralleling the clinic success reported in the literature.[5] Alignment must be considered when performing MAT or cartilage restoration. If the addition of meniscal transplantation or cartilage restoration leaves the knee with residual malalignment of 6° or more, corrective osteotomy is performed.

My view and practice have been to plan for an unloading chondroprotective osteotomy. The goal is a balanced mechanical axis, whether achieved

Take-Home Points

- Thorough preoperative planning is imperative and inclusive of history, physical examination, radiographs, and MRI and potentially CT scan.
- Plan carefully for needed graft sources (autografts and allografts).
- Rehabilitation starts preoperatively and a detailed individualized plan is often warranted.
- Indicated ligamentous repair or augmented repair with reconstruction is more likely to succeed when performed within 2 weeks of injury.
- Complex combined knee restoration surgery can be safely performed in an outpatient setting.

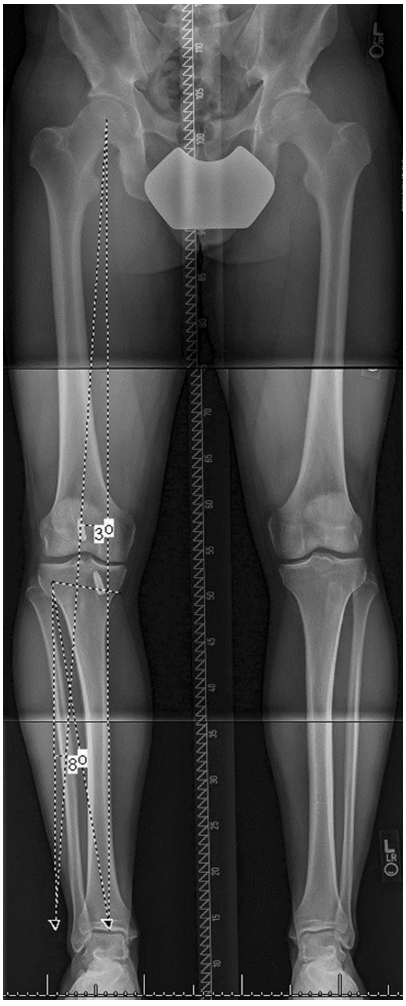

Figure 1. Bilateral standing anteroposterior hip–knee–ankle alignment radiograph used to assess mechanical axis and potential need for corrective osteotomy.

with mere joint-space restoration or with an osteotomy added.

Ligament Status

A comprehensive plan for establishing ligamentous stability is paramount to the overall clinical success of complex knee restorations. Meniscus and cartilage restoration efforts are wasted if clinically significant ligamentous laxity is not concomitantly treated with reconstruction surgery. Revision ACL surgery is by far the most commonly performed surgery in complex knee cases. Diligence in interpreting advanced MRI and physical examination findings is required to make sure there are no concomitant patholaxities in the medial, lateral, posterior, posteromedial, and posterolateral ligamentous complexes. Appropriate ligamentous reconstruction is warranted to maximize clinical results in complex knee restorations. Such cases more commonly require allograft tissue, as the availability of autograft tissue is the limiting issue with 2 or more ligament reconstructions. Military treatment facilities, in which comprehensive knee restorations are performed, have soft-tissue allografts on hand at all times. Having tissue readily available makes it less imperative to determine the most appropriate combined ligamentous reconstruction surgery before the patient arrives—a process that is often difficult. This situation is in contradistinction to the need for specific matched-for-size allograft frozen meniscus and fresh cartilage tissues, both of which require tissue-form procurement in advance of planned restoration surgery.

Rehabilitation Plan

The rehabilitation plan is driven by the part of the complex knee restoration that demands the most caution with respect to weight-bearing and range of motion (ROM) during the first 6 weeks after surgery. The most limiting restorative surgeries involve meniscus and cartilage. Recent clinical trial results support weight-bearing soon after tibial osteotomy performed in the absence of meniscus and cartilage restoration that would otherwise limit weight-bearing for 6 weeks.[7] Therefore, most of these complex knee restorations are appropriately managed with a hinged brace locked in extension for toe-touch weight-bearing ambulation, with ROM usually limited to 0° to 90° during the first 6 weeks. Quadriceps rehabilitation with straight-leg raises and isometric contractions is prescribed with a focus on maintaining full extension as the default resting knee position until normalized resting quadriceps tone returns. Full weight-bearing and advancement to full flexion are routinely allowed by 6 weeks.

Case Report

A 41-year-old male service member who was overseas was referred to my clinic for high tibial osteotomy consideration and possible revision ACL reconstruction. His symptoms were medial pain, recurrent instability, and patellofemoral crepitance. Three years earlier, he underwent autograft transtibial ACL reconstruction with significant débridement of the medial meniscus. Before his trip to the United States, I asked that new MRI scans, full-length standing hip–knee–ankle bilateral alignment radiographs, and a 4-view weight-bearing knee series (including a posteroanterior Rosenberg view) be obtained and sent for my review (**Figure 1**). In retrospect, this request obviated the need for the patient to make a second overseas trip.

Review of the patient's detailed preoperative imaging work-up and electronic medical record (available through the military's healthcare system) made it clear that far more surgical intervention was needed than originally assumed. A significant full-thickness chondral lesion of the patella and a subtotal medial meniscectomy would necessitate patellar cartilage restoration and medial MAT in addition to the high tibial osteotomy and revision ACL reconstruction.

Had this patient been sent through the military medical evacuation system, he would have had to make 2 overseas trips—one trip for preoperative evaluation and advanced imaging, whereby he would have been placed on a match list and had to wait for a requested meniscal allograft and an appropriate graft for his patella, and the other trip for his complex surgery. Fortunately, the

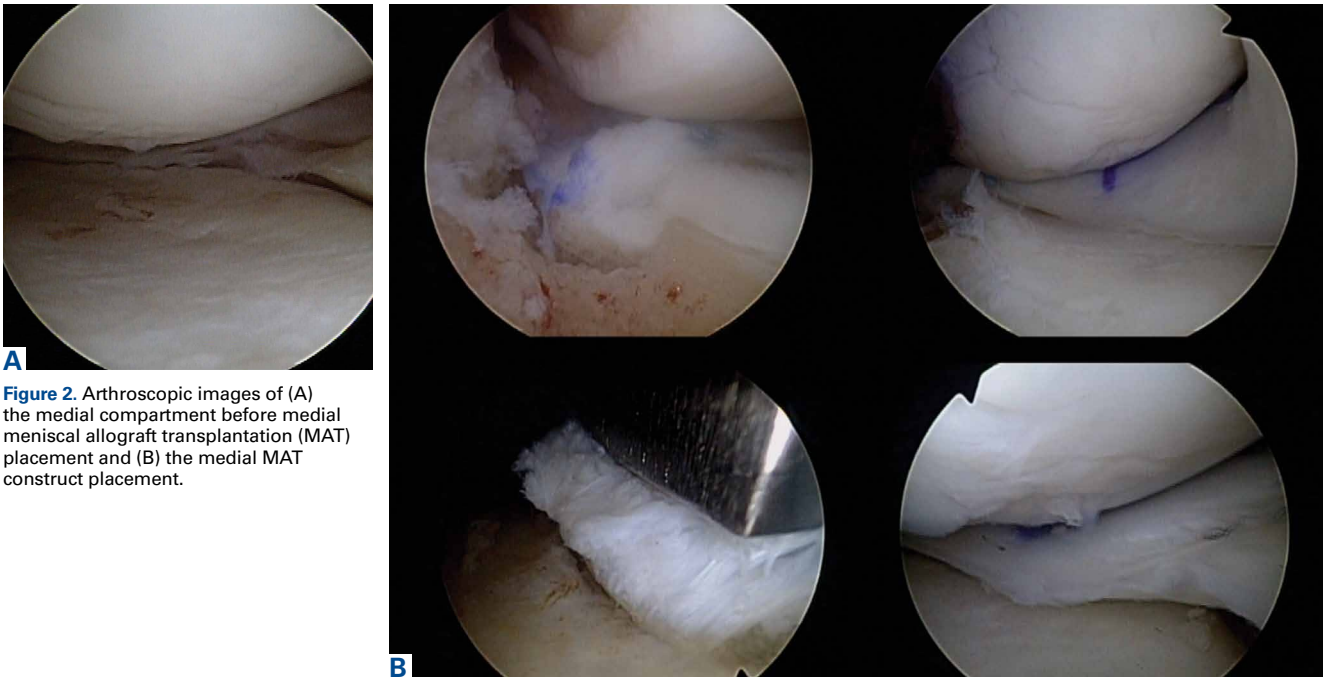

Figure 2. Arthroscopic images of (A) the medial compartment before medial meniscal allograft transplantation (MAT) placement and (B) the medial MAT construct placement.

military's integrated healthcare network with true 2-way communication and the collaborative use of integrated electronic medical records proved extremely valuable in making management of this complex knee restoration as efficient as possible. From the perspective of the soldier and his military unit, only 1 big overseas trip was needed; from the perspective of the military healthcare system, responsible use of healthcare personnel and monetary resources and well-planned complex knee restoration surgery saved a knee and allowed a soldier-athlete to rejoin the fields of friendly strife.

This patient had undergone functional complete medial meniscectomy and had significant medial compartment pain, varus alignment, and minimal medial joint-space narrowing (assumed grossly intact cartilage about plateau and condyle), plus patellofemoral pain and crepitance with a large high-grade posttraumatic patellar chondral lesion with normal patellofemoral alignment. He also had an isolated failed ACL graft from prior ACL reconstruction. The previous hardware placement was analyzed, and it was determined that the femoral interference screw could be left in place and that the tibial interference screw most likely would be removed. The mechanical axis determined from the bilateral long-leg standing images dictated a need for proximal OWMTO for correction up to 8° to allow the axis to cross the center of the knee. The 8° correction is the measured correction needed to move the axis from its pass through the medial compartment to a more balanced position across the middle of the knee.

The overall plan encompassed major concomitant corrective and restorative surgery: tibial osteotomy, medial MAT, revision ACL reconstruction, and fresh mega-patellar OCA. Once the frozen meniscus and eventually the fresh patella (both matched for size) were obtained, arrangements for the patient's trip for the complex surgery were finalized.

Surgery was started with brief arthroscopic evaluation to confirm the overall appropriateness of the planned procedure and to determine if any other minor deficiencies would warrant operative intervention. Once confirmed, the restoration proceeded as planned. The OWMTO was performed with a PEEK (polyetheretherketone) wedge implant (iBalance; Arthrex) followed by arthroscopic preparation for medial MAT with removal of any meniscal remnants and placement of passing sutures (**Figure 2A**). The meniscus was delivered across the compartment through an enlarged medial portal. The posterior horn bone plug was secured in the retrosocket with sutures tied off to an anterior tibial cortical 2-hole button (**Figure 2B**). The body of the posterior third of the meniscus was secured to the posterior capsule by tying the 2 previously placed vertical sutures to each other over the intervening capsule. The anterior horn bone plug (10

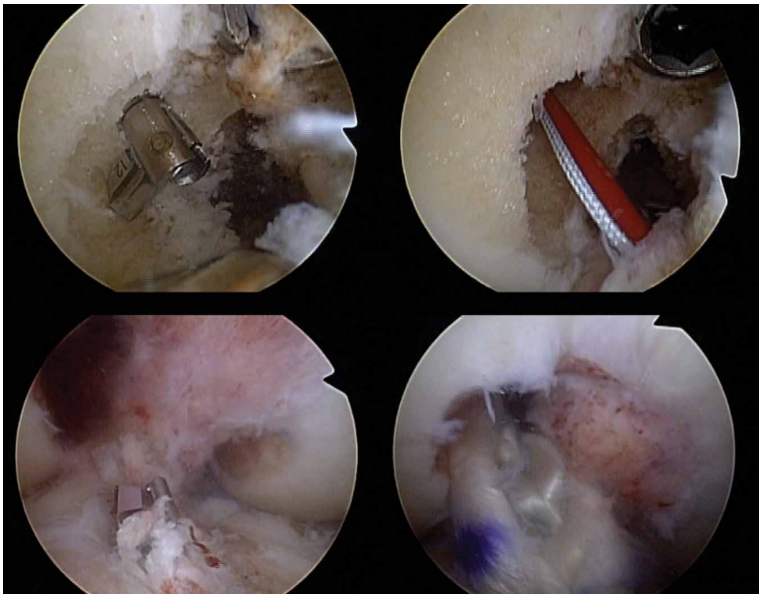

Figure 3. Arthroscopic images of revision allograft anterior cruciate ligament reconstruction portion of the case.

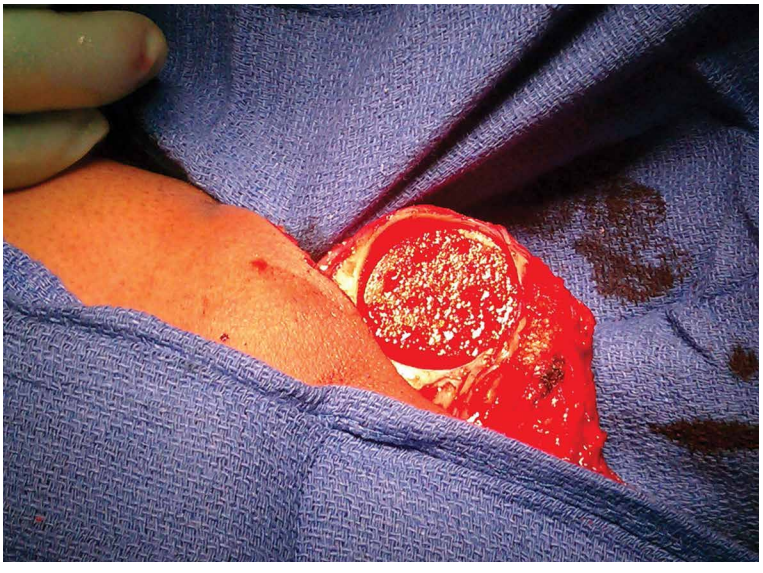

Figure 4. Surgical image of donor patella prepared to receive the matched-for-size fresh patellar osteochondral allograft.

mm in diameter × 7 mm thick) was then secured within a 10-mm socket drilled antegrade to a depth of 10 mm with a SwiveLock anchor (Arthrex) for interference bony fixation and recapitulation of the normal hoop stresses. Inside-out sutures were placed to secure the capsule to the meniscus and thereby prevent iatrogenic meniscal extrusion. A standard all-inside allograft revision ACL reconstruction was performed with an 11-mm FlipCutter and guide system (Arthrex) to make the femoral and tibial retrosockets. Passing sutures were used to deploy the ACL graft construct, which was fashioned into a quadruple-stranded GraftLink construct (Arthrex) from a 28-mm allograft peroneus longus tendon (**Figure 3**).

When the arthroscopic portion of the surgery was finished, a medial parapatellar arthrotomy was made to allow the patella to be inverted and complete fresh mega-patellar OCA placement (**Figure 4**). A drill guide system was used to prepare the host patella with the largest contained circular socket (35 mm) with a 1-mm to 2-mm cortical margin to a marginal bony depth and an 8- to 10-mm central bony depth. The donor patella was then prepared on the graft preparation guide to allow a mega-patellar osteochondral plug to be press-fit into the recipient socket after thorough pulse lavaging of the bony portion of the graft to negate as much of the marrow cellular elements as possible (**Figure 5**). After appropriate tracking was confirmed, the arthrotomy and skin incision were closed.

The knee was placed in a ROM brace locked in full extension. The patient was able to do straight-leg raises and calf pumps in the recovery room and was discharged home with a saphenous nerve block and an iPACK (Interspace between the Popliteal Artery and the Capsule of the posterior Knee) nerve block in place. Home-based therapy was started immediately. After the patient's first postoperative visit, formal therapy (discussed earlier) was initiated (**Figure 6**). Toe-touch weight-bearing with the brace locked in extension and ROM limited to 0° to 90° were maintained until 6 weeks, when full weight-bearing and full ROM were allowed. The rehabilitation course was uneventful. The patient continued on active duty and completed his military service, retiring 3 years later with 20 years of service.

Discussion

All-inside GraftLink ACL reconstruction with cortical suspensory fixation appears well suited to combined medial and lateral MAT and/or cartilage restoration—whether it be large fresh OCA combined with medial MAT (as in this patient's case) or another form of cartilage restoration. Arthroscopic MAT with anatomically fashioned and placed bone plugs minimizes the morbidity within the notch footprints and allows for discrete revision socket formation for both femoral and tibial ACL graft placement. In this case, preparation for the medial MAT and ACL sockets was followed by MAT/ACL construct implantation and secure fixation. The arthrotomy was

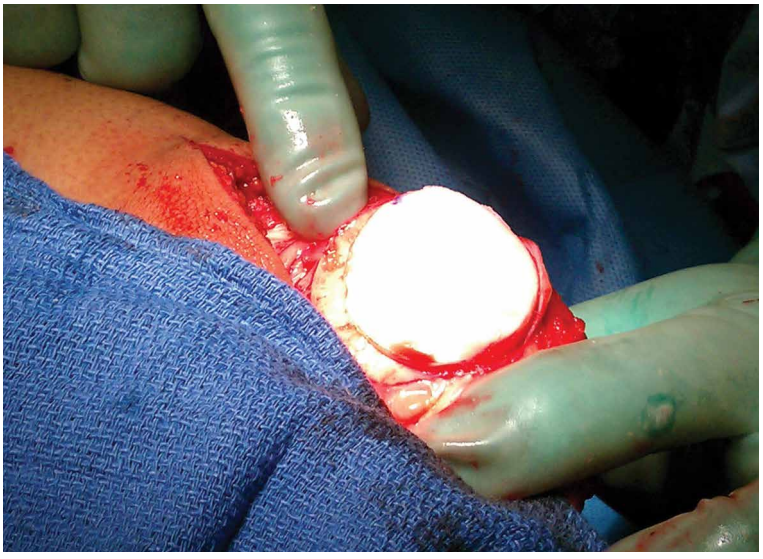

Figure 5. Fresh patella osteochondral allograft in place with press-fit fixation.

1. Osteotomy completed
2. Meniscal remnant tissue removed
3. Posterior horn socket prepared
4. Passing sutures placed out of capsule
5. Meniscal allograft preparation completed
6. Passing sutures used to pass graft via enlarged portal
7. Posterior horn plug seated and secured
8. Pre-placed posterior horn suture tails tied together over capsule
9. Anterior horn plug seated in socket (hoop forces recapitulated)
10. Inside-out meniscal repair sutures complete procedure

Figure 7. Steps of this case.

Figure 6. Postoperative radiograph confirms osteotomy and anterior cruciate ligament hardware placement.

thereby minimized and placed to allow for efficient mega-patellar OCA graft placement.

Over the past decade, I have performed similar concomitant procedures using the same surgical principles that allow for efficient and reproducible complex knee restoration (**Figure 7**). Common examples are multiligamentous reconstructions (ACL–posterior cruciate ligament–posterolateral corner, ACL–posterior cruciate ligament–medial collateral ligament, ACL–anterolateral ligament, and ACL–medial patellofemoral ligament) combined with concomitant meniscus and cartilage restoration and various osteotomies.

Although use of an algorithm for the management of complex knee restorations is not universally feasible, I offer guidelines for complex knee injuries:

- At each decision point, determine whether the knee and the patient can withstand the planned surgical intervention.
- After deciding to proceed with knee restoration, list the meniscus, cartilage, and ligament injuries that must be addressed.
- Determine which repairs (meniscus, cartilage, ligament) are warranted. Repairs generally are best performed within a period of 7 to 14 days.
- Determine which ligament injuries warrant reconstruction. Allograft tissue typically is used for multiligament reconstruction.
- Rank-order the ligament reconstruction requirements. It is fine to proceed with all of the reconstructions if the case is moving smoothly, if there are no developing tourniquet-time issues, and if the soft-tissue envelope is responding as expected.

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- Consider autograft and/or allograft tissue needs for concomitant or staged meniscus and cartilage restoration options/requirements.

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