Knee Cartilage Patellofemoral Injuries

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Summary: Cartilage injuries of the patellofemoral joint present a difficult challenge owing to the unique anatomy and high shear forces. Active duty military personnel commonly present with cartilage injuries of the patella and trochlea owing to acute trauma or chronic repetitive injury. The initial treatment for patellofemoral chondral injury is nonoperative modalities to include: rest, activity modification, anti-inflammatory medication, and physical therapy. Physical therapy predominantly focuses on strengthening the vastus medialis obliquus to improve patellofemoral alignment. Reconstructive cartilage procedures like fresh osteochondral allograft transplant and autologous chondrocyte implantation are used to restore articular congruity and minimize symptoms when nonoperative modalities and common first-line reparative techniques fail. Although there is currently no evidence-based algorithm for the management of cartilage lesions of the patellofemoral joint, there are trends in treatment that help guide the surgeon. The successful outcome of treatment for cartilage lesions depends on recognizing and addressing concomitant pathology with proximal or distal realignment and patellar unloading procedures. Outcomes also depend on appropriate patient selection with his/her commitment to an extended period of rehabilitation and the ability to modify their activities. The active duty patient does not always have the ability to participate in an extended period of rehabilitation and must be treated with the best treatment option that allows an effective return to duty. Therefore, the purpose of this article is to review the standard treatment options for chondral lesions of the patellofemoral joint and our preferred treatment options in the active duty patient.

Key Words: patellofemoral—patella—trochlea—cartilage—ACI.

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The treatment of articular cartilage lesions of the patellofemoral joint (PFJ) continues to be a difficult problem. In addition to the poor healing capacity of hyaline cartilage, the PFJ's complexity and propensity for high shear forces make surgical treatment even more difficult.[1,2] Chondral lesions may be present up to 67% of the time in knee arthroscopy and most commonly involving the patella.[3,4]

In the military population, isolated cartilage lesions of the patella or femoral trochlea are likely a result of acute or repetitive trauma associated with the high physical demands of the occupation. A recent study looking at quantitative magnetic resonance imaging (MRI) signal changes in runners before and up to 3 months after activity found the greatest signal changes in the PFJ suggesting long-term biomechanical changes in the cartilage.[5] Similarly, active duty personnel and military academy cadets are routinely required to perform high impact aerobics and military-specific tasks. This may contribute to patellofemoral cartilage damage.

The etiology of patellofemoral cartilage lesions can be multifactorial and may coexist with other conditions like osteoarthritis, ligamentous instability, osteochondritis dissecans (OCD), patellofemoral malalignment, and recurrent patellar instability.[3] The successful outcome of treatment for cartilage lesions depends on recognizing and addressing concomitant pathology with proximal or distal realignment and patellar unloading procedures. In addition, the surgeon must take into consideration the patient's age, lesion size, and patient's physical demands. Although not commonly an issue in the active duty population, of equal importance in deciding treatment should be patient's expectations, compliance with rehabilitation protocols, and comorbidities.

The objective of this article is to discuss reconstructive operative techniques for focal cartilage lesions of the PFJ in the military population. Nonoperative treatment, reparative and realignment/off-loading cartilage procedures, and arthroplasty are not the primary focus of this article and will be briefly mentioned. The goal will be to discuss the physical examination, radiographic evaluation, and the available reconstructive surgical techniques for PFJ cartilage injuries.

GENERAL CONSIDERATIONS

There are several treatment options when confronted with focal cartilage lesions and they can best by classified into 2 subcategories: reparative and restorative/reconstructive. The premise of reparative techniques is to maintain articular congruity by replacing damaged hyaline cartilage with fibrocartilage by stimulating bleeding from subchondral bone to deliver mesenchymal stem cells to the area and promote healing with fibrocartilage. Restorative/reconstructive techniques, like osteochondral allografting and autologous chondrocyte implantation (ACI; Carticel, Genzyme Biosurgery, Cambridge, MA) deliver a source of hyaline cartilage to restore articular congruity.[6,7] Studies have shown that the mechanical properties of the cartilage created by reparative bone marrow stimulating procedures is inferior to the hyaline cartilage delivered by reconstructive cartilage surgery.[8,9] Therefore, given the inferior biomechanics of fibrocartilage and the high shear stress environment of the PFJ, current operative trends favor reconstructive surgery for cartilage lesions involving the trochlea and patella.[2,9–13]

HISTORY AND PHYSICAL EXAMINATION

Evaluation of the young, athletic patient with suspected cartilage injury to the PFJ should begin with a thorough history. The history should differentiate whether the symptoms are secondary to an acute traumatic event or from recurrent trauma of the knee. The association of a traumatic event can indicate a focal cartilage lesion and may be associated with

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concomitant patella instability or ligamentous injury. A patient with chronic symptoms likely will present with a degenerative chondral injury and he/she should be examined for muscle weakness, extensor mechanism malalignment, patella height, patella tilt, and patella tracking. The description and location of symptoms is important to localizing the injury. Patients commonly report pain, weakness, recurrent effusions, instability, locking, and mechanical symptoms localized to the anterior aspect of the knee. In addition, inciting activities or factors that improve the symptoms should be elicited.

Physical examination is critical and begins with assessing gait and alignment looking for an antalgic gait and/or varus/valgus malalignment. An effusion may be present in an acute traumatic event. Range of motion (ROM) of the knee should be assessed with particular attention on the flexion angle that reproduces symptoms to help indicate the location of chondral injury. Additionally, ROM should be evaluated for mechanical symptoms and crepitus. Finally, patella tracking, mobility, apprehension, tilt, and facet tenderness to palpation should also be documented.

RADIOGRAPHIC EXAMINATION

Standard radiographic evaluation of the knee with suspected PFJ pathology includes an anteroposterior, lateral, Merchant (sunrise 45 degrees knee flexion), Laurin (sunrise 25 degrees knee flexion) Rosenberg 45 degrees posterioanterior, and weightbearing anteroposterior. The mechanical axis of the extremity and the presence of arthritic changes in the other compartments of the knee can help dictate available treatment options. Additionally, radiographs may indicate a loose body or focal osteochondral defect that can confirm findings on physical examination.

MRI is used to assess for concomitant ligamentous injury and cartilage lesions. In the young patient an MRI can be useful to assess for OCD lesions. MRI is useful for diagnosing unstable in situ OCD lesions that need fixation by the characteristic sign of T2 high-signal fluid tracking around the subchondral bone. MRI and computed tomography scan can also be helpful in determining patella tilt, tibial tubercle to trochlear groove distance, and trochlear dysplasia which all can affect the surgical treatment plan when addressing chondral lesions of the PFJ. Finally, dynamic computed tomography scans at varying angles of knee flexion from 0 to 60 degrees can better assess patella tilt and subuxation.

NONOPERATIVE TREATMENT

Initial management of patellofemoral cartilage pathology is commonly an extended period of nonoperative modalities to include: rest, activity modification, anti-inflammatory medications, and physical therapy. Physical therapy should primarily address vastus medialis obliquus weakness with dedicated quadriceps strengthening. A weakened vastus medialis obliquus can contribute to lateral maltracking of the patella in the trochlear groove. The therapist should also address tight lateral structures with stretching as well as concomitant hip adductor and abductor weakness with strengthening which can help alleviate patella maltracking. Other treatments can include injections of steroid and hyaluronic acid–although there is little evidence to support these treatments in the setting of isolated focal articular cartilage lesions. Nonoperative management is successful in majority of the cases, but patients who fail 4 to 6 months of nonoperative treatment should be evaluated for surgical intervention.[14] The best approach to surgical management of PFJ cartilage lesions is to follow a logical algorithm that addresses the specific clinical problem (Fig. 1).[15]

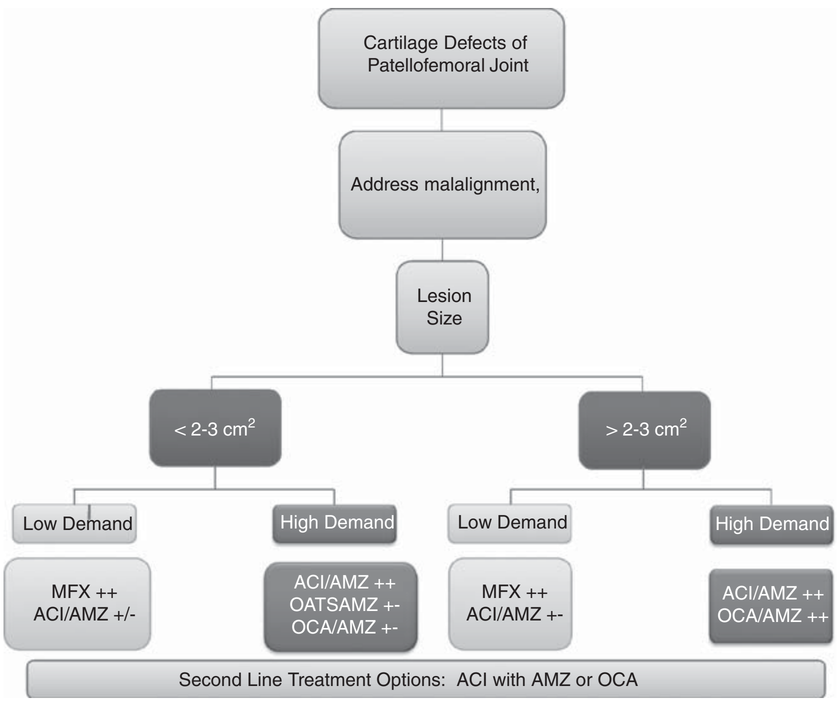

FIGURE 1. Clinical algorithm for the management of cartilage defects of the patellofemoral joint. Algorithm modified from *JBJS Am.* 2009;91:1778–1790. ACI indicates autologous chondrocyte implantation; AMZ, anteromedialization; OATS, osteoarticular transfer system; OCA, osteochondral allograft.

DEBRIDEMENT/MICROFRACTURE

Debridement and microfracture have been used as first-line treatment for cartilage lesions of the knee without bone loss. The goal of debridement is to remove loose cartilage that may become a loose body or contribute to mechanical symptoms. Microfracture is a bone marrow-stimulating procedure that stimulates bleeding and the recruitment of mesenchymal stem cells to encourage healing with fibrocartilage.

Chondroplasty has been shown to provide short-term improvement in 49% of patients with patellar lesions and a 78% patient satisfaction.[16,17] Microfracture has been most successful in the treatment of cartilage lesions $<2\times 2$ cm on the femoral condyles as opposed to the trochlea.[18,19] The success of microfracture depends on lesion type, size, location, and patient age. The PFJ has high shear forces which may exacerbate the symptoms commonly associated with cartilage lesions of the PFJ. In addition, the unique anatomy of the PFJ and the associated shear forces are likely responsible for the limited benefits of trochlear microfracture. However, there has been improvement in patient pain and function up to 18 months after microfracture of the trochlea.[19,20] On the other hand, there are no good reports on the outcomes of microfracture of the patella.

REALIGNMENT PROCEDURES

Realignment procedures of the extensor mechanism can be used in isolation but more commonly used as an adjunct to reconstructive cartilage surgery of the patella and/or trochlea. Anteromedialization (AMZ) of the tibial tubercle was first described by Fulkerson[20] for the successful management of patellofemoral malalignment and symptomatic patella subluxation. The surgery successfully decreases patellofemoral contact pressures shifting them more proximally and medially on the patella and has a success rate when performed alone in 60% to 70% of the time.[21–23] The Maquet osteotomy can also be used to decrease patellofemoral contact pressures by direct anteriorization of the tibial tubercle. A cadaveric study has shown that straight anteriorization of the tibial tubercle decreases mean trochlear contact pressure at all angles of all knee flexion and does not affect the center of force.[24] Clinical studies have shown success rates of anteriorization of the patella alone to be 62% to 80%.[25–27]

The success of distal realignment procedures seems to depend on the location, size, and grade of the chondral lesion. Patients with lesions of the central trochlea or diffusely on the patella have much poorer outcomes with an isolated realignment procedure.[28,29] Studies have shown that patients who had ACI in conjunction with an AMZ procedure, as compared with ACI alone, have better results and satisfaction rates of 86% versus 45%, respectively.[12,30,31] Therefore, patients with disease not localized to the inferolateral patella or trochlea should be considered for a cartilage procedure in conjunction with an AMZ.

FRESH OSTEOCHONDRAL ALLOGRAFT TRANSPLANT SURGERY

There are few series in the literature reporting on the outcomes of fresh osteochondral allograft transplant surgery of the PFJ. The unique surface anatomy and articulation of the trochlea and patella makes it a challenge to appropriately match the geometry of the transplant site with available allograft cartilage. In addition, the cartilage of the patella is the thickest cartilage in the human body, which creates a unique challenge to find a donor osteochondral plug with the similar cartilage thickness.

Recently, osteochondral allografts have gained popularity in "salvage procedures" for the young athlete with any combination of patella, trochlear, or condylar cartilage lesions who have failed other cartilage procedures. The benefits of osteochondral allograft transplant include: single stage surgery, availability of large osteochondral grafts, and shorter rehabilitation than other reconstructive procedures.

Outcomes have been mixed for fresh osteochondral allograft transplants of the PFJ. In 2 available series of fresh osteochondral allografts and mosaicplasty of the PFJ, success rates were reported to be 60% to 66%, with none of the patients demonstrating a good arthroscopic result.[10,32] In another retrospective review of 14 fresh patellofemoral and patellar allografts, greater than half have been shown to survive over 10 years with significant improvement in knee scores and halted progression of patellofemoral osteoarthritis on radiographs.[33] Therefore, osteochondral allograft transplant of the PFJ is viewed as a salvage procedure for young, active patients who have failed other procedures and may not be candidates for the long rehabilitation protocol associated with ACI.

In the active military population fresh osteochondral allograft transplantation is used for grades III and IV cartilage lesions of the patella and/or trochlea greater than 2 cm^2 and for lesions that have failed other reparative cartilage techniques. The choice between osteochondral allograft and ACI typically depends on the availability of fresh allograft at the time of presentation as well as the patient's expectations and willingness to participate in the recommended 18 months rehabilitation and 2-stage surgery for ACI. Typically, military personnel treated are mid to late in his/her career and both procedures present the best opportunity to retain on active duty. Therefore, time to recovery is crucial and the surgery that provides the quickest return to optimal function and the potential to be retained on active duty is the goal.

The patient is scheduled for surgery when the fresh allograft becomes available from the tissue bank. The procedure is carried out using a midline incision from the superior pole of the patella inferiorly to the medial aspect of the tibial tuberosity. Exposure of the PFJ is accessed through a tibial tubercle AMZ osteotomy as previously described (Fig. 2).[20] The dimensions of the grade III or IV cartilage lesions of the patella and trochlea are then measured (Fig. 3) using the

FIGURE 2. Exposure of trochlea and patella after tibial tuberosity osteotomy in preparation for fresh osteochondral allograft transplant.

FIGURE 3. Arthrex (Naples, FL) mega osteoarticular transfer system sizing guide.

osteoarticular transfer system (Arthrex, Naples, FL) the appropriate sized reamer is used to prepare the donor site to a depth that allows circumferential exposure of subchondral bone (Figs. 4A, B). The depth of the donor site is measured at the 12, 3, 6, and 9 o'clock positions and these corresponding areas are marked on the allograft to assist in depth sizing. The allograft is secured and marked with a surgical pen and then harvested with the corresponding reamer in a full thickness fashion (Figs. 5A–C). Using a combination of 10 mm oscillating sagittal saw and rongeur the allograft is tailored to match the appropriate thickness of the recipient site. Before transplant, both the graft and recipient site are bulb irrigated to remove debris and then thoroughly dried. The allografts are oriented appropriately in the recipient site and lightly seated to a flush position with the surrounding cartilage using an impactor and rubber mallet for a secure press-fit (Fig. 6). If a stable press-fit is not achieved the fixation can be augmented with small interfragmentary screws, headless compression screws, or bioabsorbable pins. The AMZ osteotomy is fixed in a standard fashion, once the osteochondral allografts are well seated and patella tracking is assessed, using two 4.5 mm cortical screws in a lag fashion by overdrilling the tubercle fragment.

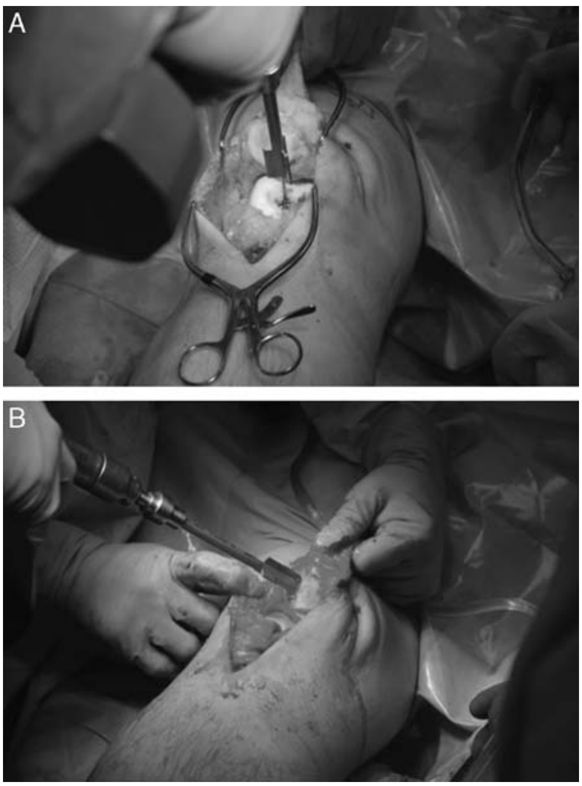

FIGURE 4. A and B, Osteoarticular transfer system reamer trochlea and patella.

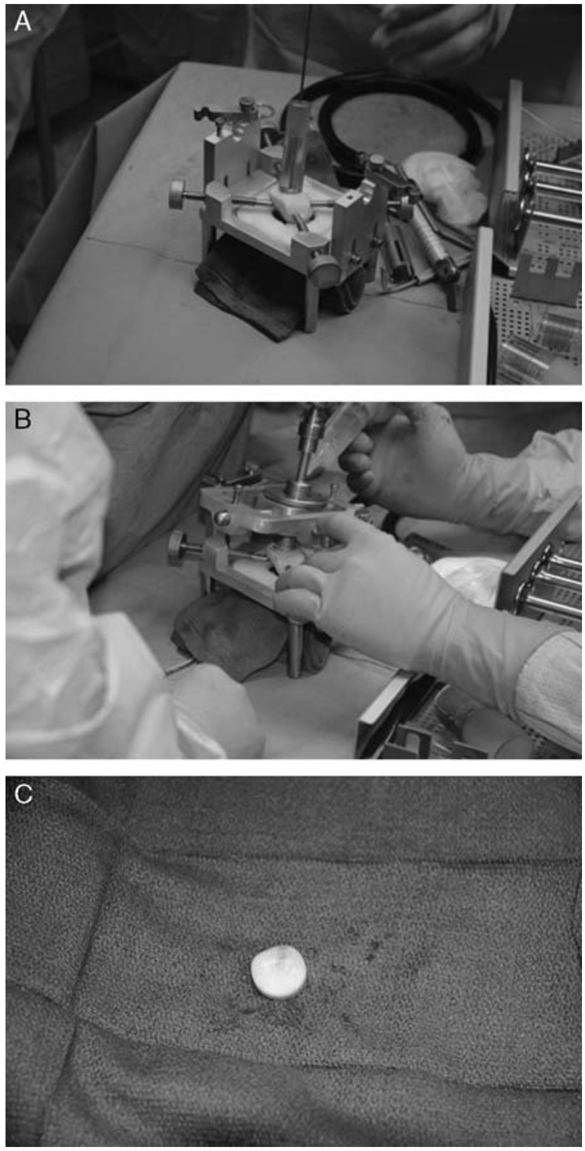

FIGURE 5. A, B, and C, Sizing and harvesting of fresh allograft lateral patella facet osteoarticular transfer system graft.

Postoperative rehabilitation typically consists of continuous passive ROM as tolerated for the first 6 weeks without motion restrictions. Weight bearing is restricted during this initial period to allow early graft healing. At 4 weeks the patient may progress with quadriceps and hamstring strengthening and foot flat weightbearing in a knee ROM brace locked

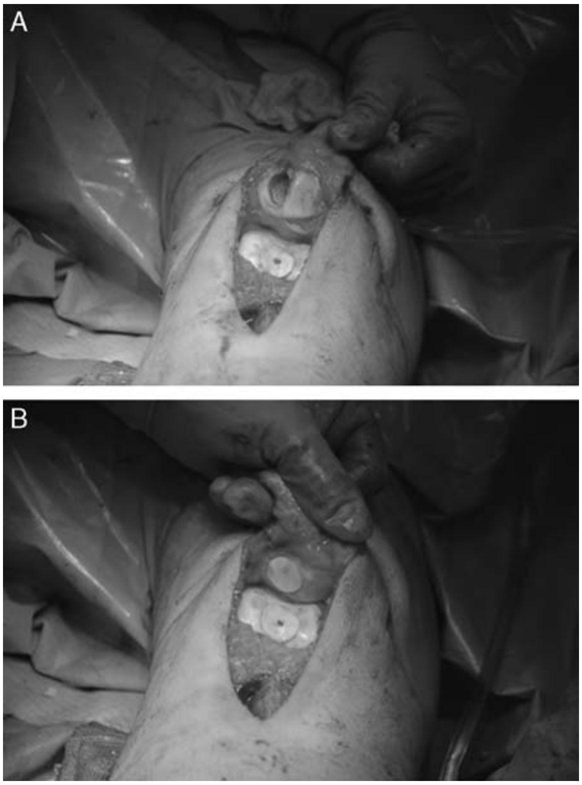

FIGURE 6. A, Implantation of central trochlea OATS allograft. B, Impantaton of lateral patella facet OATS allograft. OATS indicates osteoarticular transfer system.

in extension. The brace is discontinued when the patient demonstrates good quad control and ability to perform independent sets of active straight leg raises. Full active ROM should be achieved by 8 to 12 weeks. Advanced strength training and functional testing occurs at 6 months with expected full return to activity by 9 to 12 months.

ACI

ACI was first introduced by Peterson et al in 1987[34] as a 2-stage procedure using reimplantation of harvested chondrocytes beneath a periosteal patch for cartilage repair of the knee. Peterson et al reported 84% good or excellent outcome at 5 to 11 years after ACI. In another series, ACI was performed on the patella in 7 patients and a good or excellent result was achieved in only 2 patients (29%).[35] Success rates increased to 65% (11 of 17) at 2 years and 76% (13 of 17) at 10 years with the addition of an extensor mechanism realignment procedure.[34,36] Since that time ACI has been the most studied reconstructive cartilage procedure in the PFJ with mostly level IV evidence.[11,12,28,30,31,37] One level II prospective cohort study of ACI in patella, trochlea, and mixed compartmental lesions demonstrated a 71% good or excellent outcome of 45 patients at 2 years with 8 failures (18%) of patella or trochlea lesions. Of note, only 64% of the Minas et al cohort had a concomitant tibial tubercle osteotomy. Minas et al[2] provided a functional algorithm for the treatment of patellofemoral chondral lesions and indicated that ACI with distal realignment was best used in the setting of a maltracking patella with inferior and lateral patellar lesions with less predictable results for medial patellar and panpatellar lesions or when the trochlea is involved alone.

The use of ACI for cartilage reconstruction of the femur (condyle and trochlea) is approved by the Food and Drug Administration, whereby use in the patella is considered off-label.[38] Therefore, informed consent by the patient is an important step in the preoperative planning for the surgery. In addition, for the same reason, third party reimbursement may be challenging for the physician and patient. Other factors to take into consideration are the following: high cost of the procedure, 2-stage surgery, and prolonged period of non-weight-bearing and the recommended extended period of rehabilitation by the manufacturer (Genzyme Biosurgery, Cambridge, MA). The benefit of ACI is the ability to treat large cartilage lesions, multiple lesions, and even “kissing lesions” on the patella and trochlea in conjunction with a distal realignment with good clinical success. Although controversial, patients have also been shown to have clinical improvement with ACI in the setting of a previous marrow-stimulating procedure.[12,39]

The decision to perform ACI is made with an initial diagnostic arthroscopy to characterize the lesion and to take a cartilage biopsy from the nonweight-bearing portion of the superior femur or medial intercondylar notch. The cartilage specimen should average 200 to 300 mg in weight, and be collected in the sterile transport media to be sent to the central laboratory for processing, culturing, and cryopreservation. Once the second stage of the procedure is approved and scheduled and the cells have been expanded to nearly 12 million chondrocytes per vial, the transplant surgery is performed.

The implantation success is dependant on the careful preparation of the recipient site, the containment of the lesion with proper suturing technique of the biologic covering–cambium layer down previously harvested tibial perisoteum–and sealing the perimeter of the lesion with fibrin glue for a watertight seal to contain the injected chondrocytes. The exposure is performed through a tibial tubercle osteotomy. The lesions on the patella and trochlea are then prepared with careful ring curretage of the lesion taking care to avoid disrupting the calcified subchondral bone to prevent bleeding which may inhibit the success of the surgery (Fig. 7). In addition, the lesion should be prepared with a well-shouldered rim of surrounding cartilage (Fig. 8). At times, this is not possible owing to the location of the lesions and the biologic

FIGURE 7. Trochlea preparation with ring curette for autologous chondrocyte implantation.

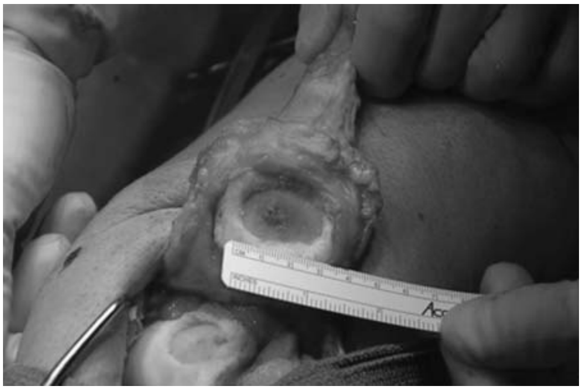

FIGURE 8. Well-shouldered cartilage lesions of trochlea and patella.

FIGURE 10. Injection of chondrocytes after watertight seal confirmed and fibrin glue applied around perimeter.

cover can be fixed using mini suture anchors versus drilling bone tunnels. At our facility we use a resorbable bilayer collagen membrane Bio Gide (Osteohealth-Shirley, NY) in an off-label use and in place of the commonly used anteromedial tibial periosteum. Therefore, the surgery time is decreased, the incision is smaller, and the potential complication of graft hypertrophy can be minimized.[11] Once the collagen sheet has been sized according to the template, which is commonly several millimeters larger than the lesion to allow for normal contour of the flap to the patella and trochlea, it is sutured to the surrounding cartilage in a standard fashion (Fig. 9). A gap in the sutures is left at the highest point of the lesion and is injected with several milliliter of sterile saline to test for water tightness. The margins are reinforced as needed and the perimeter is covered with fibrin glue for final delivery of the cells (Fig. 10).

Postoperative rehabilitation is followed according to a standard protocol provided by the manufacturer based on lesions size, lesion location, and the addition of concomitant procedures. The goal is to achieve full ROM at 6 weeks and progression to full weight-bearing by 8 weeks.

ARTHROPLASTY

Patellofemoral and total knee arthroplasty have been described and used for diffuse osteoarthritic changes of the PFJ and has limited utility in the young, active military population treated at our institution. There has been some success with patellofemoral arthroplasty in the short term in some cohorts, but the limited durability and high complication rates have limited its use in the military patient population.[40]

FIGURE 9. Sutured collagen sheet with gap at superior aspect of flap for chondrocyte injection.

DISCUSSION

There is a limited amount of literature pertaining to the management of cartilage lesions of the PFJ. Consequently, there is still no evidence-based clinical algorithm for this commonly encountered problem. The common first-line treatment for chondral injuries of the knee tend to have limited success in the PFJ owing to high shear forces and its unique anatomy. Therefore patellofemoral cartilage lesions in young active military population poses a unique challenge owing to the high demand nature of the occupation and the need to expeditiously return the soldier back to the fighting force. The lengthy time line of treatment and rehabilitation for this problem tends to place the active duty soldier into a situation of extended periods of medical disability with physical activity limitations, medical boards, reclassification, and potential medical separation. Therefore, the goal of the military surgeon is to provide the most optimal treatment for successful outcomes and fastest return to the soldier's unit.

Fresh osteochondral allografts have demonstrated some success in the young active patient with large chondral lesions of the PFJ.[10,33] Fresh osteochondral allografts may play a more significant role in the active duty soldier owing to the eliminated donor site morbidity of autograft procedures and the single stage nature of the procedure as opposed to ACI. In our experience, this has allowed for quicker rehabilitation and return to duty. Rehabilitation is a time consuming portion of any cartilage reconstructive procedure, but we have found osteochondral allografts allow for return to duty in as early as 8 months as compared with the suggested 18-month rehabilitation protocol of ACI.

There is good evidence to support improved outcomes of ACI in the setting of a distal realignment osteotomy compared with an osteotomy alone.[2,13,34,36] It is our preference to apply the findings of AMZ in the setting of ACI to osteochondral allograft transplant surgery despite the reported increased reoperation rates with a concomitant osteotomy.[31] In our experience, we have been able to return a majority of soldiers back to active duty after cartilage reconstruction for patellofemoral lesions, albeit with some limitations including limited running and alternative, low-impact cardiovascular fitness events. On the other hand, there are a few selected patients who still require a medical board and potential medical separation from the military.

SUMMARY

In conclusion, chondral lesions of the PFJ pose a unique challenge to orthopedic surgeons. With the advent of new technology like second generation ACI with a bioabsorbable delivery scaffold, there continues to be promising technology for the treatment of patellofemoral cartilage injury on the horizon.[37] The young, high-demand soldier increases the complexity of this problem for the surgeon. Evidence is lacking on the management of patellofemoral chondral lesions in military personnel and the retention on active duty after surgery. Following the guidelines from literature on civilian populations, the best outcomes are provided by a cartilage reconstructive procedure (osteoarticular transfer system, ACI) with a concomitant tibial tubercle osteotomy.[2,13,34,36]

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