Autologous Chondrocyte Implantation and Anteromedialization in the Treatment of Patellofemoral Chondrosis

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Treatment of patellofemoral (PF) chondrosis continues to evolve. While articular cartilage is aneural, damage and loss of articular cartilage is often associated with pain in the affected joint or joint compartment, such as the PF compartment. The association is indirect, as the pain originates from subchondral bone or soft tissues; thus, allocating pain to chondrosis is by exclusion of the myriad of other causes of PF pain. During this “diagnosis by exclusion,” the mosaic of other PF pain causes must be appreciated and treated concomitantly with any chondrosis treatment. PF chondrosis is often associated with abnormal PF stress such as lateral compression or excessive lateral position of the patella in the trochlea. Anteromedialization (AMZ), a treatment for such abnormalities, was popularized by Fulkerson [1]. Review of AMZ outcomes by Pidoriano and colleagues [2] revealed poor outcomes with advanced chondrosis in certain PF regions. In the same era, Britberg and colleagues [3] reported that cartilage restoration of PF chondrosis with autologous chondrocyte implantation (ACI) had poor outcomes when PF malalignment (excessive lateral patellar position) was not corrected. Subsequently, several authors have shown that by combining AMZ and ACI, very positive outcomes are possible [4-8].

Anteromedialization

Tibial tuberosity surgery has a long history, which was initially developed empirically. Medialization of the tuberosity was designed to decrease an abnormal quadriceps angle (Q angle) and redirect an excessively lateral patella to a more normal central position in the trochlea. Maquet [9] used two-dimensional mechanical calculations to predict that the force vectors acting at the patellofemoral compartment would decrease with tibial tuberosity anteriorization. Fulkerson [1] combined these approaches with an inclined osteotomy that allowed components of anteriorization and medialization (hence anteromedialization). Fulkerson’s initial series success in 1983 was reinforced by the durability of long-term outcomes of AMZ as reported by Büeck and Fulkerson [10]. The original technique of Fulkerson is well described in his book, Disorders of the Patellofemoral Joint, and was later modified by Farr using a commercially available jig [11,12]. This is briefly described in the technique below (“AMZ with ACI Operative Technique”).

Before focusing on the surgical technique, it is important to emphasize that patients considered for AMZ should have failed a thorough physical therapy program with emphasis on proximal musculature and core muscle strengthening. The pain should be activity related and have no component of complex regional pain syndrome, malingering, or secondary gain. The pain should be focused at the patellofemoral joint and associated with symptomatic lateral tilt and/or excessive...
lateral position of the patella (chronic patellar status subluxation) and an increased tibial tuberosity-trochlear groove distance (TT-TG), which may be assessed by CT or MRI [13]. In addition, full appreciation of the underlying alterations of PF biomechanics is important. Cohen and colleagues [14] showed the variable decreases in PF stress with AMZ using finite element analysis that averages approximately 20% rather than the calculated 50% of Maquet [9]. The endeavor of Kuroda and colleagues highlighted the undesirable medial knee overload with overly zealous medialization; this further emphasizes the importance of preoperative measurement of the TT-TG distances to aid in planning the extent of medialization [15]. The TT-TG distance associated with recurrent lateral patellar instability is over 15 to 20 mm, while the mean of asymptomatic patients has been reported as 13 [13]. The end goal of medialization is to reposition the tuberosity to achieve a TT-TG distance of approximately less than 15 mm, certainly avoiding low single digits as per Kuroda and Andrihi. The optimal extent of elevation remains under debate. The literature recommends a range of elevation between 10 and 15 mm (for details of these results please refer to an annotated table of anterization studies by Schepis and Watson [16]). With the goal of 10 to 15 mm of anterization, the extent of medialization desired can be calculated preoperatively using trigonometry. For example, the steepest slope possible for AMZ is approximately 60 degrees. The triangle rule, 15 mm of anterization with this slope will yield a medialization of 8.7 mm. With a constant amount of elevation, the medialization may be increased by decreasing the slope (eg, 45 degree slope = 15 mm anterization and 15 mm of medialization). If the patient has excessive lateral tibial, lateral step cut lengthening or transfixated lateral release can be performed concomitantly. If the patient has patholaxity of the medial patellofemoral ligament, repair or reconstruction of the ligament may be performed concomitantly with AMZ. The goal is to optimize the biomechanical environment of the PF compartment for cartilage restoration.

As this paper is specifically discussing AMZ with autologous cultured chondrocyte implantation or ACI (in the United States the product is distributed under the name Carticel by Genzyme, Cambridge, MA), additional levels of decision making are involved. As ACI is a two-staged procedure (stage one: arthroscopic harvest of a cartilage biopsy, stage two: implantation), the AMZ can be performed at the time of the arthroscopy and biopsy or at the time of implantation. Several factors affect this decision. First, in isolation, both AMZ and ACI are moderately large procedures with recoveries requiring weeks to months. Both result in dehabilitation and the need for extensive rehabilitation. These first two considerations would suggest performing the arthroscopic biopsy alone and the AMZ at the time of ACI. By combining the procedures, the exposure for the ACI is straightforward; however, insurance medical policies introduce complications. Preauthorization for ACI at the patellofemoral compartment sometimes requires several months to obtain. The difficulty of preauthorization is a result of Food and Drug Administration (FDA)-approved indications (only for articular cartilage defects of the trochlea and medial and lateral femoral condyles). As patellar and bipolar (patellofemoral) chondral defects are not included in these indications ("off label"), proof of efficacy and safety must be presented to the insurance companies to validate the use of ACI in these situations (peer-reviewed literature is often used as documentation for this). Even after documentation is submitted to insurance companies, some preauthorizations require months to years. In these situations, AMZ may be considered a first step, assuming the articular cartilage lesions are located in regions that are expected to have satisfactory results. (According to Pederzino and colleagues study, optimal results were noted in patients with distal lateral patellar chondrosis and intact trochlear cartilage. Poor results after AMZ were noted in knees with proximal pole chondrosis, medial patellar chondrosis, patellar chondrosis, and when the trochlea was involved [2].) These areas of chondrosis that do poorly with an isolated AMZ are the basis for combining AMZ with cartilage restoration. On the other hand, if preauthorization for PF ACI is expected, combining AMZ and ACI would allow for one time off of school or work, one rehabilitation, and one major knee surgery.

Assuming preauthorization is achieved, the plans should be reviewed with the patient. By following the technique details, a good surgical outcome is possible. However, a good "surgical outcome" in the face of a patient with persistent pain is, in fact, a failure. As such, proper patient selection and preoperative expectation counseling is extremely important. Many patients have unrealistic expectations and these need to be
modified preoperatively. The surgeon physician's goal is to decrease pain and improve function, while the patient's "preexpectation counseling" goal is often no pain with all desired activities. Once again, patellofemoral pain is a complex mosaic as eloquently detailed by Dy [17]. As considerable time may have passed from the first decision to proceed with AMZ/ACI, thorough reassessment of the patient is important to be sure all other aspects of PF pain have been addressed and preoperative rehabilitation has been optimized. While obtaining informed consent from the patient, the expected postoperative course and time to achieve specific activity goals should be reviewed.

AMZ with ACI operative technique

In the setting of ACI concomitant with AMZ, a longitudinal incision courses from the level of the quadriceps tendon to 10 cm distal to the patellar tendon attachment to the tibial tuberosity. The subcutaneous tissues are elevated to expose the lateral capsule, the patellar tendon, tibial tuberosity, and the anterior musculature compartment (Fig. 1). In light of the pathology that has led to the choice of AMZ, most of these knees have an excessively tight lateral retinaculum. Therefore, the most common deep approach is lateral, which also avoids insult to the medial quadriceps. As it is optimal to seal the joint after ACI, an option to lateral release is a step cut lateral lengthening. At the 2006 International Patellofemoral Study Group meeting, Biedert described the step cut lengthening. To perform the step cut lengthening, the superficial layer that is confluent with the expansion from the iliotibial band is incised and elevated posteriorly for 2 cm. An incision is then made through the lateral patellofemoral ligaments, capsule, and synovium 2 cm posterior to the previous incision. This allows for up to 2 cm of lateral lengthening.

The deep incision is carried distally past the patellar tendon along the lateral aspect of the tibial tuberosity. At the proximal extent of the anterior compartment, an incision is made just distal of the insertion of the iliotibial band on Gerdy's tubercle. The anterior compartment musculature is bluntly elevated from the lateral face of the tibia to the posterior border. A blunt custom retractor is placed subperiosteally both to retract the anterior compartment and to protect the deep neurovascular structures. To allow elevation without abnormal forces in the medial soft tissues, an incision is made medially immediately adjacent to the patellar tendon. An Army-Navy retractor isolates and protects the patellar tendon.

A custom cutting block (Tracker AMZ set, DePuy Mitek, Raynum, NJ) is positioned on the tibial tuberosity (Fig. 2). Proximally, the jig is immediately medial to the patellar tendon insertion on the tibial tuberosity while distally it courses

Fig. 1. Tuberosity position is excessively lateral as per MRA.

Fig. 2. Step cut through secured cutting block jig.

Fig. 3. Saw cut through secured cutting block jig.
lateral to allow the osteotomy to exit on the lateral wall of the tibia. The slope has been planned preoperatively to determine the extent of medialization with a constant elevation of between 10 and 15 mm. The slope is then set with the slope selector arm temporarily attached to the cutting block with the arm tip showing the exit of the osteotomy (see Fig. 2). The osteotomy for the maximum slope of 60 degrees exits just anterior to the posterior wall of the tibia. Decreasing the slope increases the medialization for the same elevation with the other reproducible angle of 45 degrees yielding the same excursion medially as anteriorly.

After confirming the position of the cutting block to affect the desired slope, the cutting block is temporarily fixed with two pins. An oscillating saw cooled with saline makes the cut through the captured cutting block and is observed to exit posteriorly along the lateral wall of the tibia with the retractor protecting deep tissues (Figs. 3 and 4). The cutting block is removed. The proximal and distal cuts of the sloped osteotomy are completed with the oscillating saw using the first cut in the same manner as a captured guide. To complete the osteotomy, osteotomes are used first to connect to proximal posterior cut to the lateral attachment site of the patellar tendon to the tibial tuberosity (Fig. 5). The final cut is made just proximal to the patellar tendon attachment to the tibial tuberosity lateral to medial while the patellar tendon is protected with an Army-Navy retractor (Fig. 6). The tuberosity is now free and may be retracted during the cartilage defect preparation, patch templating, and cell implantation under the sealed patch (Figs. 7–11). After the ACI is completed, the tuberosity is held in an anteromedial position (Fig. 12) and fixed with two 4.5 mm interfragmentary screws followed by measuring the extent of anterization and medialization (Fig. 13A,B; Fig. 14). Optionally, after the AMZ is fixed, the medial patellofemoral ligament can then be tightened or reconstructed (Figs. 15 and 16).
Results and discussion of AMZ and ACI

In 2002, Peterson reported marked improvements with PF ACI outcomes compared with the 1994 paper of Britberg and colleagues [3,4]. With the addition of AMZ, Peterson and colleagues reported 11 of 17 PF ACI patients with good and excellent results at 2 years and 13 of 17 at 2 to 9 years [18]. Minas and Bryant [5] confirmed these findings in 2005 with 71% good or excellent results in 45 patients noting that 62% of the PF ACI patients received AMZ. Henderson and Lavigne [6] reported similar results for PF ACI yet he divided his patients into two groups. Those with clinically perceived malalignment underwent AMZ with PF ACI and those with clinically normal alignment only receiving PF ACI. The group with AMZ PF ACI had 86% good and excellent outcomes, while the isolated PF ACI patients had 54% good and excellent results yielding a combined 71% good and excellent outcomes. Henderson suggested that slight unappreciated malalignments might have led to the lower response in those patients without concomitant
AMZ (note that the TT-TG distance was not measured). Additionally, the role of AMZ in lowering PF stress is not fully understood, as Steinwach and Kreuz [7] reported overall 87% good and excellent results in 10 trochlear ACI and 19 patellar ACI patients noting that none had an AMZ as all had reported normal alignment. We reported 80% (31 of 39) good and excellent PF ACI outcomes in patients followed for more than 2 years [8]. Within this group, like Henderson, we clinically assessed PF alignment and only performed AMZ with PF ACI on those perceived to have malalignment. Twenty-eight patients had concomitant AMZ and ACI. We reported no significant difference between those with and without AMZ, nor were there differences between monopolar and bipolar lesions. To investigate the possible role of ACI in improving isolated AMZ results, the AMZ outcomes of various PF chondrosis patterns is a baseline. Piderianno and colleagues reported the following outcomes of isolated AMZ patients: 56% of patients with medial facet patellar lesions (Type III) had good results and 20% of patients with proximal pole or panpatellar lesions (Type IV) had good outcomes. Patients with central trochlear lesions had largely poor results with anteromedial AMZ. In our PF ACI group, all treated patellar lesions were Type III or IV, and 56% of trochlear lesions were located in the central region of the trochlea. Those treated with ACI and AMZ had 74% (21 of 28) of patients with a good to excellent result. These improvements compared with AMZ alone support the earlier studies of Peterson and colleagues [4], Minas and Bryant [5], and Henderson and Lavigne [6].

These case series support the safety and efficacy of PF ACI in the short and intermediate term. The role of AMZ appears to be important in those patients with malalignment, but the clinical experience of the surgeons is difficult to objectively communicate based on the available data. It may be useful, in the future, to evaluate patients pre- and postoperatively for PF contact areas similar to the FEA modeling of Ateshian and Cohen, as well as...
measurement of the TT-TG distance and then correlate these with outcomes in an effort to further add objectively [13,14,15]. Hopefully, by using objective data points preoperatively, the optimal use of AMZ with ACI may be elucidated.

References