Anteromedialization

Review and Technique

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ABSTRACT: As a method to address patellofemoral pain, chondrosis, and malalignment, Fulkerson introduced anteromedialization of the tibial tuberosity. Short- and intermediate-term follow-up demonstrate efficacy. Patellofemoral cartilage lesion extent and region analysis allows for refined indications to optimize results. This article reviews the historical background, technique, results, and biomechanical rationale. The overview will assist in optimally integrating the procedure in the treatment armamentarium for patellofemoral disease.

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INTRODUCTION

Fulkerson originally designed the tibial tuberosity anteromedialization technique to address patellofemoral pain associated with patellofemoral chondrosis in conjunction with patellofemoral tilt and/or chronic patellar subluxation while avoiding the complication rate of the Maquet tibial tuberosity elevation.[12] The anteromedialization technique transferred areas of patellofemoral loading through medialization, which also improves patellofemoral joint congruity (improved joint contact area), and anteriorization to transfer forces proximally, while theoretically decreasing the absolute magnitude of the patellofemoral resultant force.[15] This theoretical decrease in resultant force and increase in contact area would thus decrease joint surface stress, potentially decreasing the condition of overload contributing to pain.[1]

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Long-term clinical follow-up has verified the efficacy of the procedure and a decrease in the complication rate previously associated with the Maquet anteriorization technique.[4]

Currently, interest has been renewed in anteromedialization in conjunction with cartilage restoration of the patellofemoral compartment. For cartilage restoration treatments, stress on the restoration must be optimized/minimized. The importance of optimizing patellofemoral joint stress was not initially realized in patellofemoral joint cartilage restoration, demonstrated by the poor results of patellofemoral autologous cultured chondrocyte implantation for patellofemoral cartilage defects, as originally reported by Brittberg et al.[3] In this early series, patellofemoral malalignment was not corrected, and five of the seven patellofemoral autologous cultured chondrocyte implantation patients did poorly, in contrast with a high success rate at the tibiofemoral articulation. Subsequently, with attention to alignment and elevation through anteromedialization, the results of patellofemoral autologous cultured chondrocyte implantation have approached that of the tibiofemoral joint.[25,30] This article assesses anteromedialization clinical studies, analyzes relevant biomechanics, and concludes with a review of the technique, including applications in cartilage restoration.

BACKGROUND

Fulkerson[12] originally described anteromedial transfer of the tibial tuberosity in 1983, and followed up with a clinical series in 1990.[15] The series focused on the outcomes of 30 patients observed for >2 years with 12 patients observed for >5 years. Fulkerson reported a 93% success rate subjectively, and 89% success rate by objective parameters. In a subgroup of patients with advanced arthrosis, 75% of patients experienced good results, with 0% experiencing excellent results.

Pidoriano et al[31] retrospectively reviewed a series of patients over a 10-year period, attempting to compare results relative to the geographic location of the articular cartilage disease. Eighty-seven percent of 23 patients with disease primarily located in either the distal or lateral portion of the patella experienced successful outcomes; 55% of 9 patients with medial disease experienced successful outcomes; and only 20% of 5 patients with either proximal or distal disease experienced a satisfactory outcome. A correlation was also noted between advanced disease of the central trochlea and a poor outcome.

Buuck and Fulkerson[4] reviewed 36 patients (42 knees) at an average of 8.2 years (minimum 4.4 years) follow-up. Eighty-one percent said they were the same or better than at 1-year follow-up and 86% achieved good or excellent results. Eighty-one percent returned to sports, and 36% returned to running and court sports. Three of the 4 poor results had large trochlear articular lesions.

Bellemans et al[2] reported 29 patients who underwent anteromedialization osteotomies for chronic anterior knee pain. Patients were divided into 2 subgroups according to radiographic criteria for malalignment. Group 1 had subluxation without tilt, and group 2 had subluxation with tilt. In group 1, 14 patients were treated with anteromedialization only, and 15 patients in group 2 were treated with anteromedialization with a lateral release. All but 1 patient had a successful outcome by Kujala and Lysholm rating scales. Consistent correction of radiographic subluxation was noted in group 1, as was subluxation and tilt in group 2.

Naranja et al[28] reported their results of anteromedialization, although their technique was distinctly different than that described in this article. Their technique involved performing a flat osteotomy and then elevating the shingle with a 10-mm bone graft, referred to as the "Elmsie-Trillat-Maquet" procedure. In their series of 55 procedures in 51 patients, they reported an 84% success rate, 73% by the Fulkerson patellar scoring scale.

RELEVANT BIOMECHANICS

To optimally apply the tibial tuberosity anteromedialization procedure, a sound understanding of both normal and abnormal patellofemoral biomechanics is essential. By definition, "stress" is contact force divided by the contact area. With abnormalities in patellofemoral contact area, patellofemoral stress can be elevated causing deleterious material (cartilage) and physical (overload pain) effects. The goals of the anteromedialization procedure are threefold and not mutually exclusive: 1) to transfer the patellar tracking from areas of patellofemoral chondrosis to areas of intact (normal) articular cartilage; 2) to increase the contact area by improving joint congruity; and 3) to decrease patellofemoral contact force.[15,23]

Forces across the patellofemoral articulation have been measured with Tekscan pressure transducers and Fuji pressure sensitive film and modeled using finite element analysis.[1,6,15] The common themes in these studies are that the average (mean) force across the patellofemoral joint may yield an incomplete understanding of the stress (force per unit area) implications on specific regions. Although the mean force may decrease, this may be due to a greater decrease laterally even though the medial patellofemoral forces actually increase. This is further modified by the potential of increased contact area with improved joint congruity (medializing a laterally subluxed patella). Cohen et al[6] used computer simulation of anteromedialization to demonstrate the case-specific nature of final force/stress at the patellofemoral joint, signifying the need to carefully approach each potential patient as presenting with individual considerations.

The summation of all patellofemoral joint forces is the patellofemoral joint reaction force. It can be thought of as a resultant vector of the quadriceps tendon force vector summed with the patellar tendon force (those portions of each that are perpendicular to the tangent of the patellofemoral contact vector). This force may also be defined as the force equal and opposite to the posterior compressive force that the patella exerts on the femoral articulating surface.[14] As the knee flexes, the patellofemoral joint reaction force is increased due to 1) the increasing moment arm of the flexors (ie, the applied force [center of body mass] is applied farther from the axis of rotation); and 2) the angle between the component forces of the patellofemoral joint reaction force (ie, quadriceps and patellar tendon) becoming more acute as the knee is flexed, increasing the resulting vector.[21] Calculations of the patellofemoral joint reaction force have been determined to be 0.5× the body weight in normal walking and 3.3× the body weight when ascending and descending stairs and even higher with jumping.[35] During assessment of these forces, it is important to calculate the hip/pelvic flexion, as this changes the moment arm of the body mass (ie, skiing in extension increases the moment arm and flexion of the hip, while standing up from a chair decreases the moment arm). The passive and active soft-tissue stabilizers that influence patellar position and tracking also contribute to the patellofemoral joint reaction force, but for simplicity can be ignored (but not forgotten—that is, procedures that capture or overconstrain the patella, such as excessive medial reefing, may increase patellofemoral contact forces).[14] The vastus medialis and vastus lateralis muscles (and the obliquus portion of each) of the quadriceps group have insertions to the patella independent from the rectus femoris and vastus intermedius. As a consequence, they each contribute separately to the balance of the patella—vastus medialis medially and vastus lateralis laterally.[14,18] Additionally, the vastus lateralis obliquus provides a direct lateral pull of the patella and the variable patellar attachments to the vastus medialis obliquus, and muscle volume exerts variable medial force.[14,34]

In addition to the posteriorly directed resultant force vector on the patella, the patellar and quadriceps tendon impact the patellar balance medially and laterally. The patellar tendon extends from the patella to the tibial tuberosity, which is lateral to the trochlear groove (expressed as a tibial tuberosity to trochlear groove [TT-TG] distance).[8,13] The quadriceps also provides additional lateral force in the coronal plane due to the alignment of the quadriceps as it attaches to the femur (and rectus at pelvis), which is typically in anatomic valgus.[13] Thus, the coronal plane resultant force vector of the patellar tendon during quadriceps contraction is lateral and is functionally effected during range of motion by rotation of the femur and tibia (eg, the tibia in gait follows the foot and internally rotates with pronation). One historic tool for assessing the alignment contributing to this lateral force is the quadriceps-angle (Q-angle), yet Q-angle intraobserver variation and Q-angle variants suggest the objective TT-TG distance is a more reproducible quantification of the extent of lateral tuberosity position.[32]

The contact area between the patella and femur is the denominator of stress (force per unit area). With the "normal" knee, the articular cartilage of the patella and trochlea have increased contact area during flexion of the knee (obviously, contact area changes as the patella enters the intercondylar notch), and it is further increased under load, as demonstrated by Heino et al[19] with dynamic patellofemoral magnetic resonance imaging. With knee flexion, the patellofemoral contact area shifts proximally on the patella.[7,17,20] In higher degrees of flexion, the patella changes from contact with the trochlea to contact with the medial and lateral walls of the intercondylar notch; in these flexion angles the patellofemoral contact is supplemented with tendofemoral contact between the quadriceps tendon and trochlea.[7,17,20]

Anteromedialization allows anteriorization and medialization of the tibial tuberosity—these components may first be considered separately. The procedure of anterior displacement (Maquet) of the tibial tuberosity, using two dimensional biomechanical analysis, was thought to decrease the absolute contact forces between the patella and femur and was performed as an alternative to avoid the known negative effects of patellectomy.[10,24,37] This initial mathematical work by Maquet was confirmed by the in vitro work of Ferrandez et al[11] who reported that the greatest reduction of pressure was seen in the first centimeter of tibial tuberosity anterior displacement. An investigation by Ferguson et al[10] later broadened this range to include the first 1.25 cm of displacement (93% reduction in stresses). Radin,[33] in a description of the Maquet procedure, suggested a displacement of 2-2.5 cm. In a later study, the 1-cm distance marked the beginning of a statistically significant decrease in contact forces.[15] Mathematical models have concluded a 40% reduction in stress with a 1-cm anteriorization.[24,26,38]

The isolated procedure of medialization was used historically in treatment of both recurrent lateral patellar dislocations and static lateral patellofemoral malalignment when defined as chronic static patellar subluxation. Medialization decreases the TT-TG distance and thus decreases the lateral resultant vector acting on the patella. With distal realignment, Huberti and Hayes[20] found an increase in contact area with a concomitant decrease in the Q-angle, and an inconsistent shift in contact area to the medial patellofemoral surface. This study used knees with normal Q-angles and investigated pathologically small and large Q-angles. The increase in pressure found by Huberti and Hayes[20] was later confirmed with tibial tuberosity realignment in normal knees.[23] The historical use of isolated medialization to prevent lateral dislocation has now been supplanted largely with attention to the medial patellofemoral ligament (MPFL). However, in the context of cartilage restoration procedures and chondral disease, the effects of isolated medialization (medialization and "over-medialization" are often not defined) alone have the potential of being detrimental to the patellofemoral compartment,[1,15,26] and Kuroda et al[23] has shown in vitro that it also increases medial tibiofemoral forces.

Several clinical studies indicated that patients with patellofemoral pain improved after anteromedialization.[2,5,9,12,15,22,27,36] Fulkerson et al[15] included a mechanical evaluation of five cadaveric knees that underwent anteromedialization to compliment a minimum 2-year follow-up of patients following anteromedialization. The results of this evaluation were the unloading of the lateral facet in the early degrees of flexion and loading of the medial facet at 90° of flexion. Molina et al[26] investigated the biomechanical difference between three procedures: anterior displacement, medial displacement, and the combined anteromedialization of the tuberosity. They concluded that the combined anterior and medial displacement is required to reduce stress over the patellar contact area.

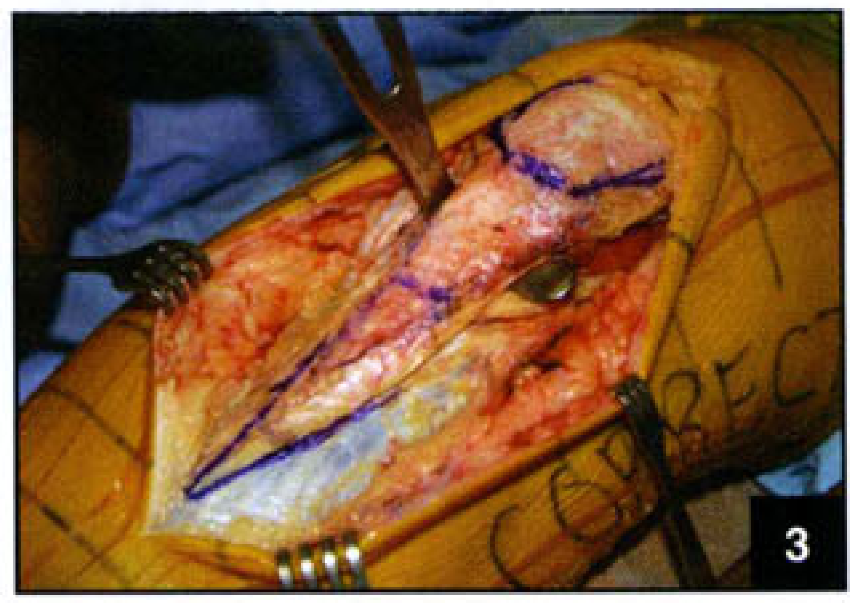

Figure 1. Incision for an isolated anteromedialization in a right knee. **Figure 2.** Exposure for anteromedialization when performed in conjunction with cartilage restoration in a left knee. **Figure 3.** As the tuberosity will be elevated anteriorly, the capsule is incised on each margin of the patellar tendon in a left knee. Note the Army/Navy retractor is deep to the tendon.

Moreover, through mathematical analysis, 0.5- to 1-cm anteriorization, combined with 1-cm medialization, provided the optimal results (ie, patellofemoral stress was minimized). [Author's editorial comment: medialization of 10 mm may not produce the same effect in knees with various TT-TG distances.] Although many studies have focused on changes in patellar biomechanics following straight anteriorization or anteromedialization, Beck et al[1] evaluated the effect on the trochlea following anteromedialization. Specifically, pressures decreased laterally, decreased slightly centrally, and increased medially following anteromedialization. In summary, anteromedialization has a solid biomechanical rationale for improving patellofemoral stress. Clinical results have verified these biomechanical predictions.

OPERATIVE TECHNIQUE

As noted above, the technique classically was used as an isolated procedure. After arthroscopic evaluation and treatment, an assessment is made to determine the need for lateral release and the extent of release necessary. The historical "turn up" sign (to demonstrate an adequate release) has been replaced by a titrated limited lateral release in recognition of patient variability. In those patients with marked clinical and computed tomography proven tilt, a lateral release will be more appropriate and more extensile than in patients with predominant subluxation and more medial/lateral translation possible with or without reversible tilt. In either case, the goal is to allow neutralization of tilt and unrestricted central positioning of the patella, without allowing medial patellar subluxation. Once again, the extent of a lateral release is patient-specific, and in some patients, a lateral release will not be necessary. The lateral release may be performed in an open or arthroscopic manner. The authors suggest confirmation of hemostasis with the tourniquet deflated (if used). Anteromedialization does not require use of a tourniquet, although it can decrease initial bleeding during the approach and osteotomy.

In patients undergoing cartilage restoration, it is easier for the patient to undergo anteromedialization and cartilage restoration at the same setting. In cases when cartilage restoration is performed concomitantly, the lateral arthrotomy can be extended more proximally than usual for exposure, but the same guidelines apply at closure: the lateral arthrotomy is closed proximal to distal until the patella is balanced in the trochlea. Too extensive of a lateral release is as detrimental as too little. Figure 1 shows the skin incision for an isolated anteromedialization and Figure 2 shows the skin incision when performed in conjunction with cartilage restoration.

As the tuberosity will be elevated anteriorly, the capsule is incised on each margin of the patellar tendon (Figure 3). These releases will remain open at closure. Fat pad hemostasis is critical. The incision along the patellar tendon lateral border is continued along the tibial tuberosity lateral crest; this allows initial sharp elevation of the anterior compartment musculature from the lateral face of the tibia beginning just distal to Gerdy's tuberosity. After an initial 1 cm of sharp dissection, the muscle is elevated with a blunt subperiosteal elevator with care not to plunge posteriorly. After reaching the posterior margin of the lateral tibia, a custom retractor (Tracker AMZ; DePuy/Mitek, Raynham, Mass) is placed immediately adjacent to the posterior tibia. This retractor will assist in protecting the anterior tibial artery and the deep peroneal nerve, but caution still should be exercised to prevent neurovascular harm (Figure 4).

The desired length of the final tuberosity "pedicle" influences the length of the tuberosity and lateral wall exposure. Note that a shorter pedicle will result in more patellar tendon rotation (during rotation of the tibial tuberosity pedicle there will be some degree of distalization), and in the extreme, can result in some measurable degree of patella distalization.

The next stage is planning the sloped cut. This involves not only consideration of the slope of the cut, but also the angulation of the cut in the coronal plane. The anterior tuberosity cut begins adjacent to the medial border of the tuberosity attachment of the patellar tendon proximally. The

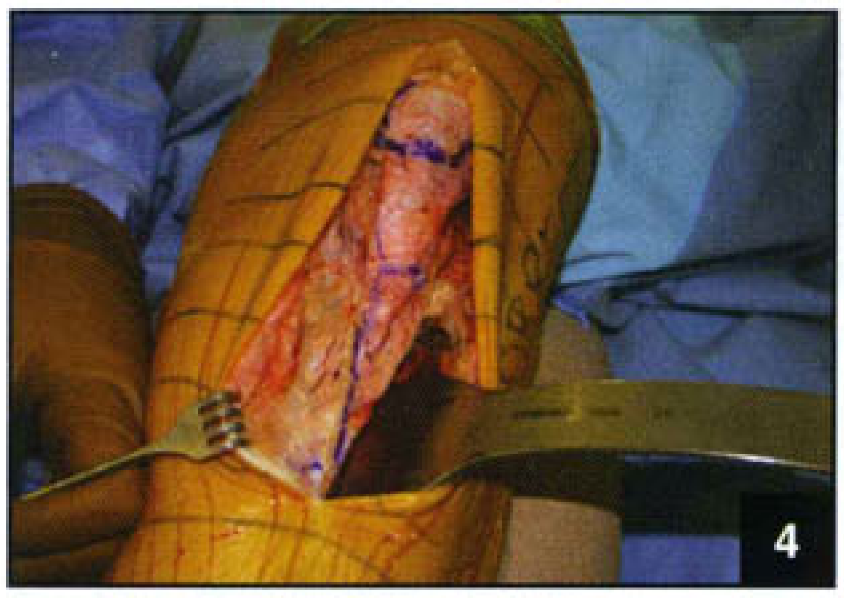
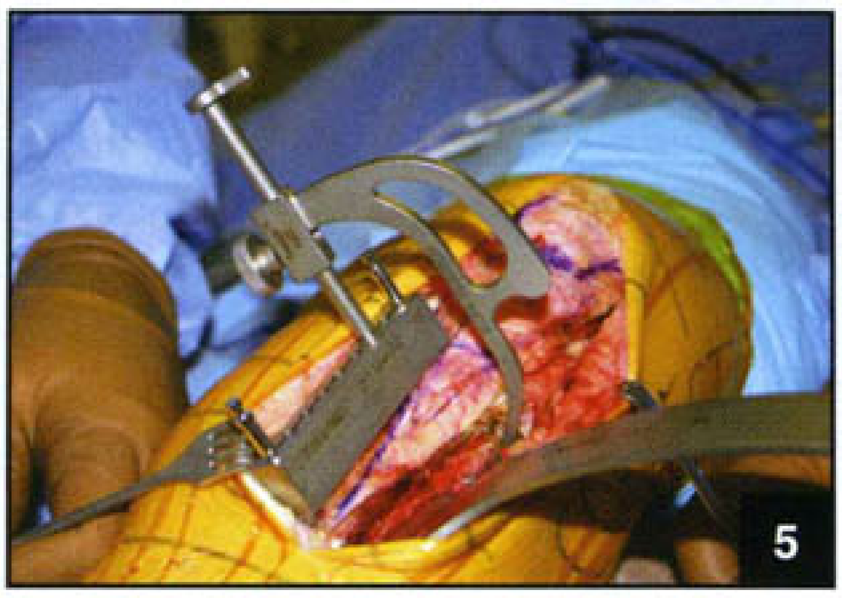
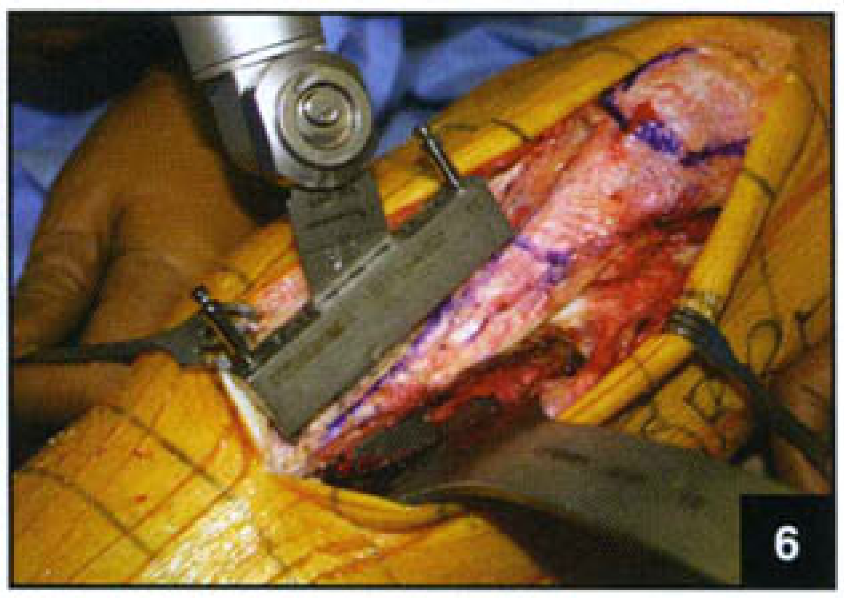

Figure 4. Retractor exposing the lateral wall of the tibia in a left knee and aiding in protecting the posterior structures. **Figure 5.** Planning the coronally angulated axially sloped cut in a left knee. The tuberosity anterior cut begins adjacent to the medial border of the tuberosity attachment of the patellar tendon proximally and angles laterally as it courses distally. The tip of the slope selector arm showing the lateral wall exit site of the sloped cut. Pins secure the cutting block. **Figure 6.** Saw exiting on the lateral wall anterior to the posterior tibial face in a left knee. Note the retractor position aids in protecting the posterior structures.

cut then courses laterally as it progresses distally. This is necessary to end the cut near or through the lateral wall of the tibia, noting the desired pedicle length is 7-10 cm. (Obviously, a cut straight distally would not end and could propagate past the desired tuberosity pedicle length.) Tapering the distal end of the cut towards the anterior cortex also yields an osteotomy with a less abrupt stress riser, and therefore, hopefully aids in reducing risk of fracture.

The technique for making the oblique anteromedialization bony cut was originally described by Fulkerson[12] using an external fixator pin guide to make multiple drill holes in the desired line of the final cut. The final cut was then made with osteotomes. To allow improved planning of the slope, the exit sites were predicted using a drill guide (similar to the arm of an anterior cruciate ligament [ACL] tibial tunnel guide, which allows planning for tunnel exit at the tibial eminence) attached to block. With the improved accuracy of predicting the slope, it was no longer necessary to predrill (note that drilling removed bone and made an irregular cut surface) and the cut could be made through an attached cutting block with a saw, allowing a smoother cut surface than multiple osteotome cuts. Alternatively, some surgeons perform the anteromedialization "free hand" without the aid of guides and jigs, but the authors believe a precise osteotomy cut and slope should not be compromised regardless of the technique.

The slope selector arm of the Tracker set is attached to the cutting jig. It is possible to simultaneously 1) plan the anterior cut orientation in the coronal plane (where saw starts); 2) plan the slope of the anteromedialization in the axial plane; and 3) directly visualize the planned lateral wall exit of the tibial cut just anterior to the junction of the lateral wall and posterior wall (Figure 5). It is important not to cut through the posterior cortex, but rather exit on the lateral face of the tibia just anterior to the posterior tibial border. The steepest slope with this technique is approximately 60°, and can be decreased to achieve more medialization. With a 60° slope for 15 mm of elevation (anteriorization) there is 8.7 mm of medialization. Optimal anteriorization probably is in the range 1-1.5 cm. Thus, with this anteriorization a constant goal, the slope is changed appropriately to effect the desired medialization (an offset graft may be added when medialization is not desired).

After the desired slope axial plane and coronal plane anterior cut angulations are finalized, the cutting jig is then anchored with two pins through drill holes. The cut is made with an oscillating saw cooled with saline (Figure 6). The cutting jig is then removed. The cut just completed in the tibia is next used as a "saw capture" guide, much the same way a saw capture jig is used in arthroplasty. The initial cut in the tibia guides the saw to finish the distal cut near or through the distal extent of the tibial tuberosity pedicle and proximally the cut is continued 2-3 mm proximal to the patellar tendon attachment on the medial aspect of the tuberosity (Figure 7).

The remaining cuts are proximal to free the tuberosity. These cuts are made with an osteotome cutting at two slightly different angles to release the bone just proximal to the patellar tendon attachment to the tibial tuberosity (Figure 8).

The tuberosity pedicle is then free to rotate around the distal pedicle, allowing both anteriorization and medialization. The tibial tuberosity pedicle can be temporarily held in position with a Kirschner wire placed through the open cancellous bone proximally, and then permanently fixed with two cortical lag screws using interfragmentary fixation (Figures 9 and 10). Fulkerson emphasizes meticulous technique, drilling the pedicle with a 4.5 bit, using a sleeve and carefully advancing a 3.2 drill bit through the posteromedial tibial cortex to avoid neurovascular compromise.[12] A depth gauge measures for a self-tapping cortical screw, or, if a tap is used, the depth of desired penetration (from the depth gauge) is marked on the tap with a marking pen to ensure that the tap does not penetrate too deeply and potentially harm posterior soft tissues.

In the original description by Fulkerson, the anterior compartment musculature is not reattached to the tibia.[12] The original thinking was that this measure would avoid

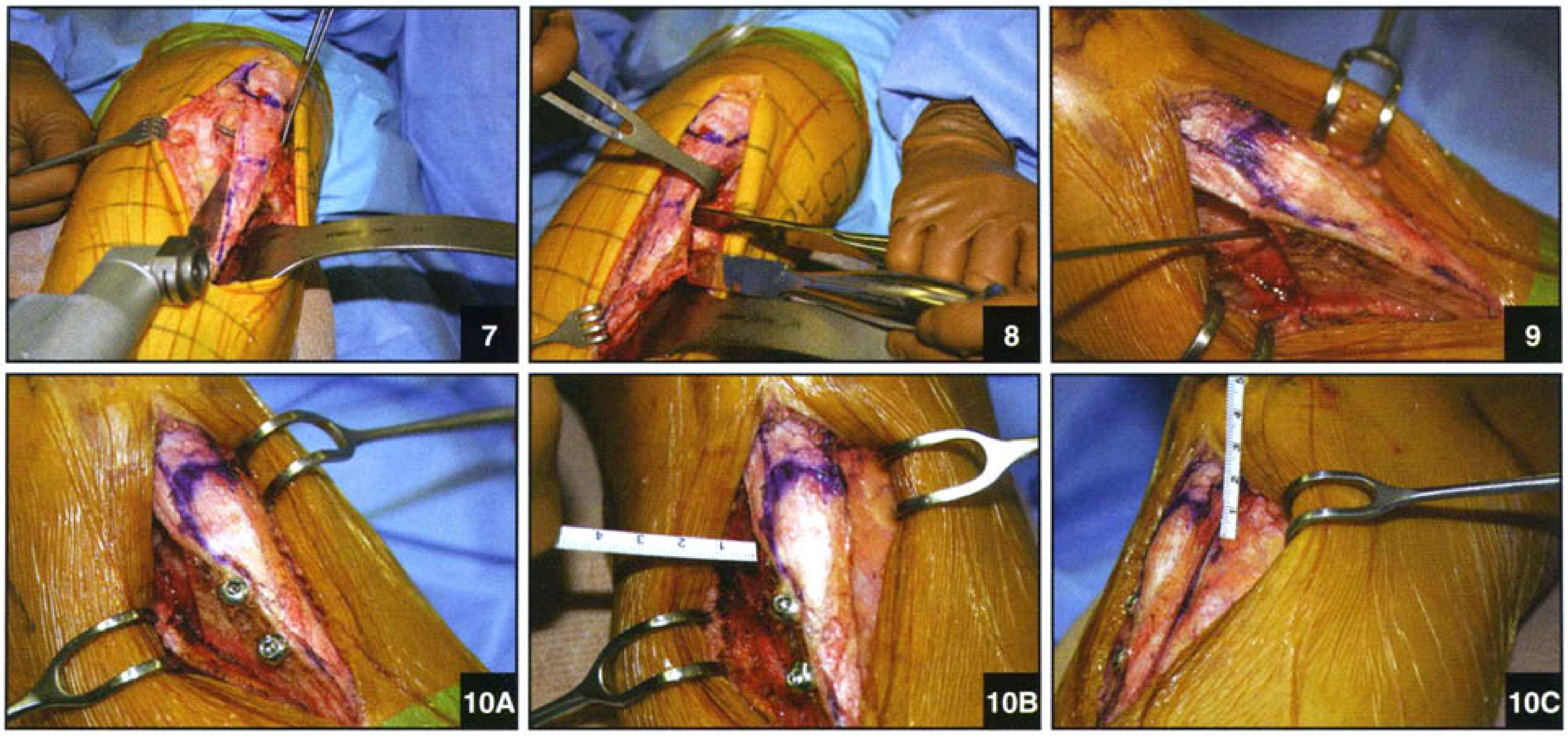

Figure 7. The cutting jig is removed and the cut just completed in the tibia is next used as a "saw capture" guide much the same way a saw capture jig is used in arthroplasty. The initial cut in the tibia guides the saw to finish the distal cut near or through the distal extent of the tibial tuberosity pedicle and proximally the cut is continued 2-3 mm proximal to the patellar tendon attachment to the tuberosity. **Figure 8.** The patellar attachment to the tibial tuberosity is exposed and protected with an Army/Navy retractor. The Tracker retractor aids to maintain exposure of the lateral wall of the tibia. The larger osteotome connects the proximal posterior slope cut to the lateral attachment site of the patellar tendon to the tuberosity. The smaller (more proximal) osteotome cuts across (at a slight angle) just proximal to the patellar tendon attachment, connecting the medial and lateral cuts and thus, freeing the tuberosity. **Figure 9.** In a right knee, the pedicle is temporarily held in position with a K-wire through the open cancellous bone proximally to allow assessment of the effect of tuberosity repositioning on the patella position. **Figure 10.** Fixation with two 4.5 AO screws using interfragmentary fixation (A). Measuring medialization (B) and anteriorization (C).

increasing pressure in that compartment postoperatively. Using this closure technique, Fulkerson never experienced a compartment syndrome or problem with anterior compartment muscle function in >500 cases (personal communication, September 2005). If a tourniquet has been used, it is released and thorough hemostasis is achieved prior to closure.

For patients without need for medialization, a local cancellous graft can be harvested and placed along the cut tibial slope before fixation. This tuberosity lateral offset will effectively neutralize the medialization, allowing a straight anteriorization alternative to Maquet. The anteromedialization may also be performed concomitantly or in a staged manner with other patellofemoral procedures, such as reconstruction of the MPFL. In that setting, the tuberosity position is selected and secured before MPFL reconstruction is performed as the anteromedialization alters the length/tension of the medial structures, which are reconstructed anatomometrically, allowing full range of motion (Figure 11).

Postoperatively, the patient is treated with a standard compression dressing and cryotherapy. The patient is encouraged to begin early patellofemoral safe quadriceps and core stabilizing and lower extremity strengthening. Range of motion is progressed as comfort permits—noting that for cartilage restoration the site of restoration may modify the recommended safe range of motion. The extremity is protected with a long-leg splint until extremity control is excellent with no risk of falling. Patients use two crutches or a walker to allow foot flat gait with ≤20 lbs of weight bearing for 6 weeks, or until after the surgeon has determined sufficient healing has occurred. Patients use crutches with protected weight bearing for a full 6 weeks in light of fractures reported with earlier weight bearing.[5]

Once the tuberosity osteotomy has healed, the patient is progressed in a standard core-strengthening program with patellar protection components as dictated by the articular surfaces. If the patient wants to participate in sporting activities and the articular surfaces allow that level of activity, the patient advances through a program of functional progression as per an ACL program of return to sport.

APPLICATION OF ANTEROMEDIALIZATION IN CARTILAGE RESTORATION

Anteromedialization is also frequently performed with cartilage repair or restoration procedures. Currently,

Figure 11. In a right knee, MPFL anatomometric length checking is demonstrated in full extension (A) and flexion (B). Postoperative incisions after anteromedialization and two incision tunnel MPFL reconstruction (C).

these procedures include autologous chondrocyte implantation, osteochondral plug transfers (either autograft or fresh "cultured" allograft), marrow stimulation (eg, microfracture), and patellofemoral osteochondral shell transplantation. These techniques may be applied to the patella, trochlea, or both. These defects often are associated with preexisting malalignment and/or instability. It is critical to correct these associated mechanical problems, which commonly include tuberosity anteromedialization for chronic lateral patellar subluxation, and repair, tightening, or reconstruction of the MPFL for lateral patellar instability (these may be isolated or coexist). Likewise, optimizing the load (stress = force/contact area) on these cartilage repair/restoration areas during the correction of malalignment is important.

From the results of Fulkerson's outcome studies, comparing results to location of chondrosis, it is questionable whether isolated anteromedialization should be performed when the articular cartilage problem is prominent (grade 3a, 3b, 3c International Cartilage Repair Society Grading and >1-2 cm^2 area) and 1) is in the proximal portion of the patella, 2) localized solely to the medial half of the patella, 3) diffusely involves the patella, or 4) involves the trochlea.[31] Additionally, the anteromedialization transfers loads to the proximal medial portion of the patella as well as the medial trochlea.[1] Nevertheless, the clinician is frequently faced with a significant traumatic loss of articular cartilage from the medial facet of the patella (after a patellar instability episode as reported by Nomura et al[29]) or diffuse mid-waist chondrosis with long-standing chronic patellar subluxation. In the young individual who remains symptomatic with cartilage lesions in these problematic areas (medial, proximal diffuse, or bipolar), as an isolated anteromedialization fairs poorly, then cartilage restoration with potential tuberosity surgery may be considered. During the concomitant anteriorization or anteromedialization and cartilage restoration, the realignment must be carefully planned and coordinated. Specific patellofemoral contact areas are noted in range of motion. As the patella loads distally to proximally through range of motion, it may also be possible to limit loading of the cartilage repair/restoration area by limiting the postoperative arc of motion until the neocartilage tissues have developed sufficiently to accept loading. When no malalignment occurs and the cartilage repair has been performed in either the distal half of the patella, the medial patella, or trochlea, a steep osteotomy with maximum slope, with or without an offset bone graft to reverse all medialization, may be performed. Although no randomized studies compare isolated anteromedialization to anteromedialization with cartilage restoration, the improved patient scores of patellofemoral chondrosis treated with anteromedialization and cartilage restoration reported by Minas and Bryant[25] are promising. Certainly, the converse has been demonstrated: failure to address malalignment and abnormal patellofemoral loading leads to poor outcomes for cartilage restoration.

Procedures that harvest tissues from the margins of the trochlea and sulcus terminals are also relevant to cartilage restoration. For example, Garretson et al[16] investigated the patellofemoral joint pressures of normal knees in regards to sites for osteochondral autograft donor plugs. From their investigation, they concluded that the lowest contact pressures existed along the medial trochlea and pressures of the lateral trochlea decreased as they shifted distally along the trochlea.[16] As predicted in the original description by Fulkerson, the combined anteriorization and medialization of the tibial tuberosity clinically appears to lower stress at the patellofemoral joint and improves the mechanical alignment.[6] Anteromedialization application during cartilage restoration procedures must be considered on a case-by-case basis (Figure 12).[12]

COMPLICATIONS

Complications after anteromedialization are similar to those encountered for other knee bony realignments and include compartment syndrome, fracture, malunion, nonunion, loss of fixation, delayed wound healing, infection, deep vein thrombosis, and pulmonary embolism. More specific to anteromedialization and patellofemoral surgery are persistent pain, progressive chondral deterioration, stiffness, arthrofibrosis, limitation of motion,

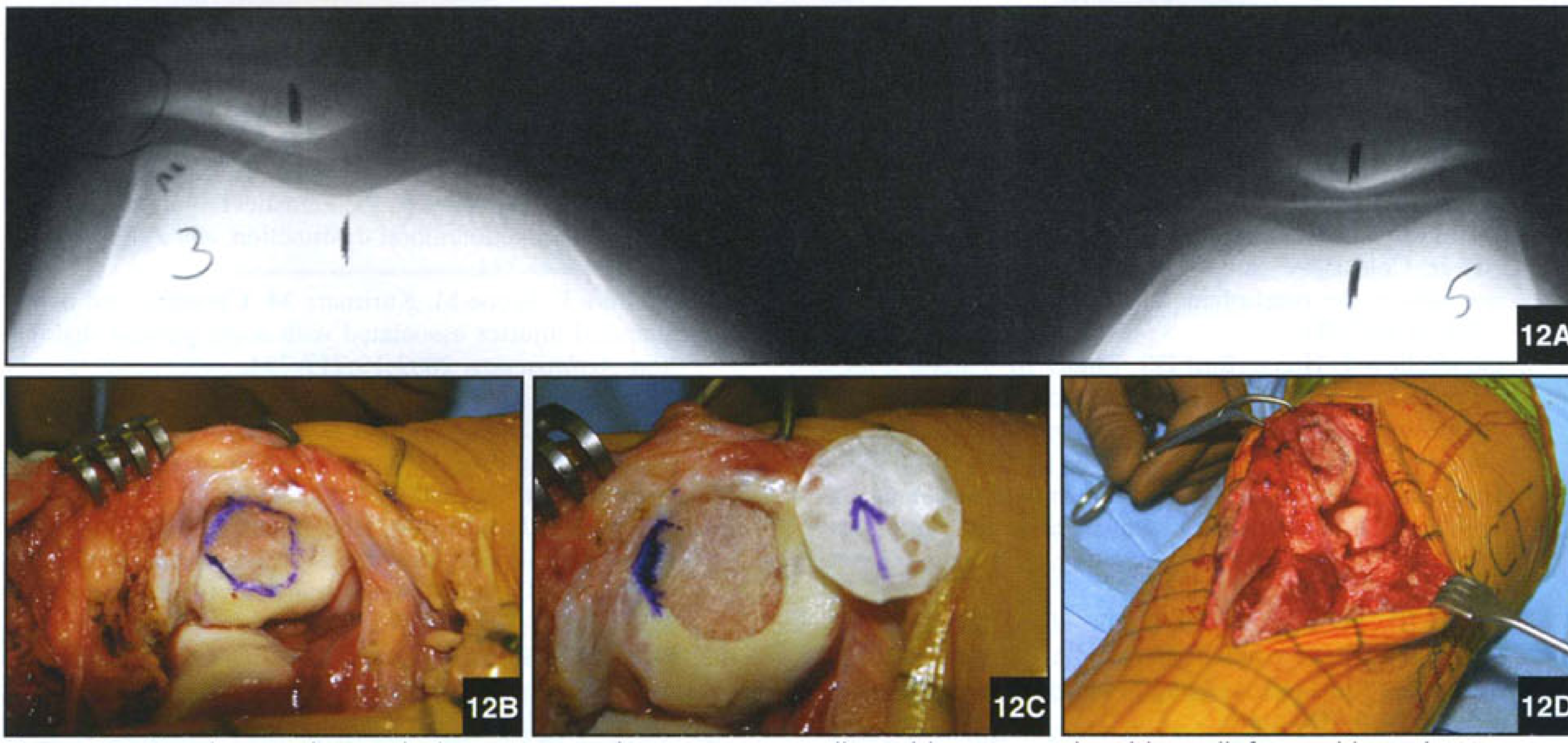

Figure 12. Merchant radiograph demonstrates chronic static patellar subluxation with mild patellofemoral lateral joint space narrowing (A). In a left knee, outline of diffuse midwaist centerolateral ICRS grade 3a, 3b, 3c chondrosis uncontained distal laterally (B). Debrided lesion with marked region of non-containment (C). Anteromedialization slope shown with completed autologous cultured chondrocyte implantation (slope will unload lateral lesion) (D).

patellar infera, and complex regional pain syndrome. Nicotine cessation is important to decrease complications as documented in other orthopedic procedures. To lessen the probability of these complications, attention to detail during surgery is paramount followed by close postoperative management. Failure to resolve pain is highly complex, therefore it is essential to make the correct preoperative diagnosis and use proper indications.

CONCLUSION

It appears that with judicious patient and patellofemoral lesion selection, anteromedialization can be effective in the management of specific patellofemoral pathologies. Anteromedialization, performed in combination with cartilage restoration, has the potential, in some cases, to improve the expected outcome to a level better than either procedure performed alone. Close monitoring of future clinical patellofemoral cartilage restoration studies will hopefully allow a more precise algorithm to optimal use of these surgical alternatives.

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