CHAPTER 47

RECURRENT DISLOCATIONS

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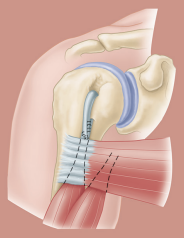

Recurrent instability can result from congenital, developmental, or traumatic ligamentous or bony containment deficiencies or from deformities caused by muscular imbalance, joint incongruity, or joint malalignment in one or more planes. Proper treatment begins with knowledge and skillful evaluation of deformities before initiating a specific treatment plan.

PATELLA

Patellar instability results from a direct or indirect valgus-producing force. When significant force results in dislocation, a tear of medial soft-tissue restraints, as well as an osteochondral defect in the medial facet of the patella or lateral femoral condyle, may result. Dislocations in skeletally immature individuals tend to recur as in other joints, with recurrences in two thirds of patients.

The amount of trauma necessary to result in patellar instability depends on soft-tissue restraints both static (medial patellofemoral ligament [MPFL]) and dynamic (vastus medialis obliquus [VMO]), bony restraints, trochlear and patellar morphology, and extremity alignment in the axial and coronal planes. Normally, the MPFL and VMO maintain patellar stability in 0 to 20 degrees of flexion. At 30 degrees, the patella is centered and stabilized by the bony contour of the trochlea. When patella alta or trochlear or patellar dysplasia is present, bony stability is compromised. Genu valgus or rotational deformities from femoral anteversion or external tibial torsion increase the quadriceps angle and result in valgus-directed force on the patella. These factors must all be considered when conservative or operative management is indicated.

CLINICAL FEATURES

In patients with recurrent dislocation or subluxation of the patella, an accurate history is still one of the most important diagnostic tools. Patellar problems can mimic various "internal derangements" of the knee. An accurate history of the mechanism of injury and the type and area of pain is important. Patients with patellar instability frequently report diffuse pain around the knee that is aggravated by going up and down stairs or hills. The pain usually is located anterior in the knee and often is described as an aching pain with intermittent episodes of sharp, severe pain. A feeling of insecurity in the knee and occasionally of "giving way" or "going out" of the knee may be present. Patellar crepitation and swelling of the knee are common. Physical findings include the previously cited factors that contribute to increasing the Q angle.

The examination begins by observing the patient's patellar height, with the patient in the seated position. An upward tilt indicates patella alta. Dynamic patellar tracking is evaluated with the examiner standing in front of the seated patient while the patient slowly extends the knee. A positive J sign (slight lateral subluxation of the patella as the knee approaches full extension) indicates some degree of maltracking. Active patellar tracking also should be examined with the knee relaxed in the extended position. When the quadriceps muscle is tightened, motion of the patella is examined. Normally, the patella should move more superiorly than laterally. With the patient supine and the knee flexed 30 degrees with a bolster behind the knee, the Q angle is measured. Insufficiency of the femoral sulcus and the MPFL, which provide 60% of the medial stabilization, is tested by applying an inferolaterally directed stress while palpating the ligament. Displacement of more than two quadrants and a soft end point generally indicate MPFL insufficiency. The patellar grind test is done by applying pressure to the patella and manually displacing it medially, laterally, superiorly, and inferiorly in the trochlear groove. This test reproduces anterior knee pain when a patellofemoral pathologic condition is present.

For the "apprehension test," the examiner holds the relaxed knee in 20 to 30 degrees of flexion and manually subluxes the patella laterally. When the test is positive, the patient suddenly complains of pain and resists any further lateral motion of the patella. The active apprehension test is more accurate: the same controlled maneuver is done while slowly flexing and extending the patient's knee. Patella laxity is evaluated by visually dividing the patella into four quadrants and passively moving the patella medially and then laterally, measuring the amount of excursion in the patellar quadrants. This is done with the knee at 0 degrees and at 20 degrees of flexion. Normally, passive patellar glide is one to two quadrants medially and laterally; motion of more than two quadrants indicates soft-tissue laxity. Excessive lateral retinacular tightness is indicated by limited medial passive patellar glide and by a negative patellar tilt. The patellar tilt test is done with the knee in 20 degrees of flexion. The examiner's fingers are placed along the medial side of the patella with the thumb on the lateral aspect. Inability to raise the lateral facet to the horizontal plane or slightly past indicates excessive lateral retinacular tightness. Tenderness along the MPFL, medial patellar facet, and lateral condyle are common with stability.

Thigh circumferences measured proximal to the patella often show quadriceps atrophy on the involved side. With the patient sitting and the knees flexed 90 degrees, a lateral or superior position of the patella sometimes can be seen. After careful examination of the uninvolved and injured knees, other joints should be examined for hyperlaxity. Hyperextension of the knees or elbows past 10 degrees, ability to touch the thumb passively to the forearm, hyperextension of the metacarpophalangeal joint of the index finger, and multidirectional laxity of the shoulder joint all are indicative of generalized ligamentous laxity. Patients with generalized ligamentous laxity have been found to have fewer articular lesions associated with dislocations than patients without ligamentous laxity. The thigh-foot angle is measured with the patient prone and the knee flexed 90 degrees. An angle of more than 30 degrees indicates significant rotational deformity of the lower extremity. The final part of the examination is done with the patient standing and consists of observation for malalignment (i.e., femoral anteversion, genu valgum, external tibial torsion, and pes planus) and core condition.

RADIOGRAPHIC FEATURES (TABLE 47.1)

The anteroposterior view of the knee can be used to confirm valgus alignment and lateral position of the patella and to look for osteochondral damage. The lateral view of the knee is helpful in determining patella alta. Blumensaat showed that with the knee flexed 30 degrees, a line extending through the intercondylar notch should just touch the lower pole of the patella (Fig. 47.1).

Patellar height is more accurately evaluated by the Insall, Clanton, or Blackburn-Peel index (see Table 47.1). The crossover sign is the best indicator of trochlear dysplasia—the earlier the crossover, the more dysplasia present. A trochlear depth of less than 3 mm or trochlear bump of more than 4 mm indicates significant dysplasia.

TABLE 47.1

Radiographic Measurements of the Patella

TECHNIQUE	MEASUREMENT	CHARACTERISTICS
Blumensaat line (Fig. 47.1), lateral radiograph, to determine patella alta	With knee flexed 30 degrees, line is drawn through intercondylar notch	Should approximate the lower pole of the patella
Insall-Salvati index lateral radiograph	LT:LP = 1.0	Patella alta if ratio ≤1.2
Trochlear depth (Dejour) lateral radiograph	Trochlear depth measured 1 cm from top of groove	Should be ≥5 mm
Patellar height (Caton-Deschamps), lateral radiograph	Ratio between articular facet length of patella (AP) and distance between articular facet of patella and anterior corner of superior tibial epiphysis (AT). Knee flexed 30 degrees.	AP/AT ratio—normal 0.6-1.3 Patella infera—ratio <0.6 Patella alta—ratio >1.3
Blackburne-Peel ratio	Length of articular surface of patella to length measured from articular surface of tibia to inferior pole of patella	Normal ratio 0.54-1.06
Patellar tilt (CT scan)	Angle formed by intersection of the tangent of the posterior condyles and the major axis of the patella on 20-degree flexion scan	Normal angle: <20 degrees Angle >20 degrees: dysplasia
TT-TG (axial radiograph, CT scan)	Two lines drawn perpendicular to posterior bicondylar line, one line through middle of trochlear groove and second through tibial tuberosity. Distance between the lines is measured	>20 mm = malalignment
Crossing sign	Anterior cortical outline of condyle intersects trochlear outline	Dysplastic sulcus
Trochlear bump	Trochlear line extends anterior to femoral cortex	Dysplastic sulcus

CT, Computed tomography; *LP*, length of the patella; *LT*, length of the patellar tendon; *TT-TG*, tibial tubercle-trochlear groove.

The most important routine view of the patellofemoral joint is the axial view of the patella. Several methods have been described for taking this axial view (Fig. 47.2B). For this radiograph to be meaningful, both knees should be exposed at the same time for comparison. The plane of the film should be perpendicular to the x-ray beam to avoid distortion, the legs should be held vertical to prevent rotation that might simulate low lateral femoral condyles, the quadriceps muscles should be relaxed to prevent the patella from being reduced at the time the radiograph is made, and the knee should be flexed in the range of 20 to 45 degrees because more flexion generally reduces most patellofemoral abnormalities.

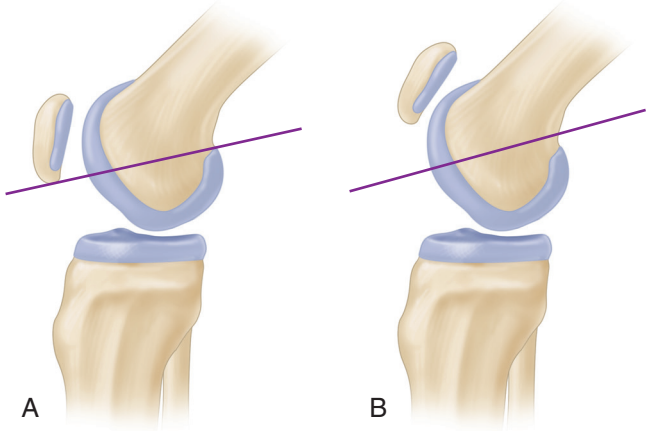

FIGURE 47.1 **A,** Normal knee. Lower pole of patella at Blumensaat line at 30 degrees of flexion of knee. **B,** Patella alta. Patella significantly proximal to Blumensaat line.

When the axial view has been obtained, the shape of the patella should be evaluated, along with the shape of the femoral trochlea and the relationship of the patella to the femur. Normally, the patella appears evenly seated within the trochlear groove of the femur, with an equal distance between both patellar facets and the adjacent femoral surfaces. Abnormalities include tilting of the patella or subluxation and complete dislocation of the patella (Fig. 47.3). The trochlea is evaluated on the Merchant view for dysplasia, sulcus angle greater than 145 degrees, and congruence—normally 60 ± 11 degrees (Figs. 47.4 and 47.5). For most dislocations or first-time dislocations, particularly in athletes, MRI or three-dimensional (3D) CT examination may be indicated to evaluate for chondral damage, loose bodies, dysplasia, and malalignment. An axial view at the superior trochlear groove is used to evaluate dysplasia; superimposed views are used to evaluate malalignment. Tibial tubercle–trochlear groove (TT-TG) distance of more than 20 mm on

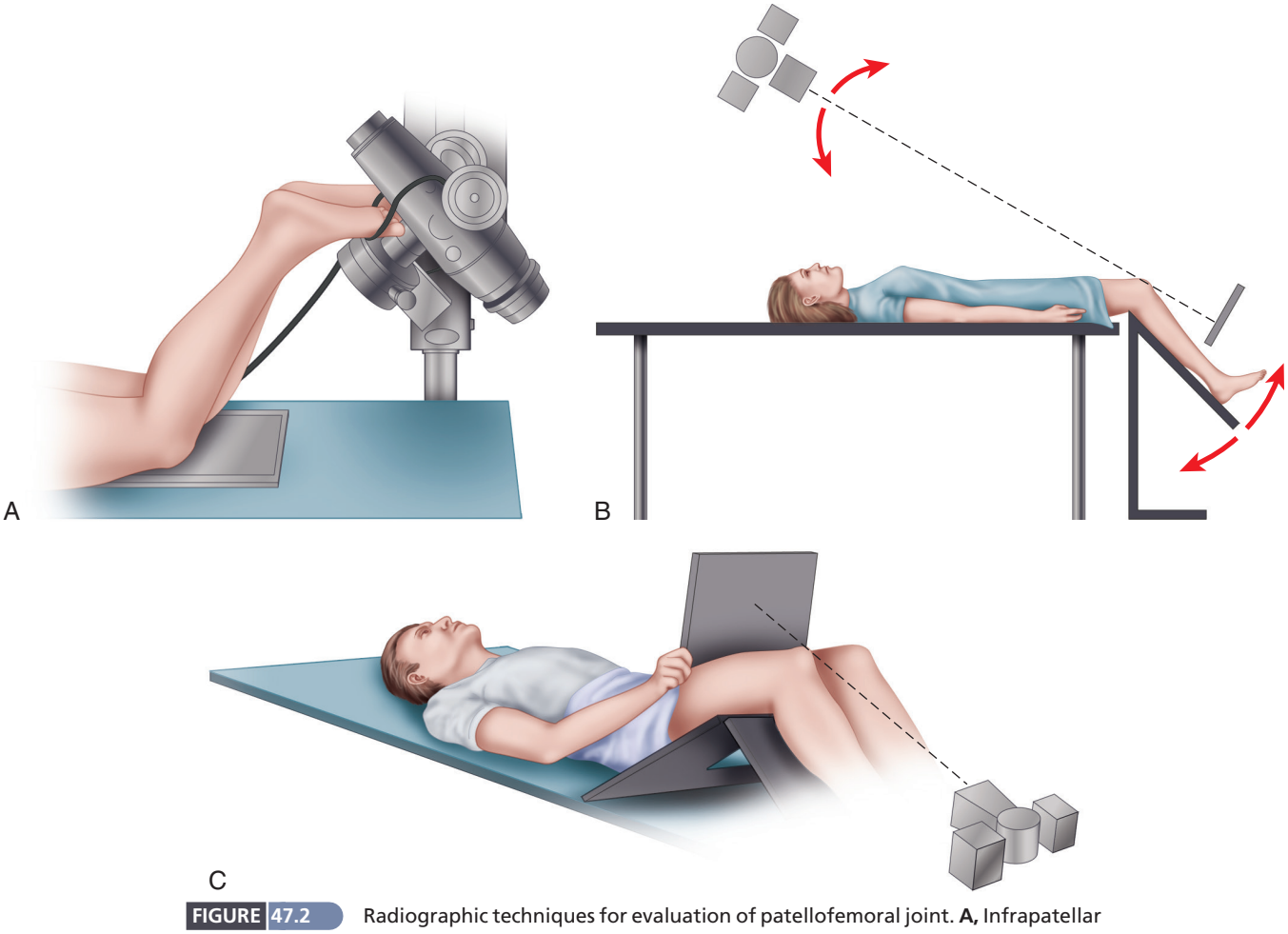

FIGURE 47.2 Radiographic techniques for evaluation of patellofemoral joint. **A,** Infrapatellar view. **B,** Axial view. **C,** Skyline view.

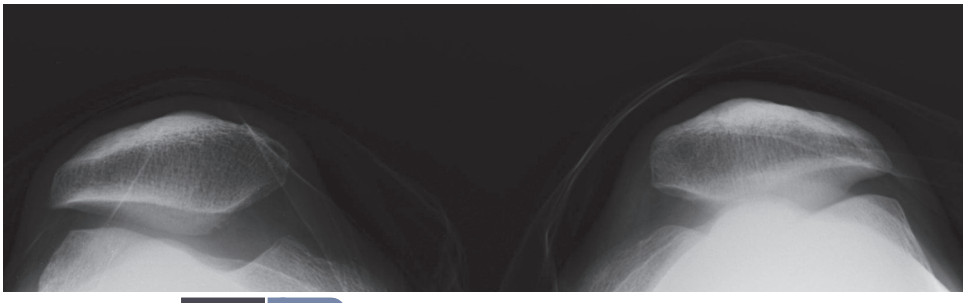

FIGURE 47.3 Lateral tilt of patella on axial view.

FIGURE 47.4 Merchant view showing hypoplastic sulcus.

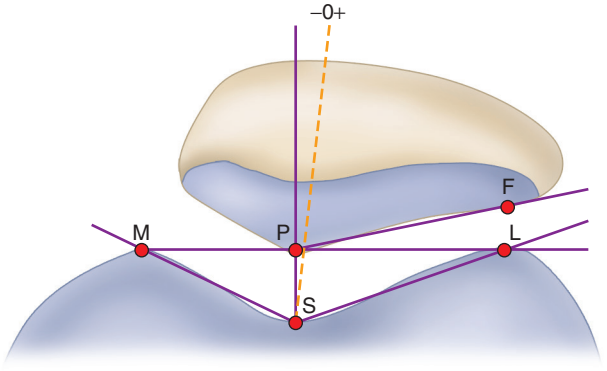

FIGURE 47.5 Measurements of patellofemoral congruence described by Merchant et al. *F,* Facet; *L,* lateral condyle; *M,* medial condyle; *P,* patellar ridge; *S,* sulcus. Angle *MSL* is sulcus angle (average, 137 degrees; standard deviation, 6 degrees). Line *SO* is zero reference line bisecting sulcus angle. Angle *PSO* is congruence angle (average, –8 degrees; standard deviation, 6 degrees). Line *PF* (lateral facet) and line *ML* form patellofemoral angle that should diverge laterally.

CT (Fig. 47.6) or MRI may indicate malalignment and may necessitate distal realignment.

CONSERVATIVE TREATMENT

■ ACUTE PATELLAR DISLOCATION OR SUBLUXATION

After an acute dislocation or subluxation of the patella, the knee is immobilized in a commercial immobilizer with a Jones-type compressive dressing and crutches are used for ambulation. If hemarthrosis is present, causing significant pain and tightness, aspiration under sterile conditions is indicated before the extremity is immobilized.

Quadriceps-setting exercises and three sets of 15 to 20 straight-leg raises are done four or five times a day during the acute period. Ice is applied for 20 minutes every 2 to 3 hours

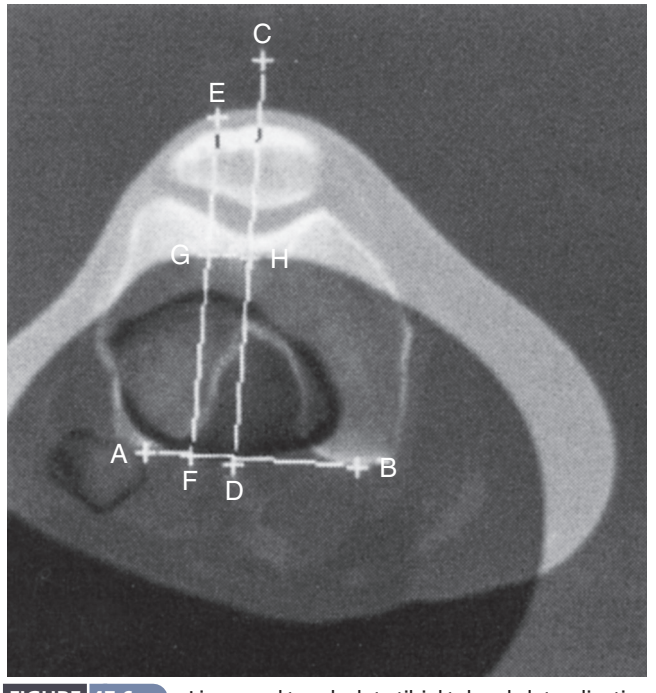

FIGURE 47.6 Lines used to calculate tibial tubercle lateralization using CT. Line is drawn on superimposed image between posterior margins of femoral condyles *(AB)*. Two lines are drawn perpendicular to this, one bisecting femoral trochlear groove *(CD)* and one bisecting anterior tibial tuberosity through chosen point in center of patellar tendon insertion *(EF)*. Distance between these two lines *(GH)* is measured in millimeters. (From Jones RB, Barletta EC, Vainright JR, et al: CT determination of tibial tubercle lateralization in patients presenting with anterior knee pain, *Skeletal Radiol* 24:505–509, 1995.)

to reduce swelling. The knee immobilizer and compressive wrap are discontinued at 3 to 5 days, after the acute reaction has resolved. The crutches are discontinued when the patient is able to do straight-leg raises with a 5-lb ankle weight and is able to walk with a near-normal gait.

Rehabilitation should emphasize closed-chain exercises, including wall sets, in which the patient squats to approximately 40 degrees while keeping the back flat against the wall for 15 to 20 seconds, for a total of 10 to 15 repetitions. Side and forward step-up exercises using a 6- to 8-inch platform should be performed after the acute inflammatory reaction has resolved. These are followed by short-arc leg presses and endurance-type strengthening using a stationary bike and Stairmaster. Core, hip, knee, and ankle exercises all are important to success. The patient can return to sports activity when quadriceps and hamstring muscle strength is at least 85% normal and sport-specific agility has been regained. In general, a patellar stabilizing brace is prescribed for the first 6 to 8 weeks during rehabilitation and long-term for sports activity.

SURGICAL TREATMENT OF PATELLAR INSTABILITY

First-time dislocations generally are treated conservatively with good results, except for patients with open physes and trochlear dysplasia, two thirds of whom will have a recurrence. These patients and those who have recurrent instability of the contralateral patella may require more aggressive treatment (Table 47.2).

Choosing treatment for malalignment requires thorough evaluation, imaging, and planning. Many instabilities are multifactorial and must be treated as such. Containment issues are most commonly treated by reconstruction of the medial quadriceps tendon–femoral ligament (MQTFL) or the MPFL. Avulsion from the patella can be repaired with some success. Severe dysplasia can be directly treated with trochleoplasty, with good stability results, but often with persistent pain and swelling and the potential for chondral damage.

Malalignment measured by a tibial tubercle–to–trochlear groove (TT-TG) distance of 20 mm with a normal trochlea or a TT-TG of more than 15 mm with a dysplastic trochlea is treated with tibial tuberosity osteotomy.

When patellar chondral damage is distal and lateral, an anterior medialization of the tuberosity can stabilize and unload the cartilage defect. Medialization procedures are contraindicated for proximal and medial chondral defects. It has been noted that an oblique tuberosity osteotomy of 30 degrees produces 1 mm of anterior elevation for each 2 mm of medial displacement. A 45-degree oblique osteotomy produces 1 mm anterior to 1 mm medial displacement. Rarely, for severe angulation deformities, distal femoral rotational osteotomy is indicated.

Patellar instability in patients with open physes can be treated by MPFL reconstruction avoiding the physis or, occasionally, soft-tissue distal patellar tendon realignment. For angular deformities, epiphysiodesis can be used to aid realignment; soft-tissue repairs have a high failure rate.

A number of factors may contribute to patellar instability, and all must be corrected for optimal results (Table 47.3). For instability with normal alignment and Dejour type A or B dysplasia, MQTFL reconstruction is indicated. Distal realignment may be indicated for dysplasia for a TT-TG distance of 15 mm. Lateral release is not an operation for instability but is indicated as an additional procedure only if the tight tissues

TABLE 47.2

Treatment of Patellofemoral Instability

PATHOLOGY	DIAGNOSTIC FINDINGS	PROCEDURE
CONTAINMENT		
Patella alta	Insall index >1:3	Distalization*
Trochlear dysplasia	Crossing sign Trochlear bump Sulcus angle >145 degrees, depth ≥3 mm	MPFL reconstruction Trochleoplasty†
Patellar dysplasia	Wiberg type C	MPFL reconstruction
ALIGNMENT		
Tibial tubercle	Q angle >20 degrees, TT-TG >20 mm, >15 mm with trochlear dysplasia	Anteromedialization of tuberosity
Femoral anteversion Severe genu valgum	Thigh-foot angle >30 degrees	Rotational osteotomy‡/ epiphysiodesis
External tibial torsion, genu valgum, hyperpronation	Observation for malalignment	Orthotics and rehabilitation
SOFT-TISSUE IMBALANCE		
Dynamic (VMO dysfunction)	TT-TG <20 mm	Rehabilitation
Static		
Incompetent MPFL or generalized hyperlaxity	Lateral glide 3 quadrants	MPFL reconstruction‡
Overconstraint	Lateral tilt (excessive lateral pressure syndrome)	Lateral release

*Distalization can result in loss of motion or of fixation.
†Trochleoplasty: risk/benefit excessively high.
‡Rotational osteotomy: high risk/benefit.
MPFL, Medial patellofemoral ligament; *TG*, trochlear groove; *TT*, anterior tibial tuberosity; *VMO*, vastus medialis oblique.

TABLE 47.3

Surgical Procedures for Treatment of Patellar Instability

LOW RISK—LOW REWARD	
Medial repair/imbrication	30% failure rate, approximately the same as conservative treatment Indication: first dislocation + repairable chondral defect Instability in skeletally mature? In combination with distal realignment
Lateral release	Excessive lateral pressure syndrome In combination with realignment procedure when excessive tightness prevents patellar centering May increase risk for both medial and lateral patellar subluxation
LOW RISK—HIGH REWARD	
MPFL reconstruction	Indicated for recurrent MPFL deficiency ± trochlear dysplasia Proximal or anterior femoral placement or overtightening results in medial facet overload May combine with distal realignment
Elmslie-Trillat procedure	Indicated for instability, TT-TG >20 mm + strong repairable medial structures Healing time and risk for stress or contact fracture of proximal tibia much less than Fulkerson procedure
Fulkerson distal realignment	Indicated for symptomatic lateral facet or distal pole arthritis + TT-TG >20 mm, >15 mm with dysplasia Contraindicated with proximal/medial facet arthritis Long healing time, increased risk of proximal tibial fracture with sports
HIGH RISK—HIGH REWARD*	
Rotational high tibial osteotomy Distal femoral osteotomy	Indicated for instability + severe rotational deformity More normalized gait compared with distal realignment
Trochleoplasty	Indicated for dysplastic trochlea Low recurrence rate Increased risk for osteonecrosis, DJD, arthrofibrosis Lateral condyle: increased pressure; increased DJD of lateral facet
Grooveplasty	Increased DJD Good results with less risk reported with MPFL reconstruction
3-in-1 procedure—extensor mechanism realignment + VMO advancement + transfer of the medial third of the patellar tendon to the MCL	Recurrent instability, TT-TG >20 mm Open physes Not as effective as MQTFL reconstruction avoiding physis

*Indicated in special circumstances when risk/benefit ratio is acceptable.
DJD, Degenerative joint disease; *MCL*, medial collateral ligament; *MPFL*, medial patellofemoral ligament; *TT-TG*, tibial tubercle–trochlear groove; *VMO*, vastus medialis oblique.

prevent the patella from relocating. Routine lateral release should not be done because it may create more instability.

RECONSTRUCTION OF THE MEDIAL PATELLOFEMORAL LIGAMENT

The MPFL can be repaired by making a 3-cm incision over the site of injury as shown by MRI. An incompetent ligament with damage limited to the femoral attachment can be repaired and reinforced by use of the adductor magnus tendon (Fig. 47.7). Chronic instability with a Q angle of less than 20 degrees or an extensively damaged MPFL should be treated using a semitendinosus hamstring tendon graft technique. Nelitz et al. reported no growth abnormalities or recurrences in 21 skeletally immature patients treated with MPFL reconstruction. Two patients with severe dysplasia had persistence of apprehension. In their systematic review, Vavken et al. also found no growth abnormalities or recurrences in the 425 patients (456 knees) reported. Hopper et al. found that severe dysplasia reduced satisfactory results from 83% to 57%.

Numerous techniques have been described for MPFL reconstruction, most using autogenous doubled semitendinosus-hamstring grafts placed in a physiometric position confirmed by palpation of landmarks and imaging, and tested for isometry. The technique we have been using for over a decade involves appropriate placement of a strong, physiologically tensioned graft through the quadriceps tendon, thus reproducing the MQTFL. This technique has resulted in low recurrence rates, no risk of patellar fracture, and minimal risk of loss of motion.

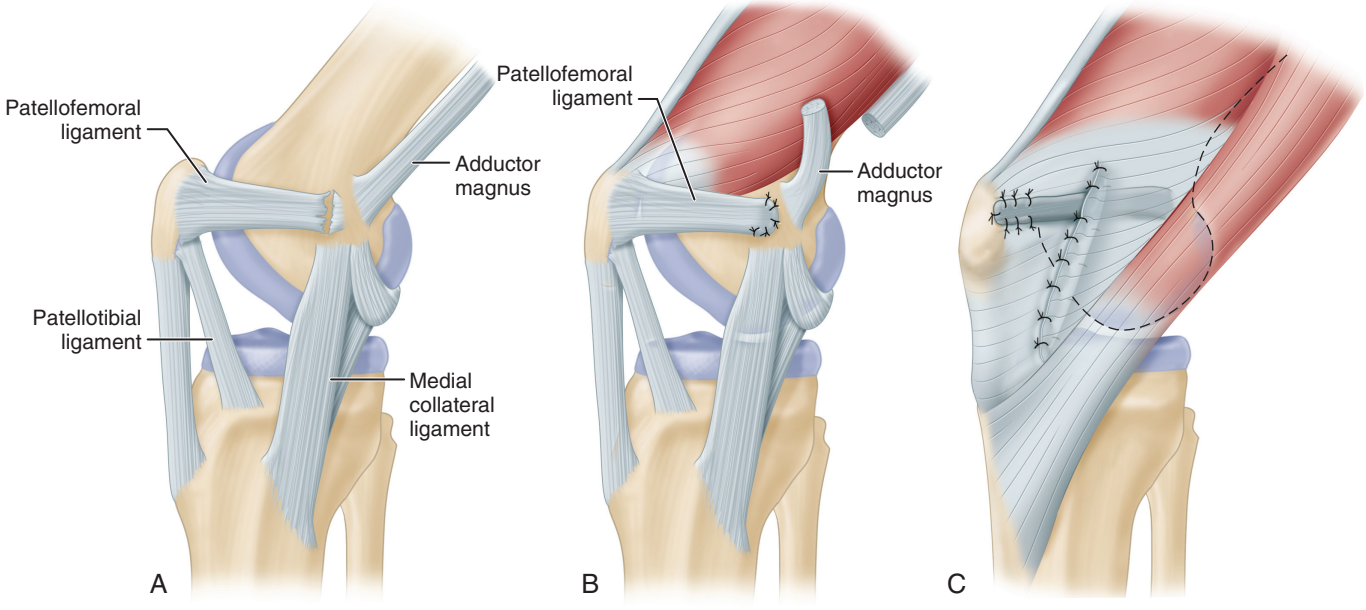

FIGURE 47.7 **A,** Medial patellofemoral ligament detached from medial femoral epicondyle after acute patellar dislocation. **B,** Medial patellofemoral ligament with firm edge of vastus medialis obliquus muscle reinserted to periosteum of medial femoral epicondyle, and adductor magnus tendon harvested. **C,** Adductor magnus tendon fixed near medial border of patella, and retinaculum duplicated.

MEDIAL QUADRICEPS TENDON-FEMORAL LIGAMENT RECONSTRUCTION

TECHNIQUE 47.1

(PHILLIPS)

- With the patient supine, place a tourniquet on the upper thigh. Use a lateral post on the operating table to assist with arthroscopic examination.
- After sterile preparation and draping, arthroscopically examine the knee through standard medial and lateral portals to evaluate patellar tracking and look for intraarticular damage. This evaluation is essential for determining appropriate treatment.
- Make a 3-cm incision 3 cm medial to the inferior portion of the patellar tuberosity and harvest the semitendinosus tendon in standard fashion. Size the folded graft so that the appropriately sized tunnel can be reamed later. Place a 0 Vicryl Krakow suture in each tail of the semitendinosus graft (Fig. 47.8A).
- Make two 2-cm incisions, the first just medial to the superior border of the patella and the second starting at the adductor tubercle and extending just distal to the medial epicondyle of the femur, to expose the patellofemoral ligament.
- Dissect subcutaneously to expose the proximal medial retinaculum at its insertion into the proximal portion of the patella. Make a 1.5-cm incision in the retinaculum adjacent to the quadriceps insertion.
- Make a second 1-cm vertical incision 1.5 cm lateral to the first incision through the quadriceps at its insertion into the patella. Use a Kelly clamp to spread the soft tissues and pass a looped no. 2 suture to use as a shuttle for the graft.
- Use blunt dissection to spread between layers 2 and 3 (between the MPFL and the capsular layer), staying extrasynovial and developing the plane with a curved Kelly clamp directed toward the medial epicondyle, spreading between the layers to create a soft-tissue tunnel. Use the Kelly clamp to pass a looped suture to use as a shuttle for the tunnel thus created (Fig. 47.8B).
- Shuttle one tail of the graft through the slit in the quadriceps, and then shuttle both tails through the MPFL tunnel to the femoral insertion site.
- Select the site for the femoral tunnel approximately 4 mm distal and 2 mm anterior to the adductor tubercle, in the "saddle" region between the tubercle and the medial epicondyle. Confirm correct position with imaging (Figs. 47.8C and 47.9).
- Place a Beath-tip guidewire at the chosen spot, and pass two suture tails from the graft around the wire. Mark the sutures so that pistoning of the graft can be identified with range of motion of the knee.
- Move the knee through a range of motion and observe the sutures, which should have minimal motion between 0 and 70 degrees of flexion and slight laxity above 70 degrees. If tension increases with flexion, the femoral tunnel site is too far proximal (most commonly) or possibly too far anterior. If the sutures tighten excessively in extension, the tunnel is too far distal or too far posterior. If necessary, correct the guidewire position and repeat the evaluation.

FIGURE 47.8 Phillips reconstruction of the medial patellofemoral ligament. **A,** Semitendinosus tendon graft. **B,** Creation of soft-tissue tunnel. **C,** Correct position confirmed radiographically. **D,** Whip stitch placed in each end of graft. **E,** Graft tails passed through soft-tissue tunnel. **F,** Closure. **SEE TECHNIQUE 47.1.**

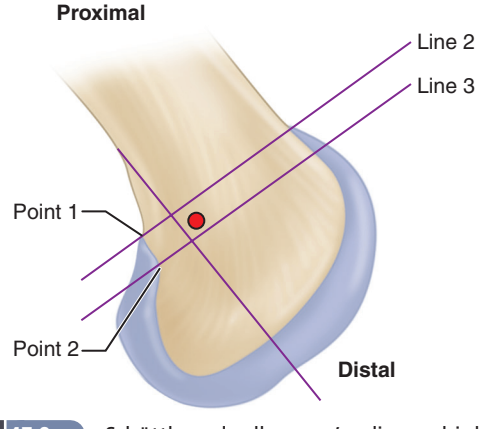

FIGURE 47.9 Schöttle and colleagues' radiographic landmark for femoral tunnel placement in medial patellofemoral ligament reconstruction. Two perpendicular lines to line 1 are drawn, intersecting the contact point of the medial condyle and posterior cortex (point 1, line 2) and intersecting the most posterior point of the Blumensaat line (point 2, line 3). For determination of vertical position, distance between line 2 and the lead ball center is measured as is the distance between line 2 and line 3. **SEE TECHNIQUE 47.1.**

- At the selected femoral tunnel site, ream a 30-mm tunnel the diameter of the doubled tendon.
- Pull the graft taut, and stress the patella so as to allow for one to two quadrants of lateral passive glide. When the physiologic amount of tension on the graft is determined, make a mark on the graft, which will correspond to the aperture of the femoral tunnel (Fig. 47.8D).
- Cut the graft 20 mm distal to this mark to allow 20 mm of graft to be placed into the tunnel.
- Place absorbable whip sutures into the tails of the graft (see Fig. 47.8D), place them into the tip of a Beath pin, and pull them out laterally (Fig. 47.8E).
- Before fixation with a biocomposite screw, move the knee through a range of motion, once again making sure that the tendons do not become taut in flexion and that the tendon length is appropriate to allow one to two quadrants of passive glide at 30 degrees of flexion so as not to overconstrain the patella.
- With the knee held in 60 degrees of flexion, maintain this graft length while it is secured with a biocomposite screw equal to the tunnel size chosen. Again, move the knee through a range of motion to make sure motion is not inhibited.

- Repair the retinaculum and place a stay suture in the quadriceps tendon just proximal to the split. Close the subcutaneous tissues with 2-0 Vicryl and the skin with absorbable monofilament suture (Fig. 47.8F). Apply a postoperative dressing and a knee brace.

POSTOPERATIVE CARE The knee joint is immobilized in extension with a simple knee brace for 3 days after surgery. Range-of-motion exercises and gait with weight bearing on two crutches are started and gradually progressed. Weight bearing is allowed as tolerated immediately after surgery. Walking with full weight bearing is usually possible 2 or 3 weeks after surgery. Achieving at least 90 degrees knee flexion by the end of postoperative week 3 is encouraged. Jogging is allowed after 3 months, and participation in the original sporting activity is allowed 4 to 6 months after surgery, depending on the patient's rehabilitation progress.

DISTAL REALIGNMENT

Indications for distal realignment include patellar instability secondary to malalignment indicated by a Q angle of more than 20 degrees and anterior TT-TG distance of more than 20 mm. When trochlear dysplasia is present, less malalignment is tolerated, and a TT-TG distance of as little as 15 mm may require realignment procedures. If chondral damage is present distal and lateral on the patella, an oblique osteotomy helps unload these areas and transfer weight bearing proximal and medial. Bony distal realignment procedures are contraindicated in skeletally immature patients.

We recommend the Trillat procedure for dislocations due to malalignment with an Insall index of less than 1:3 and grade 2 or less chondromalacia noted at arthroscopy. We have found the modification described by Shelbourne, Porter, and Rozzi to be an effective technique.

TECHNIQUE 47.2

(MODIFIED BY SHELBOURNE, PORTER, AND ROZZI)

- Make a 6-cm lateral parapatellar incision approximately 1 cm lateral to the patellar tendon.
- Perform a lateral release from the tibial tubercle to the level of the insertion of the vastus lateralis tendon on the proximal patella. The release is considered adequate when the patellar articular surface can be everted 90 degrees laterally.
- Approach the tibial tubercle through the same parapatellar incision, and identify the patellar tendon insertion. Using a 2.5-cm flat osteotome, raise a flat, 6-cm long, 7-mm thick osteoperiosteal flap, tapering anteriorly and hinged distally with periosteum. Do not violate the soft tissues.
- Rotate the bone flap medially, cracking the cortex distally, and hold it in place with a Kirschner wire while the knee is moved through a full passive range of motion to evaluate patellar tracking.
- If tracking is acceptable and the transferred tubercle fits flush with the underlying tibia, fix it with one or two AO 4-mm cancellous lag screws. Use a 2.7-mm bit to drill through the tubercle and tibia. Angle the drill toward the joint and advance it until the posterior cortex is felt. Angling the drill proximally allows fixation to be placed in cancellous bone near the proximal tibia. Bicortical fixation is not used, and the screw should be long enough (usually 40-50 mm) to come near, but not penetrate, the posterior cortex.

POSTOPERATIVE CARE Weight bearing is allowed to tolerance using a straight-leg splint for ambulation for the first 6 weeks after surgery. At 1 week after surgery, closed chain kinetic strengthening is begun, with a goal of achieving 70% strength by 6 weeks. A functional progression program that allows the patient to return to unrestricted sports is begun 12 weeks after surgery. Most athletes can return to sport at 6 to 9 months.

OBLIQUE OSTEOTOMY OF THE TUBEROSITY

We generally prefer a slightly oblique osteotomy of the tuberosity, such as that described by Fulkerson and by Brown et al. that transfers the tuberosity anteriorly and medially. This procedure is indicated when grade 3 or 4 chondromalacia is associated with recurrent dislocations. A guide can be used to cut a flat osteotomy surface that angled from anteromedial just deep to the anterior crest of the tibia in a posterolateral direction. Increased obliquity of the cut increases anterior translation; however, the more superficial cut avoids a stress riser effect and reduces the risk of later fracture through the osteotomy. It is important to taper the osteotomy distally to prevent a stress riser.

Although this technique has been reported to produce 86% good to excellent results, complications have included stress risers and stress fractures through the area months after clinical and radiographic healing are present. Mechanical testing showed that a flat (Elmslie-Trillat) osteotomy had significantly higher mean load-to-failure and total energy-to-failure rates than the oblique osteotomy technique. In general, this procedure is not indicated for athletes and should be reserved for patients with patellofemoral degenerative changes.

For recurrent patellar dislocation and significant patella alta with an Insall index of more than 1.3, medial and distal transfer of the tuberosity occasionally is indicated. Preoperative radiographs are used to determine the amount of distal transfer necessary and to ensure the inferior pole of the patella is not placed distal to the Blumensaat line, creating patella baja. The tuberosity is detached distally, and 5 to 10 mm of bone is resected from the distal tip of the tuberosity to allow distal transfer before secure fixation. Because loss of flexion or loss of fixation may occur, distalization is not routinely done.

FULKERSON OSTEOTOMY

TECHNIQUE 47.3

- Make a 9-cm lateral parapatellar incision extending from the inferior pole of the patella distally. Exposure is similar to the Elmslie-Trillat procedure, with the difference being in the oblique osteotomy of the tuberosity.
- Extend the cut distally about 6 cm with the medial tip of the cut being more superficial.
- Drill holes to perforate the cortex distally so that the fragment can be hinged.
- Using an osteotome, complete the osteotomy deep and just proximal to the insertion of the patellar tendon and pry the tuberosity medially so that the Q angle is corrected to between 10 and 15 degrees. This usually requires moving the tuberosity anteriorly 8 to 10 mm. Obliquity of the osteotomy determines the amount of anterior displacement. A 30-degree osteotomy produces 1 mm of anteriorization for each 2 mm of medialization, whereas a 45-degree cut produces a 1 mm to 1 mm translation.
- Secure the transferred tuberosity by placing a drill bit proximally through the tuberosity and tibia with the knee in 90 degrees of flexion to decrease risk to neurovascular structures.
- Move the knee through a range of motion, and evaluate patellar tracking.
- If tracking is satisfactory, secure the tuberosity with two countersunk, low-profile, cancellous screws (Fig. 47.10) or bicortical screws.
- Close the medial retinaculum in a pants-over-vest fashion, plicating the medial side. Do not close the lateral retinaculum.

POSTOPERATIVE CARE Weight bearing is allowed as tolerated after surgery. Immobilization is continued 4 to 6 weeks, at which time range-of-motion and strengthening exercises are instituted. Return to sports usually is allowed at 6 to 9 months after surgery. In our opinion, there is some long-term risk for fracture after this procedure if an osteotomy of more than 30 degrees is done.

For severe rotational deformities, a distal femoral rotational osteotomy or proximal tibial osteotomy rarely may be indicated. Epiphysiodesis can be done for severe coronal malalignment deformities in immature patients. Most recurrent instability problems in skeletally immature patients are treated with MQTFL procedures, with the femoral fixation looped around the adductor tendon insertion or in a carefully placed tunnel distal to the physis.

TROCHLEOPLASTY

Sulcus-deepening trochleoplasty is a technically demanding procedure with precise indications: high-grade trochlear dysplasia with patellar instability and/or abnormal tracking. The primary goal is to improve patellar tracking by decreasing the prominence of the trochlea and creating a new groove with normal depth. Associated abnormalities should be evaluated and corrected (Box 47.1).

TECHNIQUE 47.4

- After administration of regional anesthesia, supplemented with patient sedation, position the patient supine and prepare and drape the extremity.

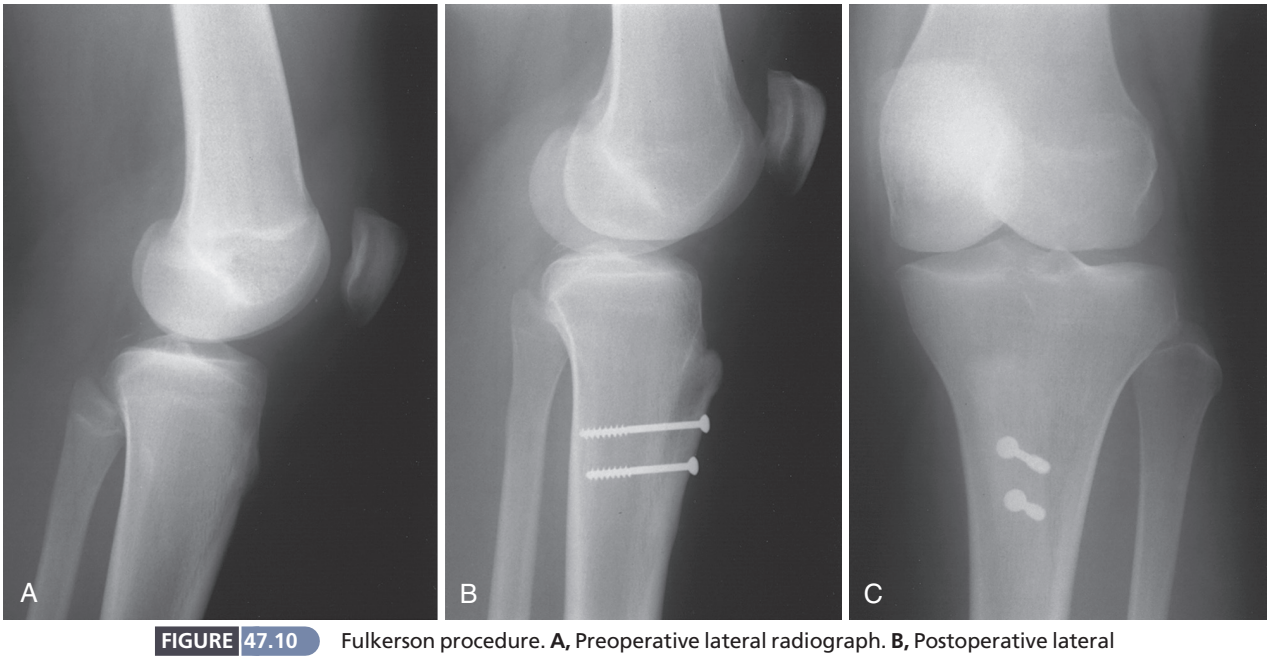

FIGURE 47.10 Fulkerson procedure. **A,** Preoperative lateral radiograph. **B,** Postoperative lateral radiograph. **C,** Anteroposterior radiograph. **SEE TECHNIQUE 47.3.**

- With the knee flexed to 90 degrees, make a straight midline skin incision from the superior patellar margin to the tibiofemoral articulation.
- Move the knee into extension and develop a medial full-thickness skin flap.
- Make a modified midvastus approach with sharp dissection of the medial retinaculum starting over the 1 to 2 cm medial border of the patella and blunt dissection of the vastus medialis oblique (VMO) fibers starting distally at the patellar superomedial pole and extending approximately 4 cm into the muscle belly.
- Evert the patella for inspection and treatment of chondral injuries if needed, and then retract it laterally.
- Expose the trochlea by incising the peritrochlear synovium and periosteum along their osteochondral junction and reflecting them from the field with a periosteal elevator. The anterior femoral cortex should be visible to orientate the amount of deepening. Changing the degree of flexion/extension allows a better view of the complete operative field and avoids extending the incision.
- Once the trochlea is fully exposed, draw the new trochlear limits with a sterile pen. Use the intercondylar notch as a starting point to draw the new trochlear groove. From there, draw a straight line directed proximally and 3 to 6 degrees laterally; the superior limit is the osteochondral edge. Draw two divergent lines, starting at the notch and passing proximally through the condyle-trochlear grooves, representing lateral and medial facet limits; these lines should not enter the tibiofemoral joint (Fig. 47.11A).
- To access the undersurface of the femoral trochlea, remove a thin strip of cortical bone from the osteochondral

BOX 47.1

Associated Abnormalities That May Require Correction in Addition to Trochleoplasty

- Tibial tubercle-trochlear groove (TT-TG) >20 mm: tibial tuberosity medializing osteotomy to obtain TT-TG distance between 10 and 15 mm.
- Patella alta (Canton-Deschamps index >1.2): distalization osteotomy to obtain normal patellar index of 1.0.
- Lateral patellar tilt >20 degrees: VMO plasty or reconstruction of the MPFL with a double-looped gracilis tendon graft.

MPFL, Medial patellofemoral ligament; *VMO*, vastus medialis obliquus.

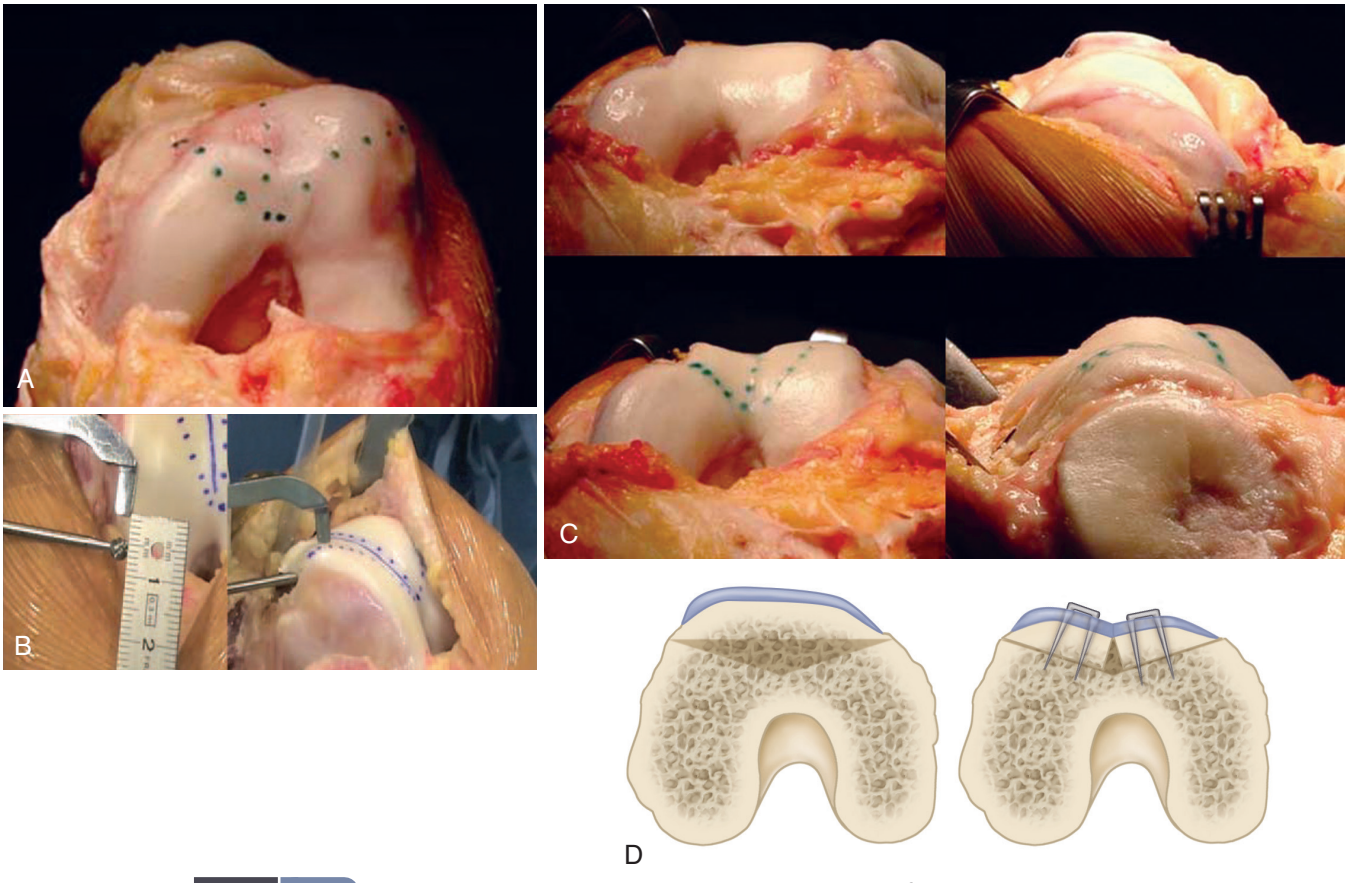

FIGURE 47.11 DeJour sulcus-deepening trochleoplasty. **A,** Drawing of the new trochlear limits. **B,** Removal of subchondral bone under the trochlea to correct the prominence and reshape the groove. **C,** Shape of the trochlea before (above) and after (below) sulcus-deepening trochleoplasty. **D,** Fixation of new trochlea with two staples after restoration of trochlear sulcus and more "anatomic" shape. (From DeJour D, Saggin P: The sulcus deepening trochleoplasty—the Lyon's procedure, *Int Orthop* 34:311–316, 2010.) **SEE TECHNIQUE 47.4.**

edge. The width of the strip is similar to the prominence of the trochlea from the anterior femoral cortex (the bump). Gently tap with a sharp osteotome and then use a rongeur to remove the bone.

- To remove cancellous bone from the undersurface of the trochlea, use a drill with a depth guide set at 5 mm to ensure uniform thickness of the osteochondral flap and maintain an adequate amount of bone attached to the cartilage (Fig. 47.11B). The guide also avoids injuring the cartilage or getting too close to it and causing thermal injury. The shell produced must be sufficiently compliant to allow modeling without being fractured.
- Extend cancellous bone removal up to the notch; remove more bone from the central portion where the new trochlear groove will lie (Fig. 47.11C).
- Use light pressure to mold the flap to the underlying cancellous bone bed in the distal femur. If needed, cut the bottom of the groove and the external margin of the lateral facet to allow further modeling by gently tapping over a scalpel.
- If the correction obtained is satisfactory, fix the new trochlea with two staples, one in each side of the groove, with one arm in the cartilaginous upper part of each facet and the other arm in the anterior femoral cortex (Fig. 47.11D).
- Test patellar tracking. Suture the periosteum and synovial tissue to the osteochondral edge and anchor them in the staples.

POSTOPERATIVE CARE Immediate weight bearing is permitted, and no limitation is placed on range of motion. Continuous passive motion is indicated to model the trochlea and patella, and frequent knee movement is encouraged to help ensure cartilage nutrition and further molding of the trochlea by the tracking patella. Because trochleoplasty is rarely done as an isolated procedure, postoperative care must consider associated procedures. Radiographs, including anteroposterior and lateral views and an axial view in 30 degrees of flexion, are reviewed at 6 weeks. At 6 months, a CT scan is obtained to document correction.

IATROGENIC MEDIAL PATELLAR INSTABILITY

Iatrogenic medial patellar instability is diagnosed when manual medial subluxation re-creates a patient's symptoms. Treatment consists of repairing the vastus lateralis if previously released and revising a distal realignment to a more lateral position. If the initial procedure was proximal and inadequate tissues remain, repair or reconstruction using the lateral portion of the patellar tendon is done (Fig. 47.12).

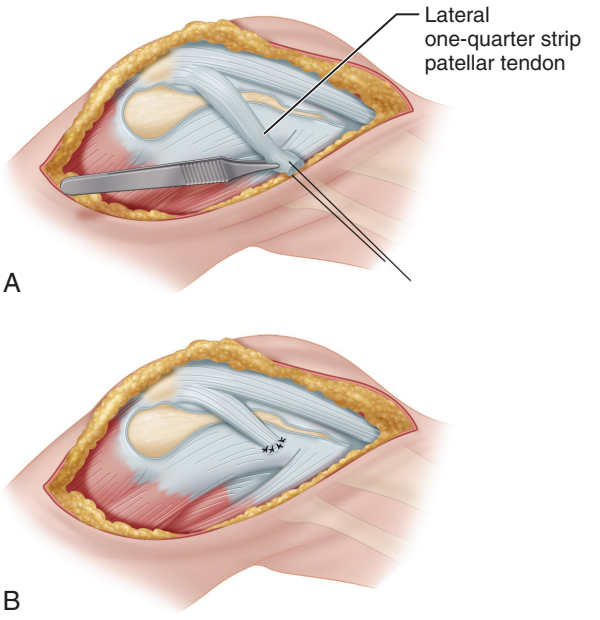

FIGURE 47.12 Reconstruction using patellar tendon. **A,** Lateral one-quarter strip of patellar tendon is developed. **B,** Strip is attached at lateral tibial tubercle by suture to periosteum or through bony tunnel.

HIP

With the evolution of hip arthroscopy and MR arthrography of the hip, the diagnosis and treatment of hip instability have greatly improved. The diagnosis is indicated by recurrent "giving way," pain, or popping with hip extension and external rotation during activities, such as getting out of a car or kicking or pivoting maneuvers during sports. The physical examination should include evaluation for generalized ligamentous laxity, as well as examination of the uninvolved hip for comparison. Tests that may indicate pathologic laxity include the dial test, passive external rotation of the more than 45 degrees, particularly if symptoms are reproduced. Other tests to reproduce symptoms of instability are the Ganz test, in which hip extension and external rotation produce anterior capsular pain. Finally, direct axial traction may produce apprehension. Moving the hip from flexion, abduction, and external rotation into extension, adduction, and internal rotation may re-create catching or popping associated with labral pathology.

Plain anteroposterior and lateral radiographs are helpful in evaluating acetabular dysplasia and impingement. A center-edge (CE) angle of less than 20 degrees, a crossover sign, and a Sharp angle of more than 42 degrees also are indicative of dysplasia (see Chapter 6). MR arthrography is used to evaluate for labral tears or capsular redundancy that may be related to recurrent instability.

Hip instability may be categorized as loss of bony acetabular containment, disruption of the capsulolabral complex, or a combination of the two. Recurrent trauma from stress at extremes of motion may result in capsulolabral deficiency and instability. Bony development problems can cause containment issues resulting in impingement or straight-forward instability. Finally, hyperlax joints from collagen deficiencies, Ehlers-Danlos and Marfan syndromes, and generalized joint laxity can result in symptomatic hip instability.

Treatment of these conditions must be tailored to the pathology, as in any other joint. Many of these procedures are now done arthroscopically and are described in Chapter 51.

STERNOCLAVICULAR JOINT

Most recurrent dislocations of the sternoclavicular joint are anterior and require only conservative treatment; posterior dislocations, although uncommon, require reduction because

of the proximity and potential compromise of the subclavian vessels, esophagus, and trachea. A complete discussion of acute dislocations and their treatment is presented in Chapter 60.

Recurrent atraumatic anterior subluxation of the sternoclavicular joint with shoulder abduction and extension usually occurs in young girls. Often it is associated with laxity of other joints and generally is a self-limiting condition. Most patients with recurrent anterior sternoclavicular joint dislocation should be treated with a generalized upper extremity strengthening program and avoidance of activities that produce stress on the sternoclavicular joint. Surgery is recommended only if severe symptoms limit activities of daily living. The surgical procedures, which include open repair of the sternoclavicular capsule, reconstruction of the sternoclavicular joint, and resection of the medial end of the clavicle and securing of the clavicle to the first rib, all are fraught with potentially severe complications, including injury to major vessels, persistent pain, unsightly scar formation, and recurrence of dislocation.

A strong semitendinosus graft is recommended for reconstruction of the joint. A figure-of-eight configuration through drill holes in the manubrium and midclavicle produces a strong, stable configuration that was shown in mechanical testing to restore native joint stiffness better than resection arthroplasty (Fig. 47.13). The reconstruction should be reinforced with local tissue repair, in particular the important posterior capsular tissue. It is wise to have a thoracic surgeon available for the procedure because of the potential complications associated with the procedure. Because of the possibility of pin migration and potentially severe complications, pins or wires should not be placed across the joint.

After reconstruction, the shoulder is immobilized in a sling for 6 weeks. On the second day, the patient is allowed to perform gentle pendulum exercises but is cautioned against active flexion or abduction of the shoulder above 90 degrees. Pushing, pulling, and lifting are avoided for 3 months. Strengthening exercises are started at 8 to 12 weeks. The patient is restricted from returning to strenuous manual labor for a minimum of 3 months.

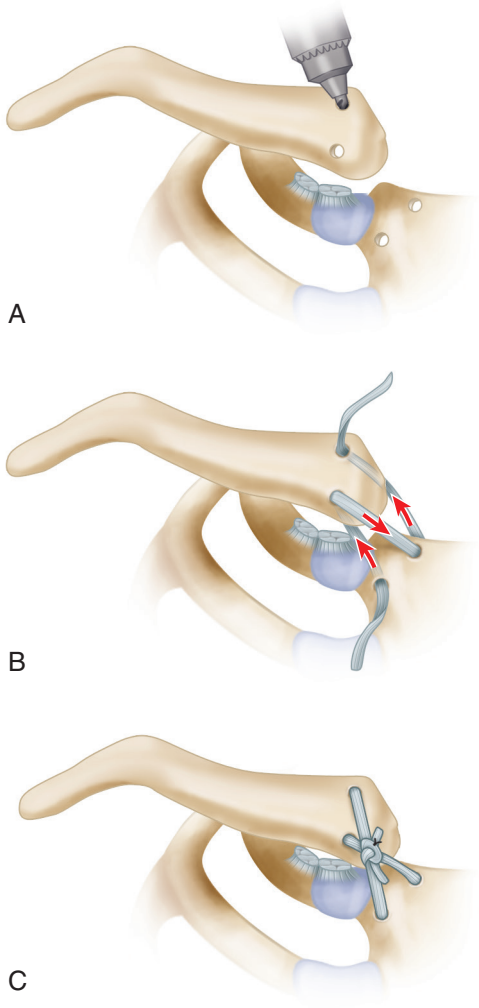

FIGURE 47.13 Semitendinosus figure-of-eight reconstruction. **A,** Drill holes passed anterior to posterior through medial part of clavicle and manubrium. **B,** Free semitendinosus tendon graft woven through drill holes so tendon strands are parallel to each other posterior to the joint and cross each other anterior to the joint. **C,** Tendon tied in square knot and secured with suture.

SHOULDER

The shoulder, by virtue of its anatomy and biomechanics, is one of the most unstable and frequently dislocated joints in the body, accounting for nearly 50% of all dislocations, with a 2% incidence in the general population. Factors that influence the probability of recurrent dislocations are age, return to contact or collision sports, hyperlaxity, and the presence of a significant bony defect in the glenoid or humeral head. In a study of 101 acute dislocations, recurrence developed in 90% of the patients younger than 20 years old, in 60% of patients 20 to 40 years old, and in only 10% of patients older than 40 years old. Contact and collision sports increase the recurrence rate to near 100% in skeletally immature athletes. The duration of immobilization also does not seem to affect stability; a recent meta-analysis determined that there is no benefit for conventional sling immobilization longer than 1 week for primary anterior dislocation. Immobilization in external rotation is thought to decrease recurrence rates, but this has not been proven; meta-analyses found a recurrence risk of 36% with immobilization in internal rotation compared with 25% with external rotation bracing, but the numbers were small and the difference was not significant. Burkhart and DeBeer, Sugaya et al., and Itoi et al. have shown that glenoid bone loss of more than 20% results in bony instability and increased recurrence rates. This is because the "safe arc" that the glenoid provides for humeral rotation is diminished, resulting in instability when the deficient edge is loaded at extremes of motion (Fig. 47.14).

NORMAL FUNCTIONAL ANATOMY

An understanding of the normal functional anatomy of the shoulder is necessary to understand the factors influencing the stability of the joint. The bony anatomy of the shoulder joint does not provide inherent stability. The glenoid fossa is a flattened, dish-like structure. Only one fourth of the large humeral head articulates with the glenoid at any given time. This small, flat glenoid does not provide the inherent stability for the humeral head that the acetabulum does for the hip. The glenoid is deepened by 50% by the presence of the

glenoid labrum. The labrum increases the humeral contact to 75%. Integral to the glenoid labrum is the insertion of the tendon of the long head of the biceps, which inserts on the superior aspect of the joint and blends to become indistinguishable from the posterior glenoid labrum. Matsen et al. suggested that the labrum may serve as a "chock block" to prevent excessive humeral head rollback. The shoulder joint capsule is lax and thin and, by itself, offers little resistance or stability. Anteriorly, the capsule is reinforced by three capsular thickenings or ligaments that are intimately fused with the labral attachment to the glenoid rim.

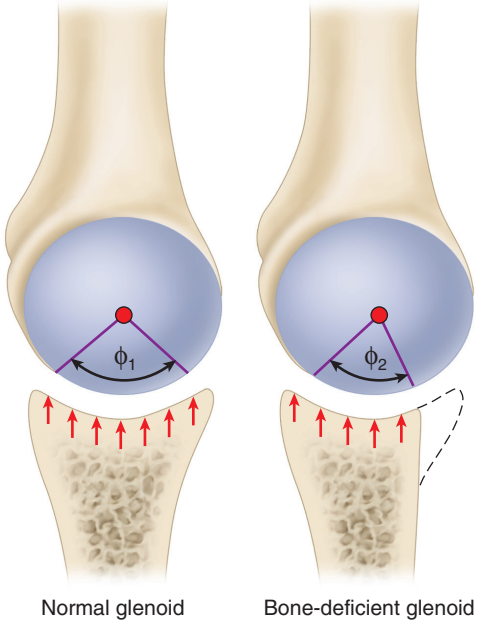

FIGURE 47.14 Glenoid bone loss shortens "safe arc" through which glenoid can resist axial forces. Φ_2 (bone-deficient condition) is less than Φ_1.

The superior glenohumeral ligament attaches to the glenoid rim near the apex of the labrum conjoined with the long head of the biceps (Fig. 47.15). On the humerus, it is attached to the anterior aspect of the anatomic neck of the humerus (Fig. 47.16). The superior glenohumeral ligament is the primary restraint to inferior humeral subluxation in 0 degrees of abduction and is the primary stabilizer to anterior and posterior stress at 0 degrees of abduction. Tightening of the rotator interval (which includes the superior glenohumeral ligament) decreases posterior and inferior translation; external rotation also may be decreased. The middle glenohumeral ligament has a wide attachment extending from the superior glenohumeral ligament along the anterior margin of the glenoid down as far as the junction of the middle and inferior thirds of the glenoid rim. On the humerus, it also is attached to the anterior aspect of the anatomic neck. The middle glenohumeral ligament limits external rotation when the arm is in the lower and middle ranges of abduction but has little effect when the arm is in 90 degrees of abduction. The inferior glenohumeral ligament attaches to the glenoid margin from the 2- to 3-o'clock positions anteriorly to the 8- to 9-o'clock positions posteriorly. The humeral attachment is below the level of the horizontally oriented physis into the inferior aspect of the anatomic and surgical neck of the humerus. The anterosuperior edge of this ligament usually is quite thickened. There is a less distinct posterior thickening, a hammock-type model consisting of thickened anterior and posterior bands and a thinner axillary pouch. With external rotation, the hammock

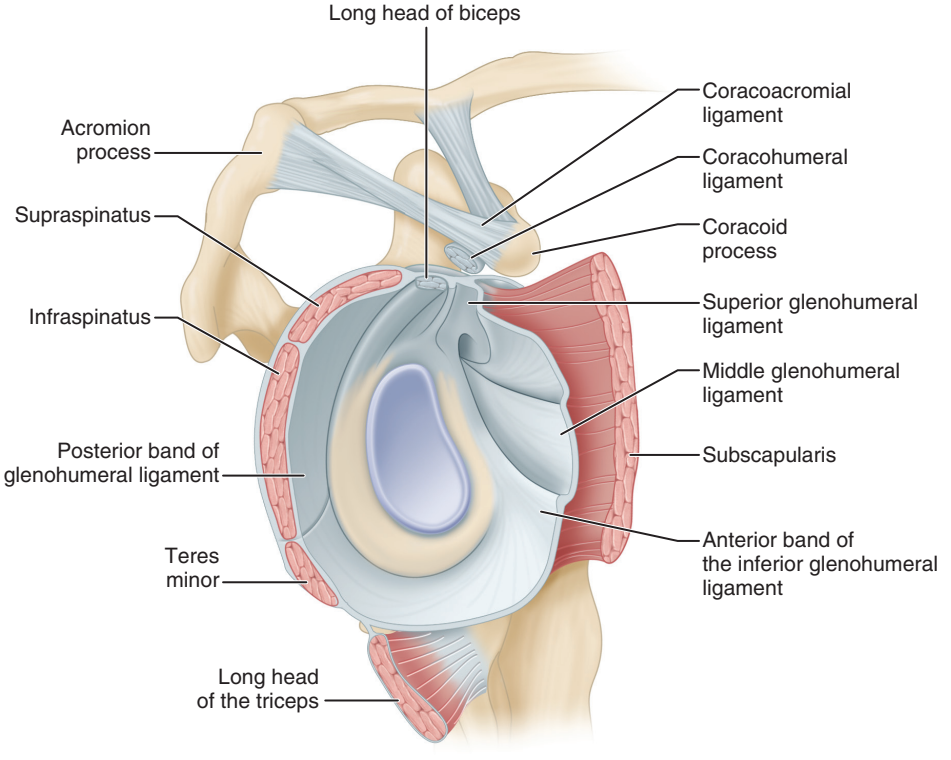

FIGURE 47.15 Glenoid and surrounding capsule, ligaments, and tendons.

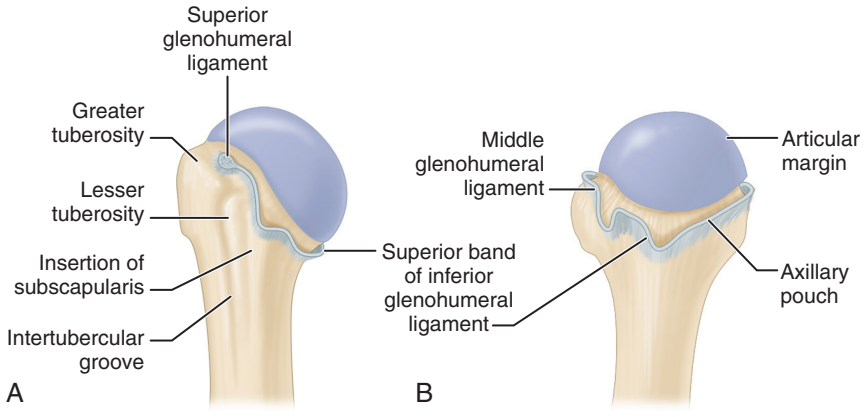

FIGURE 47.16 Upper part of left humerus showing attachments of glenohumeral ligaments on anterior **(A)** and medial **(B)** aspects of surgical and anatomic neck.

slides anteriorly and superiorly. The anterior band tightens, and the posterior band fans out. With internal rotation, the opposite occurs. The anteroinferior glenohumeral ligament complex is the main stabilizer to anterior and posterior stresses when the shoulder is abducted 45 degrees or more. The ligament provides a restraint at the extremes of motion and assists in the rollback of the humeral head in the glenoid.

The muscles around the shoulder also contribute significantly to its stability. The action of the deltoid (the principal extrinsic muscle) produces primarily vertical shear forces, tending to displace the humeral head superiorly. The intrinsic muscle forces from the rotator cuff provide compressive or stabilizing forces. Concavity compression is produced by dynamic rotator cuff muscular stabilization of the humeral head when the concavity of the glenoid and labral complex is intact. Loss of the labrum can reduce this stabilizing effect by 20%. In the concavity of the glenoid-labral complex, synchronous eccentric deceleration, and concentric contraction of the rotator cuff and biceps tendon are necessary for humeral stability during midranges of humeral motion. Asynchronous fatigue of the rotator cuff from overuse or incompetent ligamentous support can result in further damage to the static and dynamic supports. MRI studies have shown fatty infiltration and thinning of the subscapularis tendon in recurrent anterior instability.

Several authors have noted the importance of synchronous mobility of the scapula and glenoid to shoulder stability and emphasized the importance of this dynamic balance to appropriate positioning of the glenoid articular surface so that the joint reaction force produced is a compressive rather than a shear force. With normal synchronous function of the scapular stabilizers, the scapula and the glenoid articular structures are maintained in the most stable functional position. Strengthening rehabilitation of the scapular stabilizers (serratus anterior, trapezius, latissimus dorsi, rhomboids, and levator scapulae) is especially important in patients who participate in upper extremity-dominant sports. Although the glenoid is small, it has the mobility to remain in the most stable position in relation to the humeral head with movement. Rowe compared this with a seal balancing a ball on its nose. The glenoid also has the ability to "recoil" when a sudden force is applied to the shoulder joint, such as in a fall on the outstretched hand. This ability to "recoil" lessens the impact on the shoulder as the scapula slides along the chest wall.

Scapular dyskinesis is an alteration of the normal position or motion of the scapula during coupled scapulohumeral movements and can occur after overuse of and repeated injuries to the shoulder joint. A particular overuse muscle fatigue syndrome has been designated the SICK scapula: scapular malposition, inferior medial border prominence, coracoid pain and malposition, and dyskinesis of scapular movement.

The demonstration of Ruffini end organs and Pacinian corpuscles in the shoulder capsule helps solidify the concept of proprioceptive neuromuscular training as an important part of shoulder stabilization. Another force that has a lesser effect on glenohumeral stability is glenoid version. Glenoid version probably is not a significant contributor to instability except in a severely deformed shoulder. Cohesion produced by joint fluid and the vacuum effect produced by negative intraarticular pressure in normal shoulders play lesser roles in joint stability.

PATHOLOGIC ANATOMY

No essential pathologic lesion is responsible for every recurrent subluxation or dislocation of the shoulder. In 1906, Perthes considered detachment of the labrum from the anterior rim of the glenoid cavity to be the "essential" lesion in recurrent dislocations and described an operation to correct it. In 1938, Bankart published his classic paper in which he recognized two types of acute dislocations. In the first type, the humeral head is forced through the capsule where it is the weakest, generally anteriorly and inferiorly in the interval between the lower border of the subscapularis and the long head of the triceps muscle. In the second type, the humeral head is forced anteriorly out of the glenoid cavity and tears not only the fibrocartilaginous labrum from almost the entire anterior half of the rim of the glenoid cavity but also the capsule and periosteum from the anterior surface of the neck of the scapula. This traumatic detachment of the glenoid labrum has been called the *Bankart lesion*. Most authors agree that the Bankart lesion is the most commonly observed pathologic lesion in recurrent subluxation or dislocation of the shoulder, but it is not the "essential" lesion.

Excessive laxity of the shoulder capsule also causes instability of the shoulder joint. Excessive laxity can be caused by a congenital collagen deficiency, shown by hyperlaxity of other joints, or by plastic deformation of the capsuloligamentous complex from a single macrotraumatic event or repetitive

microtraumatic events. Hyperlaxity has been implicated as a cause of failure in surgical correction of chronic shoulder instability. An arthroscopic study of anterior shoulder dislocations found that 38% of the acute injuries were intrasubstance ligamentous failures, and 62% were disruptions of the capsuloligamentous insertion into the glenoid neck. The "circle concept" of structural damage to the capsular structures was suggested by cadaver studies that showed that humeral dislocation does not occur unless the posterior capsular structures are disrupted, in addition to the anterior capsular structures. Posterior capsulolabral changes associated with recurrent anterior instability often are identified by arthroscopy.

A humeral head impaction fracture can be produced as the shoulder is dislocated, and the humeral head is impacted against the rim of the glenoid at the time of dislocation. This Hill-Sachs lesion is a defect in the posterolateral aspect of the humeral head. Instability results when the defect engages the glenoid rim in the functional arc of motion at 90 degrees abduction and external rotation. In a cadaver model, humeral head defects of 35% to 40% were shown to decrease stability, whereas glenoid defects of as little as 13% were found to decrease stability. Glenoid rim fractures or attrition also can occur with an anterior or posterior dislocation. If these lesions involve more than 20% to 25% of the glenoid, they can result in recurrent instability despite having an excellent soft-tissue repair. These lesions are difficult to see on plain radiographs; if a defect is visible in an acute dislocation or one is evaluating recurrent instability, (3D) CT is the best method for evaluating the extent of the defect (Fig. 47.17).

It seems that no single "essential" lesion is responsible for all recurrent dislocations of the shoulder. Stability of this inherently unstable joint depends on a continuing balance between the static and dynamic mechanisms influencing motion and stability. In addition to the various possible primary deficiencies influencing instability, secondary deficiencies can be caused by repeated dislocations. Erosion of the anterior glenoid rim, stretching of the anterior capsule and subscapularis tendon, and fraying and degeneration of the glenoid labrum all can occur with repeated dislocation. The primary deficiency and the secondary deficiencies need to be considered at the time of surgery and in postoperative rehabilitation to correct the instability. Because no single deficiency is responsible for all recurrent dislocations of the shoulder, no single operative procedure can be applied to every patient. The surgeon must search carefully for and identify the deficiencies present to choose the proper procedure.

CLASSIFICATION

Successful treatment of shoulder instability is based on a thorough understanding of the various posttraumatic lesions that can be associated with a deficient capsulolabral complex and on correct classification of the patient's primary and secondary lesions. Classification and treatment of shoulder instability are based on the direction, degree, and duration of symptoms; the trauma that resulted in instability; and the patient's age, mental set, and associated conditions, such as seizures, neuromuscular disorders, collagen deficiencies, and congenital disorders.

The direction of instability should be categorized as unidirectional, bidirectional, or multidirectional. Anterior dislocations account for 90% to 95% of recurrent dislocations, and posterior dislocations account for approximately 5% to 10%.

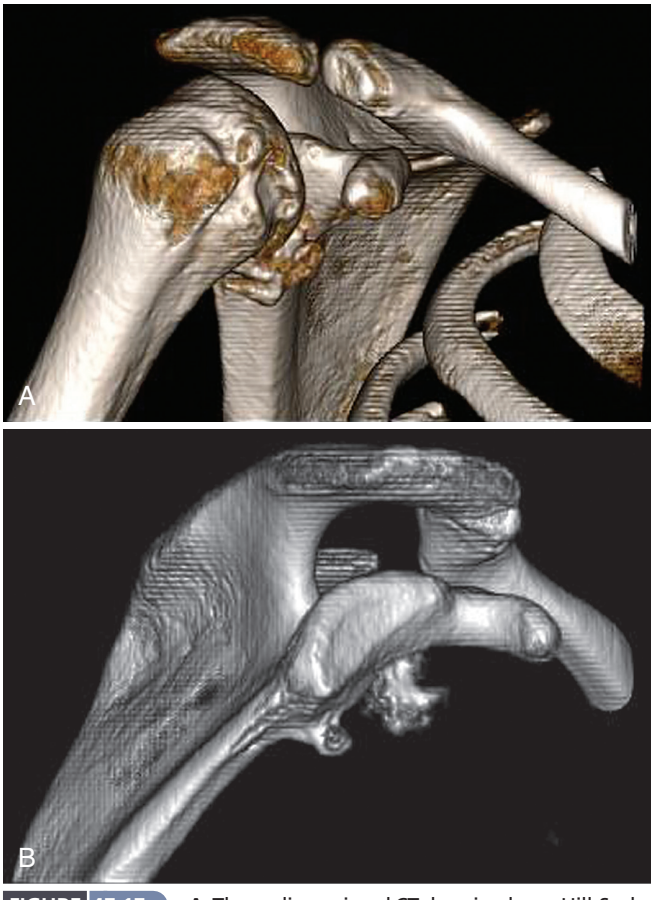

FIGURE 47.17 **A,** Three-dimensional CT showing large Hill-Sachs lesion and deficient glenoid. **B,** Three-dimensional CT with humeral head subtracted showing loss of anterior glenoid surface.

Despite increased understanding of shoulder instability, 50% of posterior shoulder dislocations can be missed unless an adequate examination and appropriate radiographs are done. Inferior and superior dislocations are rare. Superior instability generally arises secondary to severe rotator cuff insufficiency.

Instability is categorized as subluxation with partial separation of the humeral head from the glenoid or dislocation with complete separation of the humeral head from the glenoid concavity. The duration of the symptoms should be recorded as acute, subacute, chronic, or recurrent. The dislocation is classified as chronic if the humeral head has remained dislocated longer than 6 weeks.

The type of trauma associated with the dislocation is important in determining whether conservative or operative treatment is appropriate. Instability should be categorized as *macrotraumatic*, in which a single traumatic event results in dislocation, or *microtraumatic* (acquired), in which repetitive trauma at the extremes of motion results in plastic deformation of the capsulolabral complex. Secondary trauma to the rotator cuff and biceps tendon may cause asynchronous rotator cuff function. These injuries most commonly occur in pitchers, batters, gymnasts, weightlifters, tennis players and others who play racquet sports, and swimmers, especially with the backstroke or butterfly stroke. The flexibility that allows an athlete to compete at a high level may be attributed to a generalized ligamentous laxity, which also predisposes the athlete to injury. Trauma may cause decompensation of

a previously stable capsuloligamentous complex. A thorough history of the initial traumatic event, symptoms, and family history and a thorough examination of the injured shoulder, contralateral shoulder, and other joints are necessary.

Age also is important in predicting pathologic lesions and outcomes, with recurrence rates of more than 90% reported in patients younger than 20 years old compared with a recurrence rate of about 10% to 20% in patients older than 40 years old.

In most studies, the recurrence rate for adolescents treated with surgical stabilization was higher than that for patients in other age groups. These differences can be explained by the greater elasticity in adolescent ligaments that results in greater plastic deformation before failure of the system. This deformation must be considered in surgical treatment approaches.

Although recurrence of the dislocation is uncommon in patients 40 years old or older, associated rotator cuff tears are present in 30%, and such tears are present in more than 80% of patients older than 60 years. Fractures of the greater tuberosity also are more prevalent in patients older than 40 years old; some series report an incidence of 42%. In this age group, surgical treatment of rotator cuff tears or fractures of the greater tuberosity generally takes precedence over treatment of the capsular injury.

The mental set of the patient must be evaluated before treatment is started. Some patients with posterior instability learn to dislocate their shoulder through selective muscular contractions. Although voluntary dislocation does not indicate pathologic overlay, some of these patients have learned to use voluntary dislocation for secondary gain, and in these patients surgical treatment is doomed to failure.

In patients with primary neuromuscular disorders or syndromes and recurrent dislocation, conservative, nonoperative treatment should be the initial approach. If instability remains after appropriate medical treatment, surgery may be necessary in conjunction with continued nonoperative treatment. Patients with primary collagen disorders, Ehlers-Danlos syndrome, or Marfan syndrome should be treated with extensive supervised conservative treatment. If surgical intervention becomes necessary, the possibility of the abnormal tissue stretching out and allowing dislocation to recur should be stressed to the patient and family. When severe dysplastic or traumatic glenohumeral deformity is present, capsular and bony procedures may be necessary. Reformatted 3D CT images are beneficial in determining the need for osteotomy or bone grafting procedures in these patients.

Matsen's simplified classification system is useful for categorizing instability patterns: TUBS (traumatic, unidirectional Bankart surgery) and AMBRII (atraumatic, multidirectional, bilateral, rehabilitation, inferior capsular shift, and internal closure). Microtraumatic or developmental lesions fall between the extremes of macrotraumatic and atraumatic lesions and can overlap these extreme lesions (Fig. 47.18). Classification of 168 shoulders according to four systems used for describing shoulder instability revealed variations in the criteria that resulted in marked variations in the number of patients diagnosed with multidirectional instability.

FIGURE 47.18 Matsen's classification system.

HISTORY

The history is important in recurrent instability of the shoulder joint. The amount of initial trauma, if any, should be determined. High-energy traumatic collision sports and motor vehicle accidents are associated with an increased risk of glenoid or humeral bone defects. Recurrence with minimal trauma in the midrange of motion often is associated with bony lesions, which must be treated. The position in which the dislocation or subluxation occurs should be elicited. In complete dislocations, the ease with which the shoulder is relocated is determined. Dislocations that occur during sleep or with the arm in an overhead position often are associated with a significant glenoid defect that requires surgical treatment.

Dislocations that are reduced by the patient often are subluxations or dislocations associated with generalized ligamentous laxity. The signs and symptoms of any nerve injury should be elicited. Most important, the physical limitations caused by this instability should be documented.

Recurrent subluxation of the shoulder is commonly overlooked by physicians because the symptoms are vague and there is no history of actual dislocation. The patient may complain of a sensation of the shoulder sliding in and out of place, or he or she may not be aware of any shoulder instability. The patient may complain of having a "dead arm" as a result of stretching of the axillary nerve or of secondary rotator cuff symptoms. It is important to differentiate primary from secondary rotator cuff impingement. Rotator cuff symptoms develop secondary to ligamentous dysfunction. Internal impingement of the undersurface of the posterior rotator cuff against the posterior glenoid and labrum is caused by anterior humeral subluxation with the shoulder externally rotated. This secondary impingement is more common than primary impingement in patients younger than 35 years old who are involved in upper extremity–dominant sports. Posterior shoulder instability may present as posterior pain or fatigue with repeated activity (e.g., blocking in football, swimming, bench press, rowing, and sports requiring overhead arm movement).

PHYSICAL EXAMINATION

The physical examination of a patient with instability begins by asking the patient which arm position creates the instability, what direction the shoulder subluxes, and if he or she can safely demonstrate the subluxation. Both shoulders should be thoroughly examined, with the normal shoulder used as a reference. The examination includes evaluation of the shoulders for atrophy or asymmetry, followed by palpation to determine the amount of tenderness present in the anterior or posterior capsule, the rotator cuff, and the acromioclavicular joint. Active and passive ranges of motion are evaluated with the patient upright and supine to record accurately the motion in all planes. The strengths of the deltoid, rotator cuff, and scapular stabilizers are evaluated, recorded, and graded from 0 to 5, with 5 being normal. Scapular winging or dysfunction should be noted during active range of motion and during strength examination. Winging may indicate scapular weakness and can be evaluated by having the patient do a press-up from the examination table or an incline type of push-up off the wall.

Stability is evaluated with the patient upright. A "shift-and-load" test is done by placing one hand along the edge of

the scapula to stabilize it and grasping the humeral head with the other hand and applying a slight compressive force. The amount of anterior and posterior translation of the humeral head in the glenoid is observed with the arm abducted 0 degrees. Easy subluxation of the shoulder indicates loss of the glenoid concavity, which must be surgically treated.

The sulcus test is done with the arm in 0 degrees and 45 degrees of abduction. This test is done by pulling distally on the extremity and observing for a sulcus or dimple between the humeral head and the acromion that does not reduce with 45 degrees of external rotation. The distance between the humeral head and acromion should be graded from 0 to 3 with the arm in 0 degrees and 45 degrees of abduction, with 1+ indicating subluxation of less than 1 cm, 2+ indicating 1 to 2 cm of subluxation, and 3+ indicating more than 2 cm of inferior subluxation that does not reduce with external rotation. Subluxation at 0 degrees of abduction is more indicative of laxity at the rotator interval, and subluxation at 45 degrees indicates laxity of the inferior glenohumeral ligament complex.

Anterior apprehension is evaluated with the shoulder in 90 degrees of abduction and the elbow in 90 degrees of flexion, with a slight external rotation force applied to the extremity as anterior stress is applied to the humerus. This generally produces an apprehension reaction in a patient who has anterior instability. Control of the proximal humerus should be maintained during any of the apprehension or stress tests to prevent dislocation during these procedures. Posterior instability can be evaluated with a Kim test or a posterior clunk test, in which the 90-degree abducted extremity is brought to a forward flexed, internally rotated position while posterior stress is applied to the elbow. The clunk is felt as the humeral head subluxes posteriorly, producing pain or a feeling of subluxation in an unstable shoulder.

The shoulder anterior drawer test should be performed with the patient supine and the extremity in various degrees of abduction and external rotation in the plane of the scapula. When examining the patient's right shoulder, the examiner's left hand is used to grasp the proximal humerus while the right hand is used to hold the elbow lightly. Anterior stress is applied to the proximal humerus using the left hand, and the amount of translation and the end point are evaluated. In performing this and other anterior or posterior instability tests, the amount of instability is graded from 0 to 3. Grade 1 means that the humeral head slips up to the rim of the glenoid, and grade 2 means that it slips over the labrum but then spontaneously relocates. Grade 3 indicates dislocation. A grade 3 instability should not be exhibited in an awake patient. Anterior stress is applied with the shoulder in various degrees of abduction and external rotation, and posterior stress is applied to evaluate for posterior instability with the arm in 90 degrees of abduction and various degrees of flexion. When examining the patient's right shoulder, posterior stress is applied with the examiner's right hand, starting at 0 degrees of forward flexion and internal rotation and proceeding to 110 degrees. The examiner's left hand stabilizes the scapula and palpates the posterior part of the glenohumeral joint with the palm. It also can be used as a buttress to ensure that posterior dislocation does not occur during this procedure. Apprehension is evaluated with anterior and posterior stress during these procedures.

The Jobe relocation test can be used for evaluating instability in athletes involved in sports requiring overhead motion (Fig. 47.19). This test is done with the patient supine and the shoulder in 90 degrees of abduction and external rotation. Various degrees of abduction are evaluated while anterior stress is applied by the examiner's hand to the posterior part of the humerus. If this produces pain or apprehension, posteriorly directed force is applied to the humerus to relocate the humeral head in the glenohumeral joint while the shoulder is placed in abduction and external rotation. The posteriorly directed stress used to relocate the humerus is released. A feeling of apprehension or subluxation on the part of the patient indicates anterior instability.

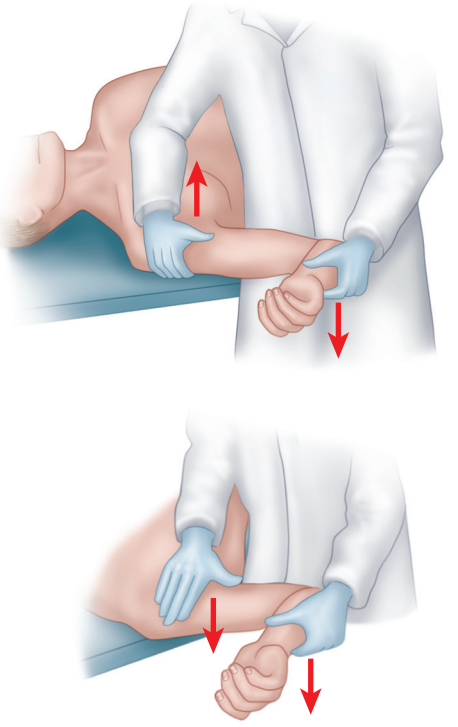

FIGURE 47.19 Jobe's relocation test and a positive relocation test and a positive apprehension test are highly predictive of recurrent instability.

Bony deformity of the glenoid or humerus is indicated by apprehension or instability at low ranges of motion (<90 degrees of abduction) and when inferior instability is prominent. Hyperlaxity is indicated by a positive sulcus test, a positive Gagey hyperabduction test, and the Beighton hyperlaxity scale (Table 47.4). The hyperabduction test is done by stabilizing the scapula with one hand placed superiorly while passively abducting the shoulder with the other hand. A side-to-side difference of more than 20 degrees is suggestive of inferior capsular laxity. External rotation of more than 85 degrees at 0 degrees of abduction is indicative of hyperlaxity, which may need to be corrected with rotator interval closure.

It is imperative to distinguish secondary rotator cuff impingement from primary impingement. The relocation and anterior apprehension tests are valuable in young athletes in sports requiring throwing or overhead motion. It also is imperative to rule out scapular dysfunction that can be corrected with physical therapy. Although rarely associated with shoulder instability, neck problems should be also ruled out, such as degenerative discs or degenerative arthritis that causes pain radiating into the posterior or lateral aspect of the shoulder.

TABLE 47.4

Beighton Hyperlaxity Score

CHARACTERISTIC	SCORING*
Passive dorsiflexion of the little finger beyond 90 degrees	1 point for each hand
Passive apposition of the thumb to the ipsilateral forearm	1 point for each hand
Active hyperextension of the elbow beyond 10 degrees	1 point for each elbow
Acute hyperextension of the knee beyond 10 degrees	1 point for each knee
Forward flexion of the trunk with the knees fully extended so that the palms of the hands rest flat on the floor	1 point

*A score of ≤4 points, on a 9-point scale, is diagnostic of hyperlaxity.

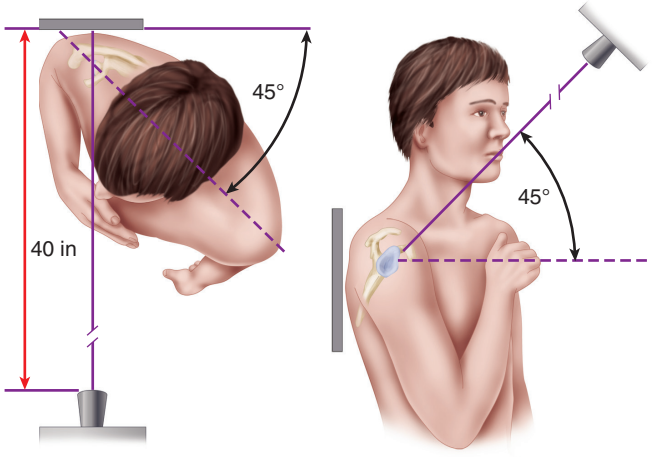

FIGURE 47.20 Garth et al. radiographic technique for apical oblique view of shoulder. With patient seated and injured shoulder adjacent to vertical cassette, chest is rotated to 45-degree oblique position. Beam is directed 45 degrees caudally, passing longitudinally through scapula, which rests at 45-degree angle on thorax while extremity is adducted. Origin of coracoid, midway between anterior and posterior margins of glenoid, aids in orientation on radiograph.

RADIOGRAPHIC EVALUATION

The diagnosis of an unstable shoulder often is made by history and physical examination, but an unstable shoulder can be documented by routine radiographs. The initial radiographic examination should include anteroposterior and axillary lateral views of the shoulder. If the initial radiographic evaluation is inconclusive, special views, gadolinium-enhanced MRI, or CT arthrography can be used to show posttraumatic changes not otherwise detected. The most common special views that can be obtained in the office are the anteroposterior view of the shoulder in internal rotation, the West Point or Rokous view, and the Stryker notch view. An anteroposterior radiograph of the shoulder in internal rotation often shows a Hill-Sachs lesion that may not be apparent on routine views. Garth et al. also described an apical oblique radiograph that frequently shows posterior humeral head defects that might not be seen on routine films (Fig. 47.20). The West Point view is used to show calcification or small fractures at the anteroinferior glenoid rim. This is a modified, prone, axillary lateral view of the shoulder obtained with the shoulder abducted 90 degrees and the elbow bent with the arm hanging over the side of the table. The x-ray beam is directed 25 degrees medially and 25 degrees cephalad with the cassette placed above the shoulder perpendicular to the table (Fig. 47.21). The Stryker notch view is obtained with the patient supine and the elbow elevated over the head. The x-ray beam is directed 10 degrees cephalad (Fig. 47.22).

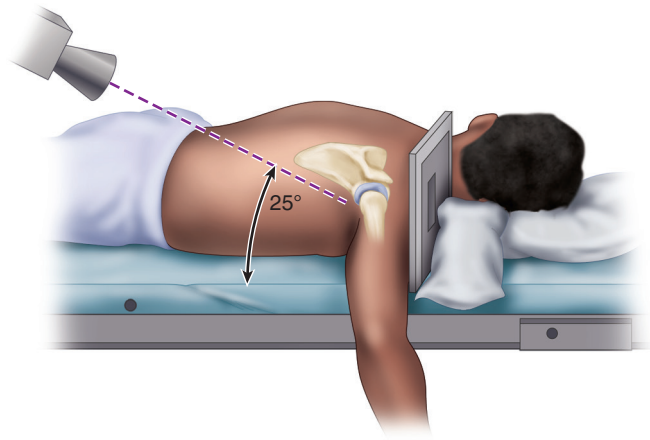

FIGURE 47.21 Radiographic technique for West Point view of shoulder to show glenoid labrum lesions. With patient prone and pillow beneath shoulder, cassette is placed superior to shoulder.

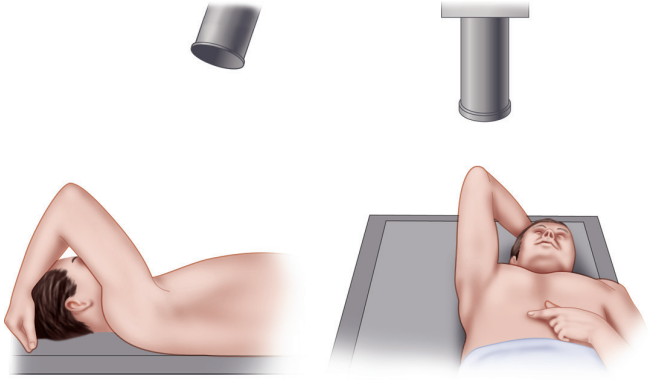

FIGURE 47.22 Radiographic technique for Stryker notch view of humerus.

MRI or MRA is indicated for evaluating soft-tissue lesions associated with instability. MRI obtained within a few days of dislocation generally shows blood in the joint, which can aid in visualization and make MRA unnecessary. MRA is helpful in evaluating humeral avulsion glenohumeral ligament (HAGL) lesions, but occasionally it may show a tear but actually cover up the details of the exact tear site (Fig. 47.23). Evaluation of the glenoid track, as described by Yamamoto et al., evaluates Hill-Sachs lesions based on both the location and size of the humeral head defect and the amount of glenoid bone loss. It has been shown to be highly predictive in a clinical setting. Metzger et al. found that lesions falling outside the track engaged more than 85% of the time. The examination is measured on MRI (Fig. 47.24) and is essential

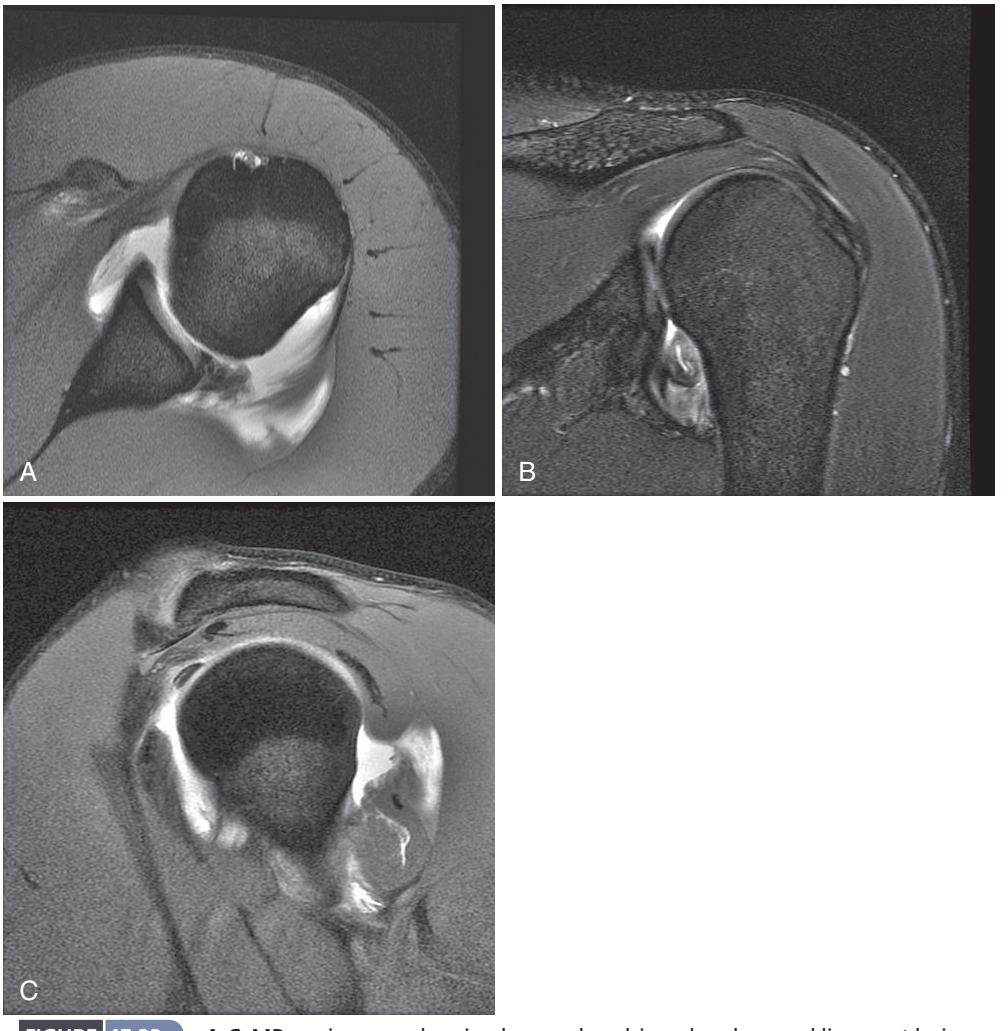

FIGURE 47.23 **A-C,** MR angiograms showing humeral avulsion glenohumeral ligament lesion.

in determining appropriate surgical intervention for on-track versus off-track lesions.

CT, particularly 3D CT, is the most sensitive test for detecting and measuring bone deficiency or retroversion of the glenoid or humerus for evaluation of recurrent instability. CT is indicated when there is blunting of the glenoid cortical outline or an obvious bone defect on plain radiographs. CT also is indicated for evaluating recurrences that occur with trivial trauma, low-angle instability, and failed surgical procedures (Fig. 47.25).

EXAMINATION USING ANESTHETIC AND ARTHROSCOPY

Examination with the patient under anesthesia may support the clinical diagnosis or sometimes show unsuspected planes of instability, especially in multidirectional instability patterns. For anterior instability, the arm is abducted. Anterior and posterior stress is applied with the scapula stabilized. Minimal anterior translation of the humeral head occurs unless there is instability. The most significant findings of instability are demonstrable at 40 degrees and 80 degrees of external rotation. Translation of two grades more than the opposite uninvolved side resulted in 93% sensitivity and 100% specificity for instability. For posterior instability, the arm is pushed posteriorly. Normal shoulders may permit posterior displacement of 50% of the diameter of the glenoid without pathologic instability.

Arthroscopy can be combined with examination using anesthesia and is an excellent technique for confirming the presence of shoulder instabilities. The examiner should grade the instability in all planes as previously described, remembering that this examination under anesthesia is used to support the clinical history and examination with the patient awake. Arthroscopy should be performed to identify all intraarticular pathology so that treatment may be rendered accordingly. Arthroscopy portals and time should be limited to reduce extravasation into the soft tissues, which can make surgical exposure more difficult.

ANTERIOR INSTABILITY OF THE SHOULDER

SURGICAL TREATMENT

More than 150 operations and many modifications have been devised to treat traumatic recurrent anterior instability of the shoulder. There is no single best procedure. Factors that have been stressed as important in achieving a successful result are adequate exposure and accurate surgical technique. The pathologic condition should be defined, and a procedure should be done that corrects this condition most anatomically. Ideally, the procedure for recurrent instability

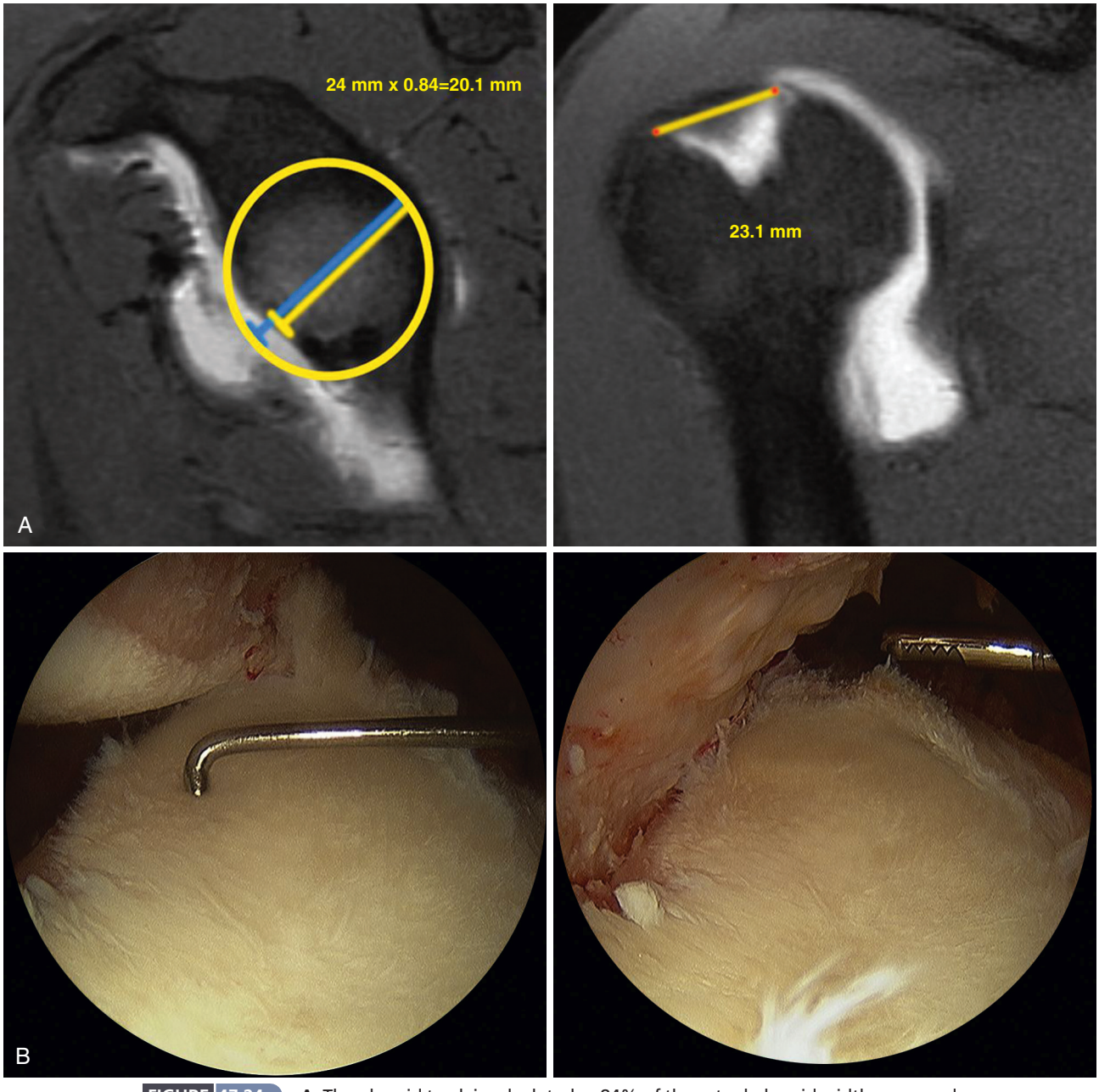

FIGURE 47.24 **A,** The glenoid track is calculated as 84% of the actual glenoid width measured on the sagittal oblique MR image. A best-fit circle is placed on the glenoid to calculate the expected width before bone loss; therefore, both percentage of bone loss and glenoid track can be determined. In this case, the actual glenoid width is 24 mm, with 4 mm of bone loss (17%). The glenoid track is 84% of 24 mm, or 20.1 mm. **B,** The distance from the rotator cuff footprint to the medial margin of the Hill-Sachs lesion is measured on the coronal MR image. In this case, it is 23.1 mm. Because the Hill-Sachs width to the footprint (23.1 mm) is greater than the glenoid track measurement (20.1 mm), it is considered outside the glenoid track and at high risk for engaging. (From Metzger PD, Barlow B, Leonardelli D, et al: Clinical application of the "glenoid track" concept for defining humeral head engagement in anterior shoulder instability. A preliminary report, *Orthop J Sports Med* 1:1, 2013.)

should include the following factors: (1) low recurrence rate, (2) low complication rate, (3) low reoperation rate, (4) does no harm (arthritis), (5) maintains motion, (6) is applicable in most cases, (7) allows observation of the joint, (8) corrects the pathologic condition, and (9) is not too difficult.

Operative procedures can be done open or arthroscopically with comparable results. When the appropriate procedure is accomplished to restore the anatomy, outcomes of Bankart repairs are affected by what Balg and Boileau described as the Instability Severity Index Score (ISIS; Table 47.5).

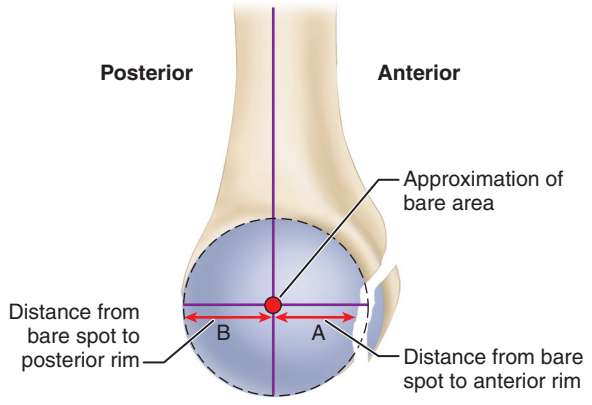

FIGURE 47.25 Estimation of bone loss based on glenoid rim distances. En face view of glenoid is viewed on a CT scan. With use of intersection of longitudinal axis and widest anteroposterior diameter of glenoid, the bare spot is approximated on the glenoid fossa. A best-fit circle centered at the bare-spot approximation is drawn about the inferior two thirds of the glenoid *(red)*. Distances from the bare spot to anterior rim *(A)* and posterior rim *(B)* are measured. The percent bone loss is calculated according to the indicated equation. (From Provencher MT, Bhatia S, Ghodadra NS, et al: Recurrent shoulder instability: current concepts for evaluation and management of glenoid bone loss, *J Bone Joint Surg* 92A:133–151, 2010).

At present, our preferred surgical procedures are arthroscopic Bankart or capsular plication procedures as indicated. When an open procedure is desired, we prefer the Jobe capsulolabral reconstruction or Neer capsular shift for anterior instability and a glenoid-based shift for posterior instability. For glenoid bony defects that cannot be repaired, we reconstruct the anterior defects with a Latarjet procedure and use an autograft iliac crest extracapsular bone graft posteriorly. Moderately sized (20% to 30%) humeral head defects are treated with an arthroscopic remplissage procedure and Bankart repair, and larger defects (35% to 45%) are treated indirectly by increasing the glenoid arc using a Latarjet procedure or by allograft repair of the defect. In a contact or collision athlete any significant Hill-Sachs lesion is treated with a remplissage procedure, unless in a throwing athlete (Table 47.6).

BANKART OPERATION

In the original Bankart operation, the subscapularis and shoulder capsule are opened vertically. The lateral leaf of the capsule is reattached to the anterior glenoid rim. A medial leaf of the capsule is imbricated, and the subscapularis is approximated. The Bankart operation is indicated when the labrum and the capsule are separated from the glenoid rim or if the capsule is thin. The advantage of this procedure is that it corrects the labral defect and imbricates the capsule without requiring any metallic internal fixation devices. The main disadvantage of the original procedure is its technical difficulty.

TABLE 47.5

Instability Severity Index Score Based on a Preoperative Questionnaire, Clinical Examination, and Radiographs

PROGNOSTIC FACTORS	POINTS
AGE AT SURGERY (YEARS)	
<20	2
>20	0
DEGREE OF SPORT PARTICIPATION (PREOPERATIVE)	
Competitive	2
Recreational or none	0
TYPE OF SPORT (PREOPERATIVE)	
Contact or forced overhead	1
Other	0
SHOULDER HYPERLAXITY	
Shoulder hyperlaxity (anterior or inferior)	1
Normal laxity	0
HILL-SACHS LESION ON ANTEROPOSTERIOR RADIOGRAPH	
Visible in external rotation	2
Not visible in external rotation	0
GLENOID LOSS OF CONTOUR ON ANTEROPOSTERIOR RADIOGRAPHS	
Loss of contour	2
No lesion	0
***TOTAL* (POINTS)**	**10**

From Balg F, Boileau P: The instability severity index score: a simple preoperative score to select patients for arthroscopic or open shoulder stabilisation, *J Bone Joint Surg* 89B:1470–1477, 2007. Copyright British Editorial Society of Bone and Joint Surgery.

Since the original description of the Bankart procedure, modifications have allowed the procedure to be done with more ease and less surgical trauma. The procedure can be done through a subscapularis split; or in larger, more muscular individuals, the subscapularis split can be extended superiorly approximately 1 cm medial to the biceps tendon, releasing the subscapularis muscle in an L-shaped fashion. This L-type release provides excellent exposure of the rotator interval, and the inferior third of the subscapular muscle can be retracted inferiorly to expose the inferior capsule, while protecting the axillary nerve. The subscapularis split approach preserves neuromuscular function and minimizes the possibility of postoperative tendon detachment. We have had success using either the subscapularis split or the L-split, depending on the patient, and the modified Bankart procedure (Fig. 47.26). We have used a procedure similar to that described by Montgomery and Jobe for recurrent traumatic dislocations and recurrent microtraumatic subluxations with anterior and inferior instability. A 17-year follow-up of 127 patients with open Bankart repair found only two patients with recurrent instability, reminding us that his procedure produces results that are hard to duplicate by any other means. Keys to success of this procedure are (1) maximizing the healing potential by abrading the

TABLE 47.6

Our Preferred Open Surgical Treatment (90% to 95% Are Done Arthroscopically)	
Traumatic Bankart	Jobe capsulolabral reconstruction
Acute bony Bankart	Screw or anchor fixation
+Hyperlaxity	Rotator interval closure
HAGL	Suture anchor repair
MULTIDIRECTIONAL	**REPAIR BANKART/KIM LESIONS**
Anteroinferior prominent	Humeral side Neer capsular shift
Posterior prominent—glenoid side	Glenoid side shift
BONE LOSS—GLENOID	
Erosional bone loss >25%	Laterjet procedure
Erosional bone loss >40%	Eden-Hybinette procedure
BONE LOSS—HUMERAL HEAD	
20% + glenoid defect	Jobe capsular reconstruction + capsular shift + remplissage
25% (6 mm deep)	Remplissage
40%	Laterjet to increase glenoid rotational arc
BONE LOSS—ANTERIOR HUMERAL HEAD	
>30%	McLaughlin
Capsular deficiency	Achilles allograft capsular reinforcement

HAGL, Humeral avulsion glenohumeral ligament.

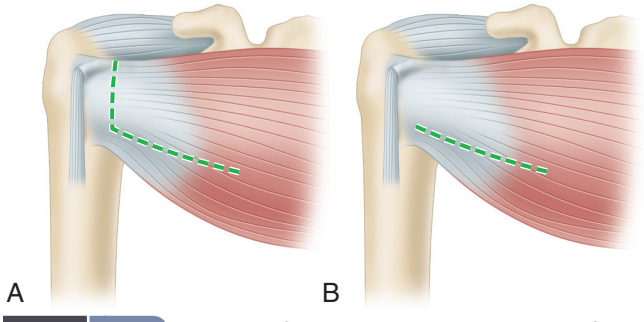

FIGURE 47.26 Division of subscapularis tendon. **A,** Lower fourth of subscapularis tendon is left intact to protect anterior humeral circumflex artery and axillary nerve. **B,** Subscapularis muscle is split horizontally and retracted superiorly and inferiorly to expose underlying capsule.

scapular neck, (2) restoring glenoid concavity, (3) securing anatomic capsular fixation at the edge of the glenoid articular surface, (4) re-creating physiologic capsular tension by superior and inferior capsular advancement and imbrication, and (5) performing supervised goal-oriented rehabilitation.

MODIFIED BANKART REPAIR

TECHNIQUE 47.5

(MONTGOMERY AND JOBE)

- Make an incision along the Langer lines, beginning 2 cm distal and lateral to the coracoid process and going inferiorly to the anterior axillary crease.
- Develop the deltopectoral interval, retracting the deltoid and cephalic vein laterally and the pectoralis major muscle medially. Leave the conjoined tendon intact, and retract it medially.
- Split the subscapularis tendon transversely in line with its fibers at the junction of the upper two thirds and lower one third of the tendon, and carefully dissect it from the underlying anterior capsule. Maintain the subscapularis tendon interval with a modified Gelpi retractor (Anspach, Inc., Lake Park, FL), and place a three-pronged retractor medially on the glenoid neck.
- Make a horizontal anterior capsulotomy in line with the split in the subscapularis tendon from the humeral insertion laterally to the anterior glenoid neck medially (Fig. 47.27A). Place stay sutures in the superior and inferior capsular flaps at the glenoid margin.
- Insert a narrow humeral head retractor, and retract the head laterally. Elevate the capsule on the anterior neck subperiosteally. Leave the labrum intact if it is still attached. Decorticate the anterior neck to bleeding bone with a rongeur.
- Drill holes near the glenoid rim at approximately the 3-, 4-, and 5:30-o'clock positions, keeping the drill bit parallel to the glenoid surface (Fig. 47.27B).
- Place suture anchors in each hole and check for security of the anchors (Fig. 47.27C). During this portion of the procedure, maintain the shoulder in approximately 90 degrees of abduction and 60 degrees of external rotation for throwing athletes. Maintain the shoulder in 60 degrees abduction and 30 to 45 degrees external rotation in nonthrowing athletes and other patients.
- Tie the inferior flap down in mattress fashion, shifting the capsule superiorly but not medially (Fig. 47.27D). The stay sutures help prevent medialization of the capsule. Shift the superior flap interiorly, overlapping and reinforcing the inferior flap (Fig. 47.27E).
- Loosely close the remaining gap in the capsule (Fig. 47.27F). The reconstruction has two layers of reinforced capsule outside the joint.

POSTOPERATIVE CARE Postoperative rehabilitation is carried out as described in Box 47.2.

Humeral avulsion of the glenohumeral ligament should always be evaluated with MRI or, better, an MRA. Anterior lesions are best treated open with a lower-third scapularis split and suture anchors placed in the anatomic footprint on the humerus. These lesions can be bipolar, involving detachment from the humerus and the glenoid, and should be carefully examined to produce a stable repair.

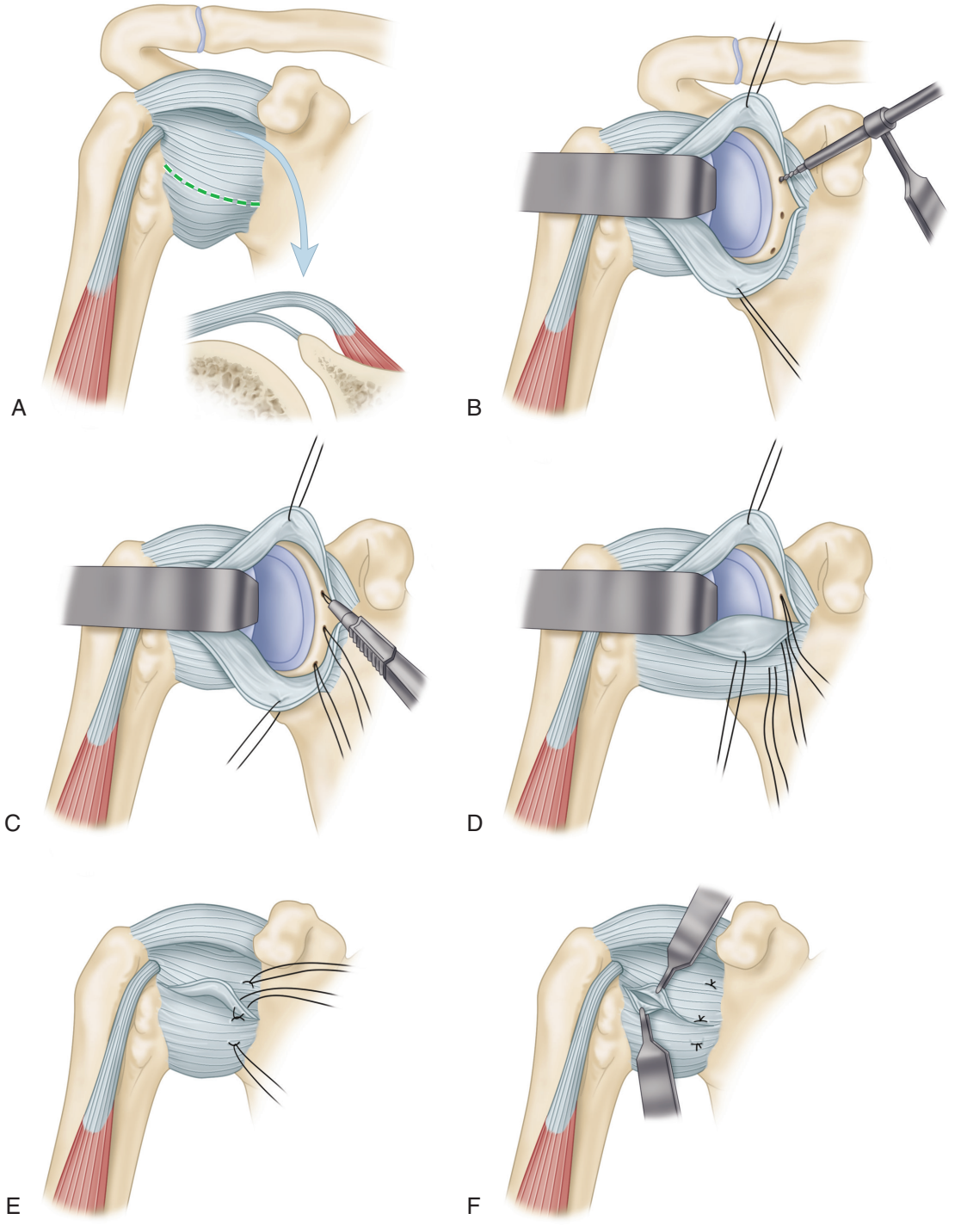

FIGURE 47.27 Montgomery and Jobe technique. **A,** Capsular incision made at center (3-o'clock position) of glenoid. Incision is extended medially over neck of glenoid. Stay suture is placed in capsule to mark glenoid attachment site. **B,** Suture anchor drill holes are started in scapular neck adjacent to glenoid articular surface and directed medially away from joint surface. For exposure of neck, sharp Hohmann retractor is placed along superior and inferior neck for capsular retraction *(not pictured).* **C,** Suture anchors are placed in each prepared drill hole. Sutures are pulled to set anchor. Each individual suture is pulled to ensure suture slides in anchor. **D,** Approximation of capsule to freshened neck. Two or three suture anchors are used to secure inferior capsule firmly to scapular neck. An Allis clamp is used by assistant to advance capsule superiorly against neck while sutures are placed. **E,** Superior and middle suture anchors are used to secure and advance superior flap in inferior direction. **F,** Final imbrication of capsule is done with interrupted nonabsorbable sutures. Extremity is maintained in 45 degrees abduction and 45 degrees external rotation during closure to prevent overconstraint. *Technical note:* Suture anchors should be at edge of glenoid articular surface and aimed medially 20 degrees. **SEE TECHNIQUE 47.5.**

BOX 47.2

Rehabilitation Program After Anterior Capsulolabral Reconstruction

Postoperative Period (0-3 Weeks)
Abduction pillow
Passive/active ROM: abduction (90 degrees), flexion (90 degrees), and external rotation (45 degrees); no extension
Isometric abduction, horizontal adduction, and external rotation
Elbow ROM
Ball squeeze
Ice

Phase I (3-6 Weeks)
Discontinue brace/pillow
Modalities as needed
Progressive passive and active ROM, protecting anterior capsule
Active internal rotation (full) and external rotation (neutral) using tubing and free weights
Prone extension (not posterior to trunk)
Shoulder shrugs and active abduction
Supraspinatus strengthening
Ice

Phase II (6 Weeks to 3 Months)
Continue ROM, gradually increasing external rotation (goal is full ROM by 2 months)
Continue strengthening exercises, with emphasis on rotator cuff and parascapular muscles
Add shoulder flexion and horizontal adduction exercises
Joint mobilization
Begin upper body ergometer for endurance at low resistance
Ice

Phase III (3-6 Months)
Continue capsular stretching and strengthening and ergometer
May include isokinetic strengthening and endurance exercises for internal and external rotation
Add push-ups (begin with wall push-up with body always posterior to elbows)
Start chin-ups at 4-5 months
Total body conditioning
Advance to throwing program or skill-specific training as tolerated
Ice

ROM, Range of motion.
From Montgomery WH, Jobe FW: Functional outcomes in athletes after modified anterior capsulolabral reconstruction, *Am J Sports Med* 22:352–358, 1994.

ANTERIOR STABILIZATION WITH ASSOCIATED GLENOID DEFICIENCY (LATERJET PROCEDURE)

In patients who have an inverted pear-shaped glenoid and an engaging Hill-Sachs lesion, we have found that the Laterjet procedure alone usually is adequate to treat this combined bone deficiency. The bone graft corrects the glenoid deficiency so that it can resist axial forces across an expanded glenoid diameter. The graft also lengthens the glenoid articular arc to prevent the Hill-Sachs lesion from engaging and is used when a large (35% to 45%) humeral head lesion is present (Fig. 47.28).

TECHNIQUE 47.6

(WALCH AND BOILEAU)

- With the patient secured in a beach-chair position and after induction of general endotracheal anesthesia, place a small pillow behind the scapula to position the glenoid surface perpendicular to the operative table. Sterilize and drape free the neck, chest, axilla, and entire arm.
- Make a 4 to 7-cm skin incision beginning under the tip of the coracoid process (Fig. 47.29A). Open the deltopectoral interval and retract the cephalic vein laterally with the deltoid. Place a self-retaining retractor into the deltopectoral interval and a Hohmann retractor on the top of the coracoid process.

HARVESTING AND PREPARATION OF THE BONE BLOCK

- Position the patient's arm in 90 degrees of abduction and external rotation, and section the coracoacromial ligament 1 cm from the coracoid.
- Adduct and internally rotate the arm to release the pectoralis minor insertion from the coracoid, and expose the base of the coracoid with a periosteal elevator to allow observation of the "knee" of the coracoid process. Use an osteotome or small angulated saw to osteotomize the coracoid process from medial to lateral at the junction of the horizontal-vertical parts (Fig. 47.29B).
- Bring the arm back into abduction and external rotation and release the coracohumeral ligament from the lateral part of the coracoid.
- Grasp the bone graft firmly with forceps and carefully release it from its deep attachments. Dissect the lateral part of the conjoined tendon, avoiding the medial aspect and potential damage to the musculocutaneous nerve.
- Evert the bone graft and decorticate its deep surface with a cutting rongeur or saw.
- With a 3.2-mm drill, drill two parallel holes in the deep surface of the bone graft.
- Measure the thickness of the bone graft with a caliper and place the graft under the pectoralis major for subsequent use; hold it in place with the self-retaining retractor, which keeps the deltopectoral interval open.

DIVISION OF THE SUBSCAPULARIS, CAPSULOTOMY, AND EXPOSURE

- With the upper limb in full external rotation, identify the inferior and superior margins of the subscapularis tendon. Use electrocautery and then Mayo scissors to divide the muscle at the superior two thirds or inferior one third junction in line with its fibers, carefully obtaining hemostasis at each step.
- Carefully carry division down to the white capsule, and then extend it medially by inserting a 4 × 4-inch sponge into the cleavage plane, thus exposing the subscapular fossa. Extend the division laterally as far as the lesser tuberosity. Place a Hohmann retractor in the subscapular fossa.

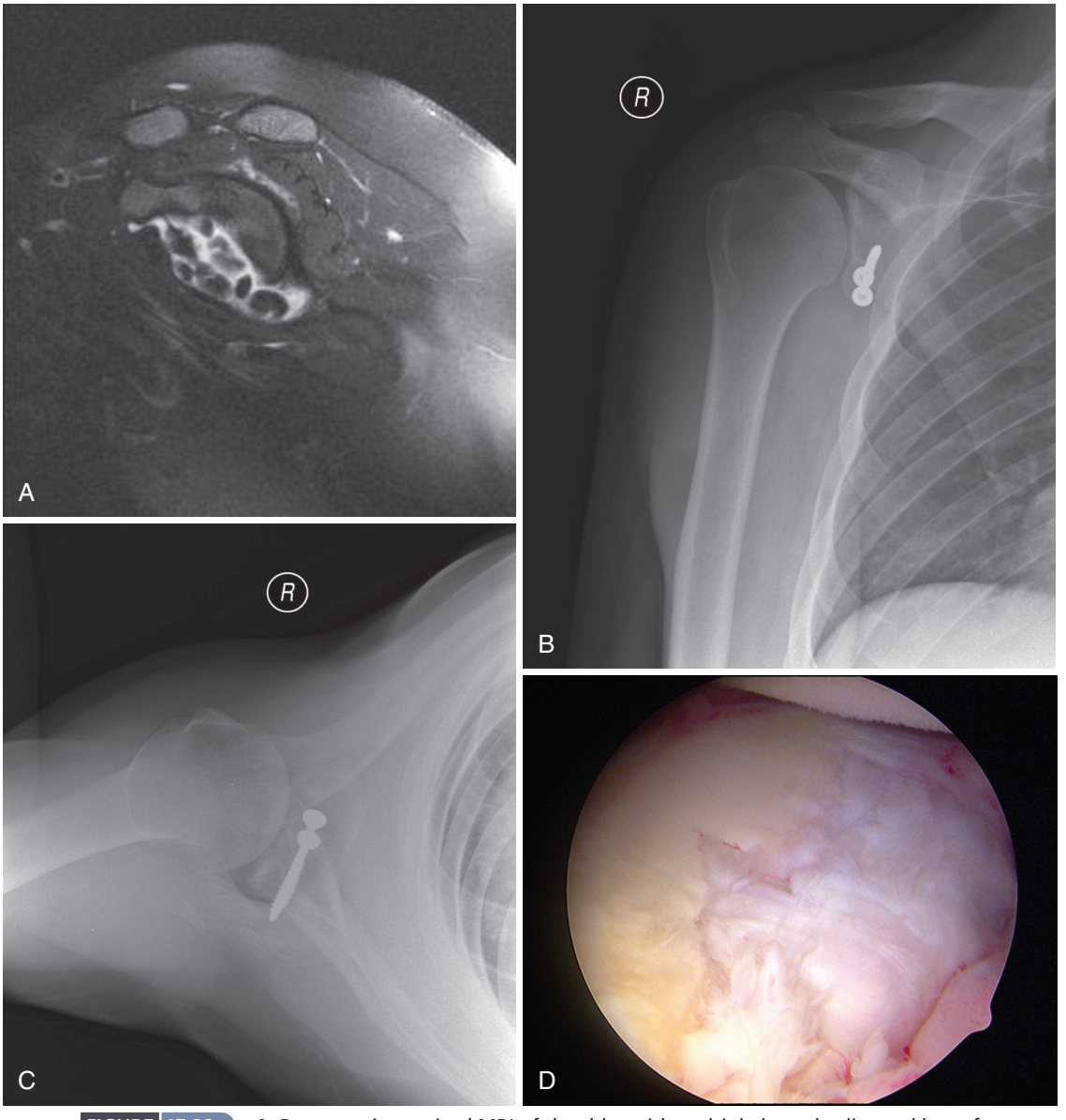

FIGURE 47.28 **A,** Preoperative sagittal MRI of shoulder with multiple loose bodies and loss of 35% of glenoid articular surface. Anteroposterior **(B)** and lateral **(C)** views after Laterjet procedure with parallel screw fixation. **D,** Arthroscopic view showing healed Laterjet procedure.

- Place the upper limb in neutral rotation to provide full exposure of the capsule, and make a 1.5-cm vertical capsulotomy at the level of the anteroinferior margin of the glenoid.
- Move the arm into full internal rotation to allow insertion of a humeral head retractor, which rests on the posterior margin of the glenoid.
- Retract the superior two thirds of the subscapularis superiorly with a Steinmann pin impacted at the superior part of the scapular neck; retract the inferior part inferiorly with a Hohmann retractor pushed under the neck of the scapula between the capsule and the subscapularis.
- With the anteroinferior rim of the scapula exposed, inspect the labrum, cartilage, and insertion site of the glenohumeral ligaments. Resect the medial capsular flap along with damaged portions of the labrum or fracture fragments.
- Use a scalpel to expose the anteroinferior margin of the glenoid and decorticate it with a curet or osteotome (Fig. 47.29C).

FIXATION OF THE BONE BLOCK

- Insert the bone block through the soft tissues and position it flush to the anteroinferior margin of the glenoid. Check the position of the bone block with the arm in internal rotation, taking care to avoid any lateral overhang; a slight medial position (no more than 1 to 2 mm) is acceptable. Never accept a lateral overhang of the coracoid in the joint; it can lead to rapid degenerative joint disease.

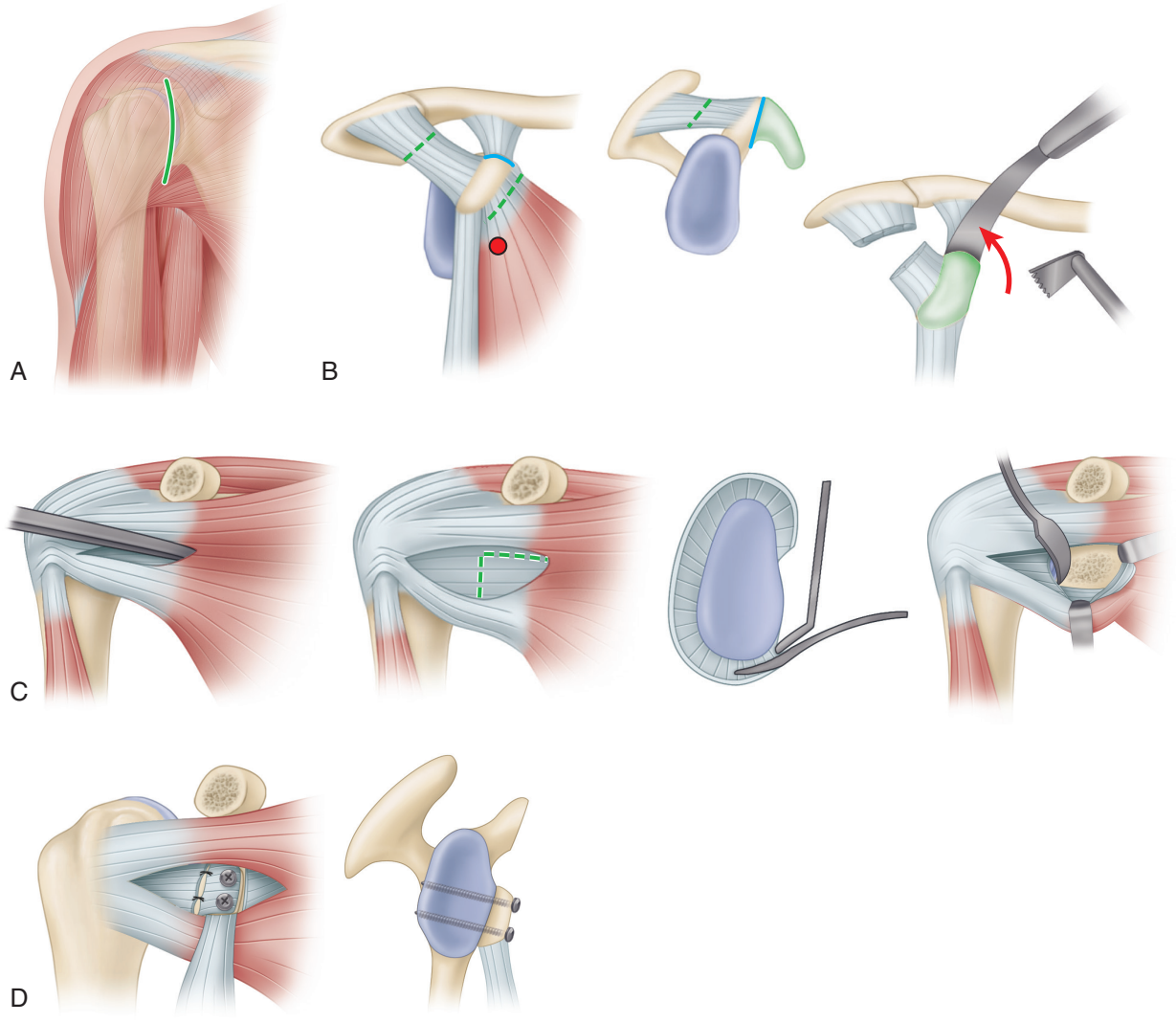

FIGURE 47.29 Laterjet-Bristow procedure (Walch and Boileau). **A,** Vertical incision under tip of coracoid process. **B,** Harvest of bone block corresponding to horizontal part of coracoid process, retaining conjoined coracobrachialis tendon and coracoacromial ligament. **C,** Division of subscapularis horizontally. Anteroinferior glenoid rim is decorticated. **D,** Bicortical fixation of bone block. Outer capsular flap is sutured to remainder of coracoacromial ligament. **SEE TECHNIQUE 47.6.**

- Insert a 3.2-mm drill through the inferior hole in the bone graft and into the glenoid neck in an anteroposterior and superior direction. Check the orientation of the articular surface and direct the drill parallel to this plane. Temporarily reflect the bone block to allow measurement of the drilling depth with a depth gauge.
- Place an AO malleolar screw into the posterior cortex to secure the bone block to the glenoid. Tighten this screw loosely to allow easy rotation and proper positioning of the superior part of the bone block. When positioning is correct, insert a second AO malleolar screw through the superior hole in the bone block and tighten both screws firmly (Fig. 47.29D). To avoid impingement with the humeral head, do not use washers with the screws.

CLOSURE

- With the arm in external rotation, repair the remnant of the coracoacromial ligament to the lateral capsular flap with two interrupted absorbable sutures.
- Remove the sponge placed earlier in the subscapular fossa, and move the arm through all ranges of motion to evaluate mobility.
- Coat the cut surface of the coracoid with bone wax, place a suction drain, and close the superficial soft-tissue layers.

POSTOPERATIVE CARE Patients require immobilization in a sling or shoulder immobilizer for 2 weeks after surgery. Forward flexion is begun thereafter, and external rotation is begun at 6 weeks. Strengthening exercises are started 8 weeks after surgery.

RECONSTRUCTION OF ANTERIOR GLENOID USING ILIAC CREST BONE AUTOGRAFT

The Eden-Hybbinette procedure was originally described using an iliac crest autograft to reconstruct the anterior glenoid. Glenoid bone loss approaching 40% of the anterior glenoid or posterior bone loss of 25% with recurrent posterior dislocation should be reconstructed with an autogenous iliac crest bone graft, or, occasionally for posterior lesions, the medial aspect of the acromion can be used as a graft. Provencher et al. described using allograft from the lateral aspect of a distal tibia for reconstruction. At present, however, an iliac crest autograft is recommended because of its availability, greater healing potential, and less potential for resorption than an allograft.

TECHNIQUE 47.7

(WARNER ET AL.)

- Harvest a tricortical iliac crest autograft 2 cm wide and 3 cm long and contour it to make a smooth continuation of the glenoid arc.
- Drill two holes in the graft and use these to align the graft to form a smooth articular arc.
- Drill holes in the glenoid neck and mark them with electrocautery for ease in finding.
- Place sutures in the capsule and pass them around the screw shaft between the glenoid and graft sutures. Secure the graft extracapsularly.
- Appropriate graft position is vertical before closure of the lateral extent of the capsular incision.
- Decorticate the glenoid neck and secure the graft with two 4.0-mm cannulated bicortical screws.
- Anteriorly, place the graft intracapsularly, securing the capsule around the screwheads.
- Posteriorly, perform a medial-based plication.

POSTOPERATIVE CARE Postoperative care is as described for Technique 47.6.

UNSUCCESSFUL SURGICAL REPAIRS FOR ANTERIOR INSTABILITY

Failure of stabilization may occur because of failure to correct the pathology, failure to heal, or poor patient compliance. All potential causes of failure must be fully evaluated and should include a 3D CT evaluation for bony deficiency of the glenoid and humeral head and, on occasion, an arthrogram to identify the site of capsular failure. If failure of stabilization is determined to be caused by failure to heal, the procedure may be revised arthroscopically with the option of open repair if it is thought to be advantageous. Bony deficiency of the humeral head usually is corrected with an arthroscopic remplissage procedure. Deficiency of the glenoid more than 25% should be approached with an open Latarjet procedure (see Table 47.6). Loss of as little as 13.5% of the glenoid bone may give a sense of instability.

Recent studies have reported complication rates of up to 25% and return to previous level of sport of about 50% in patients with glenoid deformities treated with Latarjet procedures. Stability is increased with Latarjet procedures, but a meta-analysis showed arthroscopic soft-tissue procedures to have the lowest complication rates (1%) compared with arthroscopic Latarjet procedures (13.6%).

Reported complications of recurrent instability or loss of motion, neurovascular problems, infection, and postoperative degenerative changes can be reduced significantly with appropriate planning preoperatively, intraoperatively, and postoperatively. The patient's expectations and any secondary gains must be realized. Secure repair of the pathologic lesion is necessary to restore stability and preserve motion. Excessive loss of motion and injury to the glenohumeral joint from hardware have been indicated as causes of degenerative changes. Excessive loss of motion can be treated with an arthroscopic capsular release (see Chapter 52). If severe restriction of rotation (i.e., <15 degrees of external rotation) is present, an open coronal subscapularis lengthening should be considered.

The basic principles for approaching failed repairs are the same as for the primary procedure: (1) creating an optimal healing environment, (2) re-creating the glenoid concavity, (3) securing anatomic capsular fixation at the articular edge, (4) re-creating physiologic capsular tension, and (5) having supervised, goal-specific therapy. Procedures in which a bone block or a coracoid transfer is done can result in degenerative changes if malposition of the transfer causes impingement on the humeral head. The keys for successful surgical repair include appropriate patient selection, selection of the appropriate procedure to correct the pathologic lesion, a thorough understanding of the local anatomy, identification and protection of important neurovascular structures, use of a postoperative rehabilitation program consistent with the type of surgical correction done, and an understanding of the patient's goals.

MULTIDIRECTIONAL INSTABILITY OF THE SHOULDER

Neer and Foster introduced the term *multidirectional instability* in 1980. It describes glenohumeral subluxation or dislocation in multiple directions. The primary abnormality in multidirectional instability is a loose, redundant inferior pouch. It is important to distinguish multidirectional instability from routine unidirectional dislocation because the former problem is not correctable by standard repairs. Surgery in these patients is not indicated unless disability is frequent and significant, an adequate trial of conservative treatment emphasizing muscular and rotator cuff rehabilitative exercises has failed, and the patient is not a voluntary dislocator.

The principle of the procedure is to detach the capsule from the neck of the humerus and shift it to the opposite side of the calcar (inferior portion of the neck of the humerus), not only to obliterate the inferior pouch and capsular redundancy on the side of the surgical approach but also to reduce laxity on the opposite side. To reduce inferior laxity with the arm in 0 degrees of abduction, closure of the rotator interval is indicated. Internal closure also has been shown to decrease posterior translation. The approach can be anterior or posterior depending on the direction of greatest instability. When the findings include a 3+ sulcus sign and symptoms related to inferior instability, associated with anterior or posterior instability, an anterior capsular shift and closure of the rotator interval

allow better correction of inferior laxity. If the finding is posterior instability with a 1+ to 2+ sulcus sign and only mild inferior symptoms, a posterior capsular procedure is indicated.

CAPSULAR SHIFT

TECHNIQUE 47.8

(NEER AND FOSTER)

- The patient is carefully examined and questioned preoperatively to determine the probable direction of greatest instability. After delivery of a general anesthetic, the instability of the shoulder is evaluated again. Anterior instability is tested with the arm in external rotation and extension at various levels of abduction. Inferior instability is tested with the arm in 0 degrees and 45 degrees of abduction. Posterior instability is tested with the arm in internal rotation at various levels of forward elevation. If this examination and the preoperative evaluation correlate with anteroinferior instability, use an anterior approach.
- Place the patient in a tilted position with the front and the back of the shoulder exposed. Drape the arm free. Attach an arm board to the side of the table.
- Make a 9-cm incision in the skin creases from the anterior border of the axilla to the coracoid process.
- Develop the deltopectoral interval medial to the cephalic vein, and retract the deltoid laterally. Divide the clavipectoral fascia, and retract the muscles attached to the coracoid process medially.
- With the arm in external rotation, divide the superficial half of the thickness of the subscapularis tendon transversely, 1 cm medial to the biceps groove (Fig. 47.30A). Leave the deep half of the subscapularis tendon attached to reinforce the anterior aspect of the capsule, and tag the superficial half of the tendon with stay sutures and retract it medially. It is important that this superficial portion of

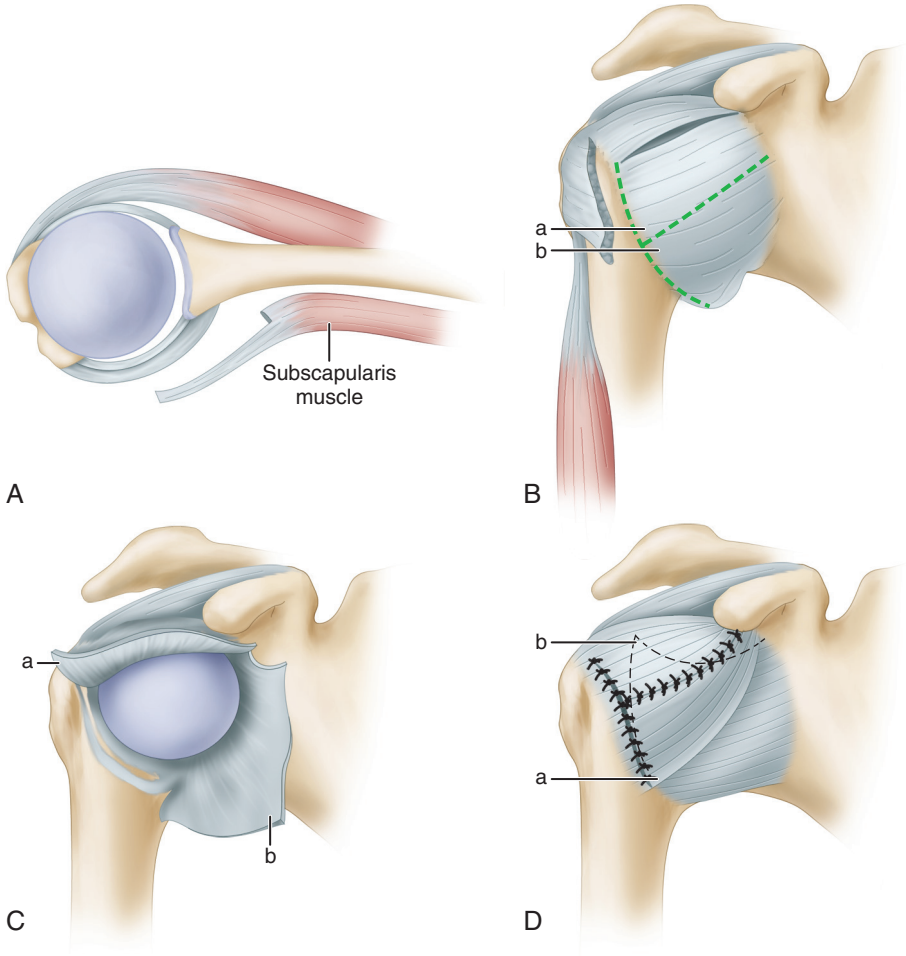

FIGURE 47.30 Neer technique of inferior capsular shift for shoulder instability. **A,** Reinforcement of capsular flaps; about half thickness of subscapularis tendon is left attached to reinforce capsule. **B,** Capsular incision. **C,** Preparation of flaps and slot. Arm is externally rotated as inferior flap is detached. **D,** Relocation of flaps with arm in slight flexion and 10 degrees of external rotation. Inferior flap *(b)* is relocated first and is pulled forward and upward. Superior flap *(a)* is brought down over inferior flap. **SEE TECHNIQUE 47.8.**

the subscapularis tendon be free so that the action of the subscapularis muscle is not tethered.
- Close the cleft between the middle and superior glenohumeral ligaments with nonabsorbable sutures.
- Make a T-shaped opening by incising between the middle and inferior glenohumeral ligaments (Fig. 47.30B).
- With a flat elevator to protect the axillary nerve and with the arm in external rotation, develop a capsular flap by detaching the reinforced part of the capsule containing the inferior glenohumeral ligament from the inferior aspect of the neck of the humerus around to the posterior aspect of the neck of the humerus (Fig. 47.30C).
- Inspect the interior of the joint, and remove any osteochondral bodies or tags of labrum.
- Test for posterior instability with and without forward traction on the inferior capsular flap to estimate the new location for the flap.
- Using curets and a small gouge, make a shallow slot in the bone at the anterior and inferior sulcus of the neck of the humerus (Fig. 47.30C). Suture the capsular flap to the stump of the subscapularis tendon and to the part of the capsule that remains on the humerus so that the capsular flap is held against the slot of raw bone. Suture anchors can be used to secure the capsule and generally are preferred.
- The tension on the capsular flap that is selected must eliminate the inferior pouch and reduce the posterior capsular redundancy (Fig. 47.30D). Suture the inferior flap first, drawing the superior flap down over it, and suture it so as to cause the middle glenohumeral ligament to reinforce the capsule anteriorly and to act as a sling against inferior subluxation.
- Hold the arm in slight flexion and about 10 degrees of external rotation on the arm board while the anterior portion of the capsule is reattached with nonabsorbable sutures. Bigliani et al. recommended repairing the capsule with the arm held in approximately 25 degrees of external rotation and 20 degrees of abduction. For throwers, they recommended relatively more abduction and external rotation to ensure full range of motion.
- Bring the subscapularis tendon over the reattached anterior portion, and reattach the tendon at its normal location.
- After closure of the deltopectoral interval with absorbable sutures and after closure of the skin with a skin stitch, maintain the arm at the side in neutral flexion-extension and in about 20 degrees of internal rotation by light plastic splints.

POSTOPERATIVE CARE Postoperatively, the extremity is placed in a commercially available shoulder immobilizer with the shoulder in 30 to 40 degrees of abduction and slight external rotation. Range-of-motion exercises for the elbow, wrist, and hand are started immediately, with Codman's exercises of the shoulder being added on the third postoperative day. External rotation to 10 degrees, forward elevation to 90 degrees, and isometric exercises are begun after 10 days. For 2 to 4 weeks, isometric strengthening is continued and external rotation is increased to 30 degrees and forward elevation to 140 degrees. At 4 to 6 weeks, resistive exercises are begun and external rotation is increased to 40 degrees and forward elevation to 160 degrees. At 6 weeks, external rotation is increased to 50 degrees and forward elevation to 180 degrees. At 3 months, external rotation can be progressed. In the dominant shoulder of throwers, external rotation should be progressed more quickly; however, progression that is too quick can lead to recurrent instability, especially in patients in late adolescence.

The internal and external rotators curb anterior and posterior displacement, and the supraspinatus and middle part of the deltoid curb inferior displacement. Complete recovery of the muscles probably is necessary to protect the repair because the capsule and ligaments normally function only as a checkrein. Lifting more than 9 kg and participating in sports are prohibited for 9 months and until muscle strength is normal on manual testing compared with the contralateral side. Ligament healing is more mature at 1 year, and patients are advised against swimming with the backstroke or butterfly stroke, heavy overhead use of the involved arm, and participation in contact sports during the first year after surgery.

CAPSULAR SHIFT WITH INCISION ADJACENT TO THE GLENOID

O'Brien, Warren, and Schwartz described a technique for a capsular shift procedure in which the T portion of the incision is made adjacent to the glenoid. This technique allows much easier repair of a detached glenoid labrum if this is present. If the instability is mainly an inferior instability with no glenoid labrum tear, however, and it is necessary to tighten well around to the posterior aspect of the humerus, we have found the technique of Neer to allow more posterior tightening. With the Neer technique, the posterior portion of the T can be extended farther as the humerus is externally rotated.

HILL-SACHS LESIONS

Large, engaging Hill-Sachs lesions involving 20% to 30% of the humeral head may be treated by disimpaction and bone grafting in the acute stage. Transfer of the infraspinatus tendon is useful in the chronic setting. Wolf et al. described an arthroscopic procedure to suture the infraspinatus tendon into the defect and reported good results. Larger defects of 30% to 40% may be treated indirectly with a Latarjet procedure, extending to the glenoid articulation; this prevents engagement of the Hill-Sachs defect. This is our preferred technique. The humeral head defect also can be approached directly and filled to prevent engagement. Small series of allograft reconstructions have shown satisfactory results, although some patients had to have the screws removed at a later date.

POSTERIOR INSTABILITY OF THE SHOULDER

Posterior shoulder dislocations and recurrent posterior instability of the shoulder account for only about 5% to 10% of all dislocations of the shoulder. Traumatic events that result in posterior dislocation often are associated with altered consciousness, such as occurs with seizures, electrical shock, and intoxication. Posterior dislocation also can be caused by a direct blow to the anterior shoulder or by a fall on a forward-flexed extremity.

Recurrent posterior subluxation, atraumatic or acquired as a result of repetitive microtrauma, is much more common

than recurrence after a traumatic posterior dislocation. These instability patterns must be evaluated carefully and categorized as unidirectional, bidirectional, or multidirectional, and the direction of dislocations and symptomatic subluxations must be determined. Repetitive overuse and microtraumatic injuries that result in posterior instability include sports requiring overhead motion, such as pitching, tennis, and swimming (especially backstroke and breaststroke), weight lifting (especially bench press), and blocking by offensive linemen, all of which inflict repetitive trauma on the posterior capsule. Andrews and Phillips described recurrent posterior instability of the dominant shoulder in batters. This most commonly occurs with a check swing or pulling of an outside pitch, which alters the normal synchronous swing mechanics and increases the posteriorly directed shear forces on the shoulder.

Many patients with instability of microtraumatic or atraumatic origin learn to sublux their shoulder voluntarily with horizontal adduction and internal rotation; however, this does not mean there is a psychologic overlay. A patient who has a bland type of affect and who is able to sublux his shoulder with muscular contraction alone is more likely to have some psychologic overlay and secondary gain. With the shoulder in the abducted position, such patients selectively use internal rotators to sublux the shoulder posteriorly. These patients rarely, if ever, should be surgically treated.

In the past, glenoid version has been implicated in posterior instability; however, we believe that glenoid version contributes significantly to posterior instability only in patients with severe congenital dysplasia or traumatic disruption of the bony architecture. Fuchs, Jost, and Gerber stated that glenoid osteotomy is indicated when more than 10 degrees of retroversion is present. Because of high complication rates, osteotomies have fallen out of favor.

CONSERVATIVE TREATMENT

The initial treatment of posterior shoulder instability should be nonoperative. The regimen includes having the patient avoid provocative activities and educating the patient to avoid specific voluntary maneuvers that would cause the posterior subluxation. A strengthening exercise program aimed at the external rotators and posterior deltoid is carried out. Normal motion also should be obtained.

Most patients with posterior instability respond to an aggressive exercise program, especially patients with generalized ligamentous laxity and instability occurring as a result of repetitive microtrauma. In athletes who use overhead motion, observation and instruction by a knowledgeable coach can provide slight alterations in mechanics that may reduce the instability episodes.

Patients who have traumatic dislocations are less likely to be helped by an exercise program. Traumatic dislocations are most common in athletes who have repetitive posteriorly directed forces to the shoulder, such as football linemen, hockey players, and platform divers. If at least 4 to 6 months of an appropriate rehabilitation program has failed, if habitual dislocation has been ruled out, and if the patient is emotionally stable, surgery may be indicated if the pain and instability preclude adequate function of the involved shoulder.

SURGICAL TREATMENT

Through the years, various types of procedures have been proposed to correct posterior instability, including soft-tissue procedures such as the "reverse" Bankart and Putti-Platt procedures, muscle transfers and capsulorrhaphies, bone blocks, and glenoid osteotomies. The results of surgical treatment of posterior shoulder instability have been as varied as the techniques designed to correct it. In general, the best results with any procedure done to correct posterior instability are obtained in patients with recurrent traumatic posterior dislocation, not the more common posterior instability syndromes.

We do not recommend surgery on patients with this atraumatic type of posterior instability, unless they have frequent and significant disability and conservative treatment has failed. The dislocation must not be habitual, and the patient must be emotionally stable.

In any patient who has persistence of instability, a positive jerk test, and a positive shift in load test and any labral pathology (as indicated by the clunk test anterior or posterior), further workup is indicated. This includes T2-weighted axial MRI with contrast enhancement to evaluate for capsular deficiency and loss of chondral labral containment as described by Kim et al. and Antoniou and Harryman (Fig. 47.31). Both authors found chondrolabral cavity lesions in more than 80% of patients with erosion, cracking, or partial detachment posteriorly and inferiorly (i.e., the Kim lesion of the labrum). These deficiencies should be evaluated as noted with MRI, but, more importantly, arthroscopically at the time of stabilization. If an open technique is to be done, arthroscopic examination for these lesions is indicated in most instances and to

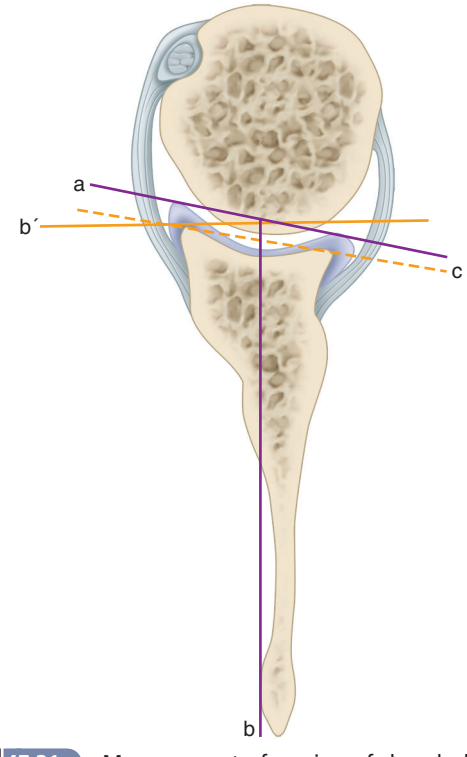

FIGURE 47.31 Measurement of version of chondrolabral and osseous portions of the glenoid. *a,* reference line representing plane of chondrolabral portion of glenoid; *b,* reference line representing plane of scapular body; *c,* reference line representing plane of osseous portion of glenoid. Angle between *a* and *b′* (perpendicular to *b*) represents version of chondrolabral portion of glenoid. Angle between *c* and *b′* represents version of osseous portion of glenoid (Kim et al.).

evaluate the rotator interval anteriorly. With a large rotator interval, a greater than 1 cm gap between the superior and middle glenohumeral ligaments at the edge of the glenoid, closure of the rotator interval should be done, particularly with external rotation of more 90 degrees at 0 degrees of abduction and a positive sulcus sign. If an open procedure is to be done posteriorly, this can be performed after completion of the arthroscopic examination and interval closure anteriorly. Also to be evaluated by MRI is severe glenoid retroversion, which is fairly unusual as previously described or, more commonly, loss of the bony glenoid rim. In the case of a fracture involving the rim, either arthroscopic or open fixation is indicated. For a larger fracture, an open procedure is indicated. For labral detachment producing pain but without true instability, the lesion is repaired in situ without capsular plication.

Treatment of posterior instability is approached the same as anterior instability by restoring the anatomy and tensioning the capsule appropriately. If surgery is required for a disabling posterior subluxation, or if posterior is the most significant plane in a multidirectional instability syndrome, the procedure that we have found most successful is the inferior capsular shift procedure through a posterior approach. We prefer either the capsular shift technique of Tibone or that of Neer and Foster for atraumatic multidirectional instability in a patient who is not an athlete who uses throwing or overhead motions. For an athlete with recurrent posterior subluxation who requires overhead movement, we prefer the muscle-splitting technique with medial shift as described by Tibone et al. The technique described by Hawkins and Janda is best reserved for a laborer or an athlete involved in contact sports, such as football or ice hockey, with recurrent posterior subluxation secondary to capsular deficiency. We have observed good to excellent results with this open procedure, but have had superior results with arthroscopic procedures unless severe bone deficiency must be treated.

NEER INFERIOR CAPSULAR SHIFT PROCEDURE THROUGH A POSTERIOR APPROACH

Neer and Foster described an inferior capsular shift procedure performed through a posterior approach. In this procedure, the posterior capsule is split longitudinally, and the capsular attachment along the humeral neck is released as far inferiorly and anteriorly as possible. The superior capsule is advanced inferiorly, and the inferior capsule is advanced superiorly. The infraspinatus is cut so that it is overlapped and shortened, adding further buttress to the posterior capsule. This procedure obliterates the axillary pouch and redundancy. It and other capsular shift procedures are indicated in posterior subluxation syndromes that are not true traumatic recurrent posterior dislocations.

TECHNIQUE 47.9

(NEER AND FOSTER)

- For the posterior approach, place the patient on the operating table in the lateral decubitus position with the involved shoulder up. The patient is held in position with a beanbag and kidney rest.
- Make a 10-cm incision vertically over the posterior aspect of the acromion and the spine of the scapula (Fig. 47.32A).
- Undermine the subcutaneous tissue to expose the deltoid muscle. Split the deltoid muscle from an area on the spine of the scapula, beginning 2 to 3 cm medial to the posterolateral corner of the acromion and extending distally 5 to 6 cm (Fig. 47.32B). To protect the axillary nerve, the deltoid muscle should not be split distally beyond the teres minor. In a muscular individual, the deltoid muscle can be reflected from the spine of the scapula or the acromion.
- Expose the teres minor and infraspinatus muscles, and develop the interval between these muscles (Fig. 47.32C).
- Detach the infraspinatus obliquely so that the superficial piece of tendon can be used later to reinforce the posterior part of the capsule (Fig. 47.33).
- Make a T-shaped opening in the posterior pouch in the posterior part of the capsule (Fig. 47.34A).
- Form a superior capsular flap by detaching 1.5 cm of capsule above the initial longitudinal capsular incision.
- Use a flat elevator to protect the axillary nerve and, with the arm in progressive internal rotation, form the inferior capsular flap by detaching the capsule from the neck of the humerus around to the anterior portion of the calcar.

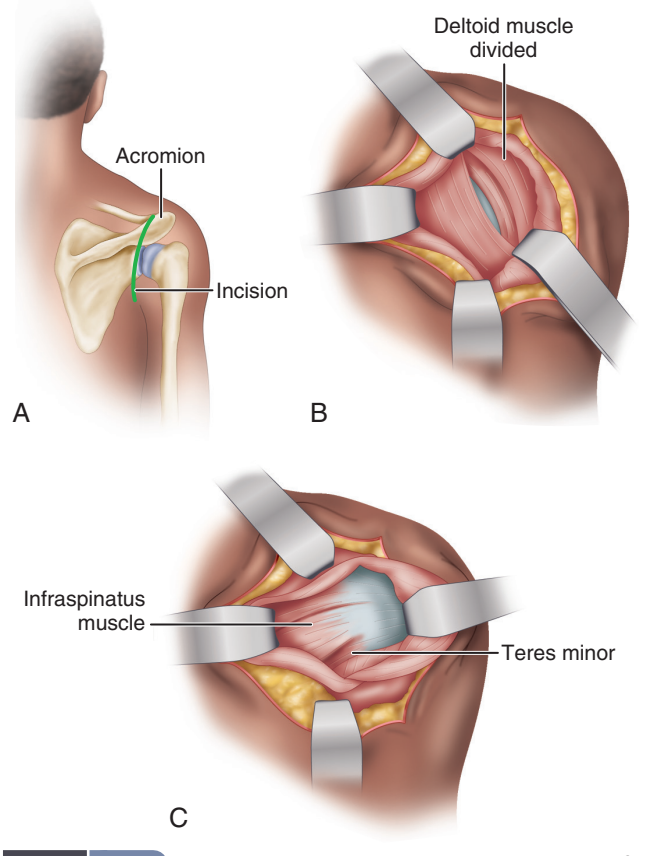

FIGURE 47.32 Neer and Foster posterior capsulorrhaphy for posterior shoulder subluxation. **A,** Saber cut skin incision just posterior to acromioclavicular joint toward posterior axillary fold. **B,** Deltoid muscle is split in line with fibers beginning 2–3 cm medial to posterolateral corner of acromion. **C,** Exposure of underlying infraspinatus and teres minor muscles. **SEE TECHNIQUE 47.9.**

- Elevate the teres minor from the capsule and leave it intact.
- Distract the joint (with the addition of muscle relaxants as necessary) so that the glenoid labrum can be inspected anteriorly. If the anterior portion of the glenoid labrum has been detached, make a second approach anteriorly through which the labrum is sutured to the bone of the glenoid (Bankart repair). If the anterior part of the labrum is intact, draw the posterior part of the capsule backward to eliminate the inferior pouch and to reduce anterior capsular laxity (Fig. 47.34B).
- With curets and a small gouge, make a shallow slot in the sulcus of the humeral neck so that the capsular flap is approximated to raw bone. Hold the arm in slight extension and moderate external rotation as the capsule is reattached (Fig. 47.34B).
- During tensioning of the flaps, Bigliani suggested holding the extremity in 5 to 10 degrees of external rotation, 10 to 15 degrees of abduction, and neutral flexion and extension. Reattach the superior flap first while drawing it downward to eliminate the posterior pouch. Next, draw the longer inferior flap over it, and turn back the excess part of the capsule for reinforcement posteriorly. Use the superficial portion of the infraspinatus to reinforce the posterior portion of the capsule further (Fig. 47.34C).
- Reattach the deep part of the infraspinatus superficially to preserve active external rotation, and carefully reattach the deltoid if it has been detached.
- Close the wound, and immobilize the arm at the side in neutral flexion-extension and 10 degrees of external rotation by means of a light plaster splint extending from the wrist to the middle part of the arm and around the waist, with the elbow bent 90 degrees. Rigid external immobilization is needed to ensure that 10 degrees of external rotation is maintained.

POSTOPERATIVE CARE The shoulder is immobilized with the arm at the side in slight abduction and neutral rotation for 6 weeks after surgery. A plastic brace maintains this position, supports the weight of the arm, and prevents inferior stress on the repair. Range-of-motion exercises with elevation in the scapular plane and external rotation and isometric exercises are begun 6 weeks after the surgery when the brace is removed. These exercises are progressed over the next 3 months to a full strengthening program. Elevation of more than 150 degrees and internal rotation exercises that might stress the repair are avoided for 3 months. Sports activities such as swimming and throwing are not allowed for 9 months to 1 year after surgery.

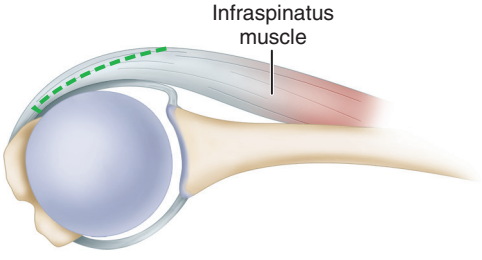

FIGURE 47.33 Neer and Foster inferior capsular shift through posterior approach. Detachment of infraspinatus tendon. **SEE TECHNIQUE 47.9.**

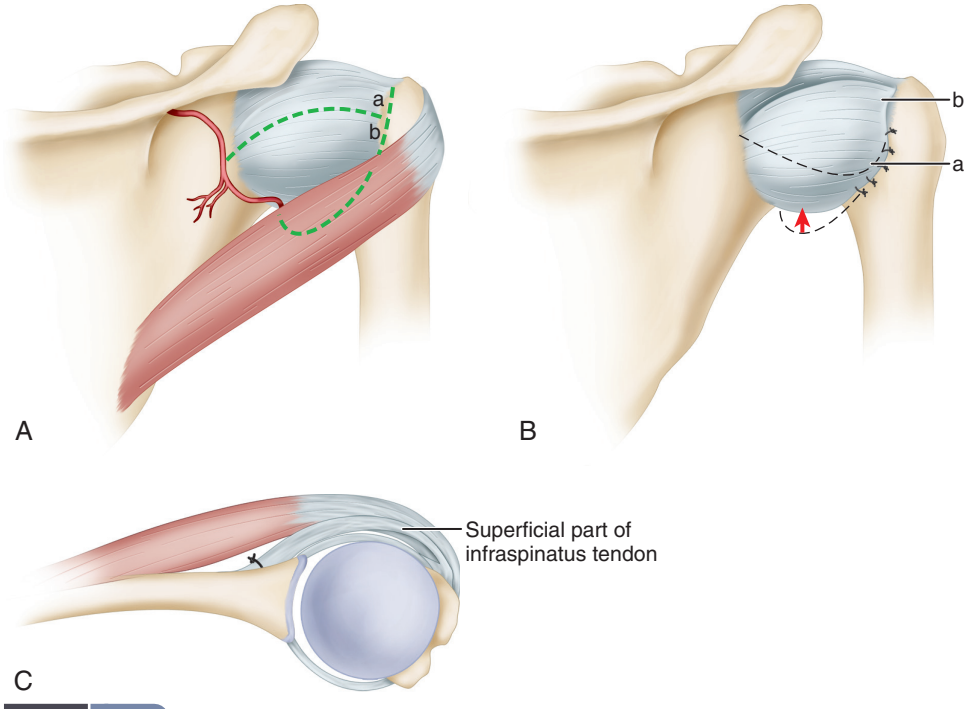

FIGURE 47.34 Neer and Foster inferior capsular shift through posterior approach. **A,** T-shaped incision to form superior flap *(a)* and inferior flap *(b)*. **B,** Relocation of flaps. **C,** Reinforcement of capsular flaps. Superficial part of infraspinatus tendon is brought down and sutured against raw bone on scapular neck; deep portion is sutured over this. **SEE TECHNIQUE 47.9.**

TIBONE AND BRADLEY TECHNIQUE

Tibone and Bradley recommended a variation on the posterior capsular shift procedure in which the interval between the infraspinatus and teres minor muscles is split to expose the posterior capsule. The capsule is shifted on the glenoid side to reduce the volume of the posterior capsule in a manner similar to that described by Neer and Foster and Bigliani et al. Shaffer et al. described an infraspinatus muscle–splitting incision in which the bipennate muscle is split between its two innervations, resulting in no long-term trauma to the muscle. They stated that this may allow better exposure of the middle portion of the posterior capsule and make the capsular shift easier. Whether the split of the bipennate infraspinatus or the split between the infraspinatus and the teres minor is used, damage to the posterior rotator cuff is reduced. The advantage of this approach is that imbrication of the posterior capsule produces a thicker posterior soft-tissue restraint. This is our preferred technique in athletes with a moderate amount of posterior instability.

TECHNIQUE 47.10

(TIBONE AND BRADLEY)

- Place the patient in the lateral decubitus position, and approach the shoulder as described in the technique for the Neer posterior capsular shift procedure.
- When the capsule has been sufficiently separated from the overlying muscles, make a transverse arthrotomy incision into the posterior capsule from a lateral to medial direction up to the labrum (Fig. 47.35A and B) and inspect the joint.
- Develop two capsular flaps by making a T-shaped incision into the capsule parallel to the glenoid cavity and just adjacent to the labrum. Tag these flaps with sutures to control them (Fig. 47.35C). The inferior capsular flap must be developed carefully because of the close proximity of the axillary nerve on the undersurface of the capsule. Usually the labrum is found intact.
- If the labrum is torn, reflect it so that holes can be made in the posterior glenoid cavity and sutures can be passed

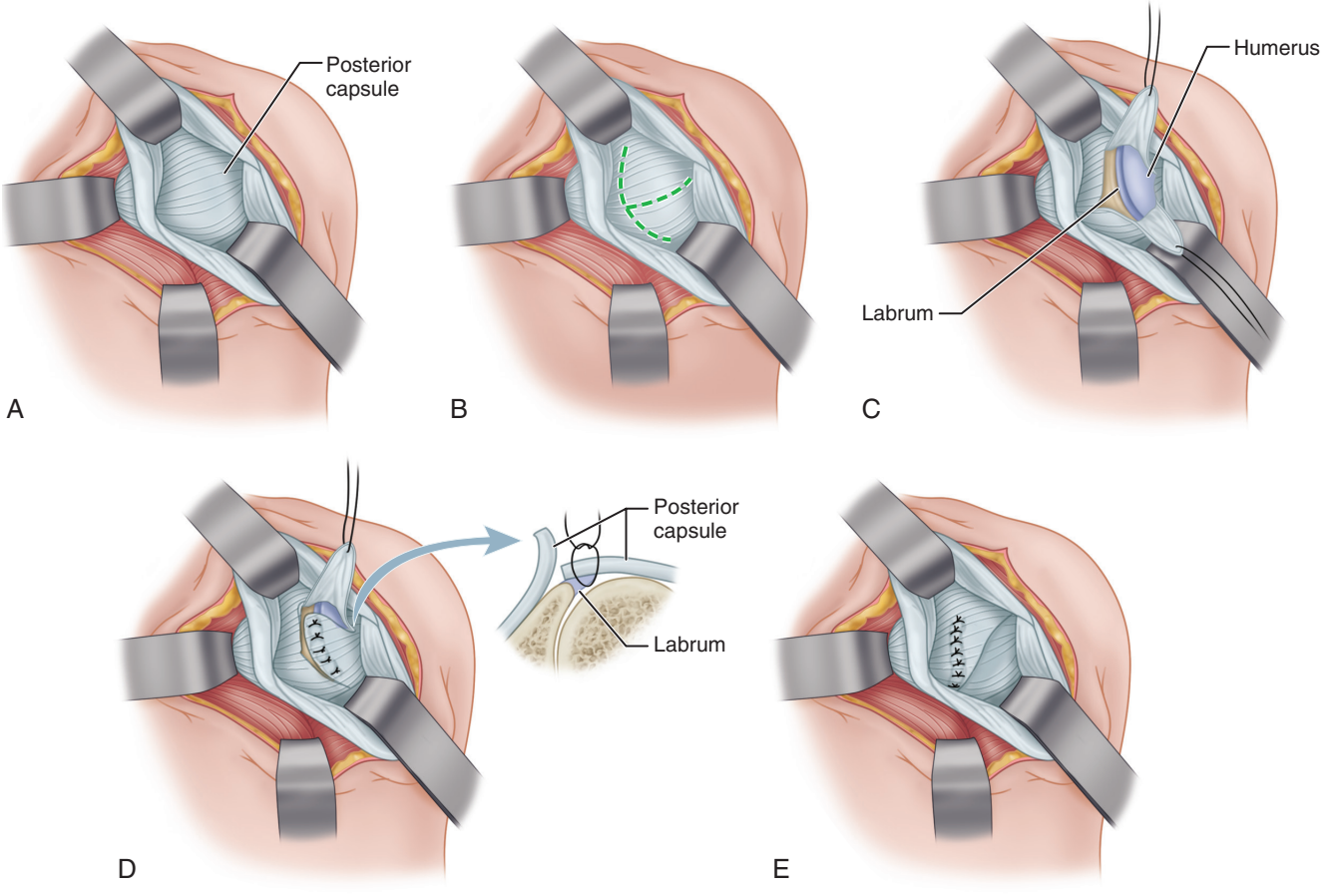

FIGURE 47.35 Tibone and Bradley posterior capsulorrhaphy for posterior shoulder subluxation. **A,** Development of interval between teres minor and infraspinatus muscle to expose capsule. **B,** Capsular incision from lateral to medial, up to glenoid labrum. **C,** Vertical capsular incision parallel to glenoid labrum. **D,** Medial and superior advancement of inferior capsular flap and attachment to labrum. *Inset,* Suture of flap to labrum. **E,** Suture of superior capsular flap over inferior flap. **SEE TECHNIQUE 47.10.**

directly through the bone as in a typical anterior Bankart repair. (Suture anchors can be used to secure the capsule to the neck adjacent to the glenoid articular cartilage.)
- When the labrum is intact, the sutures can be placed directly into the labrum.
- Advance the inferior capsular flap superiorly and medially, and attach it to the glenoid labrum with nonabsorbable sutures (Fig. 47.35D). This usually eliminates the posterior and any inferior instability.
- Suture the superior capsular flap over the inferior flap by advancing it inferiorly and medially.
- Close any remaining transverse gap in the capsule laterally with interrupted mattress sutures (Fig. 47.35E). The teres minor and infraspinatus muscles come together and usually do not need sutures.
- Close the wound in layers.

POSTOPERATIVE CARE The shoulder is placed in an abduction pillow in slight extension and neutral rotation to take stress off the repair. The pillow is removed at 3 weeks. Active and active-assisted range-of-motion exercises are started. At this time, emphasis is placed on elevating the arm in the scapular plane of the body and regaining internal and external rotation of the shoulder. At 6 weeks, forward flexion is allowed. At 12 weeks, weightlifting is started and progressed to increase strength and endurance. At 6 months, light throwing and noncontact sports can be resumed. At 1 year, a throwing athlete can return to competition.

CAPSULAR SHIFT RECONSTRUCTION WITH POSTERIOR GLENOID OSTEOTOMY

Posterior glenoplasty rarely is indicated, although it can be used if severe developmental or traumatic glenoid retroversion of more than 20 degrees is confirmed on CT reconstructed films. High recurrence rates of up to 53% have been reported with this procedure. Hawkins et al. reported a complication rate of 29%, including osteonecrosis of the glenoid and degenerative arthritis of the glenohumeral joint, after this procedure. Currently, a similar but simpler procedure using a glenoid osteotomy is preferred for severe glenoid dysplasia, whether traumatic or congenital. The same exposure can be used for bone graft reconstruction of a deficient posterior glenoid.

TECHNIQUE 47.11

(ROCKWOOD)
- Place the patient in the lateral decubitus position with the involved shoulder upward.
- Make a skin incision beginning 2.5 cm medial to the posterolateral corner of the acromion and extending downward 10 cm to the posterior axillary crease (Fig. 47.36A).
- Dissect and retract the subcutaneous tissues to expose the deltoid fibers.
- At a point 2.5 cm medial to the posterior corner of the acromion, split the deltoid distally 10 cm in line with its fibers (Fig. 47.36B). Retract the deltoid medially and laterally to expose the underlying infraspinatus and teres minor muscles.
- Reflect the teres minor tendon inferiorly down to the level of the inferior joint capsule, and divide the infraspinatus tendon. Reflect it medially and laterally, avoiding injury to the suprascapular nerve (Fig. 47.36C).
- Make a vertical incision in the posterior capsule to explore the joint. Make the incision midway between the humeral and glenoid attachments so that a double-breasted closure can be done (Fig. 47.36D). The teres minor muscle must be reflected sufficiently inferior so that the vertical cut in the capsule goes all the way down to the most inferior recess of the capsule.
- Pass a straight blunt instrument into the glenohumeral joint so that it lies on the anterior and posterior glenoid rims (Fig. 47.36E). Place an osteotome intracapsularly and direct it parallel to the blunt instrument. This is done to lessen the chance of the osteotomy cut entering the joint.
- The osteotomy site is not more than 0.6 cm medial to the articular surface of the glenoid. If the osteotomy site is more medial than this, injury to the suprascapular nerve is possible as it passes around the base of the spine of the scapula to supply the infraspinatus muscle. Each time the osteotome is advanced, pry open the osteotomy site; this helps create a lateral plastic deformation of the posterior glenoid.
- The osteotomy incision should not exit anteriorly, but should stop just at the anterior cortex of the scapula (Fig. 47.36F). The intact anterior cortex, periosteum, and soft tissue act as a hinge, which allows the graft to be secure in the osteotomy without the need for internal fixation.
- Take bone graft approximately 8 mm × 30 mm from the acromion. Use osteotomes to open up the osteotomy site, and place the bone graft into position (Fig. 47.36G).
- Place nonabsorbable sutures in the edge of the medial capsule.
- Hold the arm in neutral rotation, and suture the medial capsule laterally and superiorly under the lateral capsule (Fig. 47.36H). Suture the lateral capsule medially and superiorly over the medial capsule (Fig. 47.36I). Repair the infraspinatus tendon with the arm in neutral rotation. If the tendon is lax, double-breast it (Fig. 47.36J).
- Close the incision in layers.

POSTOPERATIVE CARE For the first 24 hours, the arm is maintained in neutral position and supported by skin traction. When the patient can comfortably stand, a modified shoulder immobilizer cast is applied by attaching a lightweight long arm cast to a belly band that sits around the abdomen and iliac crest. The arm is connected to this belly band through supports to maintain the arm in 10 to 15 degrees of abduction and neutral rotation. The cast is left in place for 6 to 8 weeks. After removal of the cast, the patient is allowed to use the arm for 4 to 6 weeks for activities of daily living. A rehabilitation program is begun, including pendulum exercises, isometric exercises, and stretching of the shoulder with the use of an overhead pulley. Afterward, resistive exercises are gradually increased.

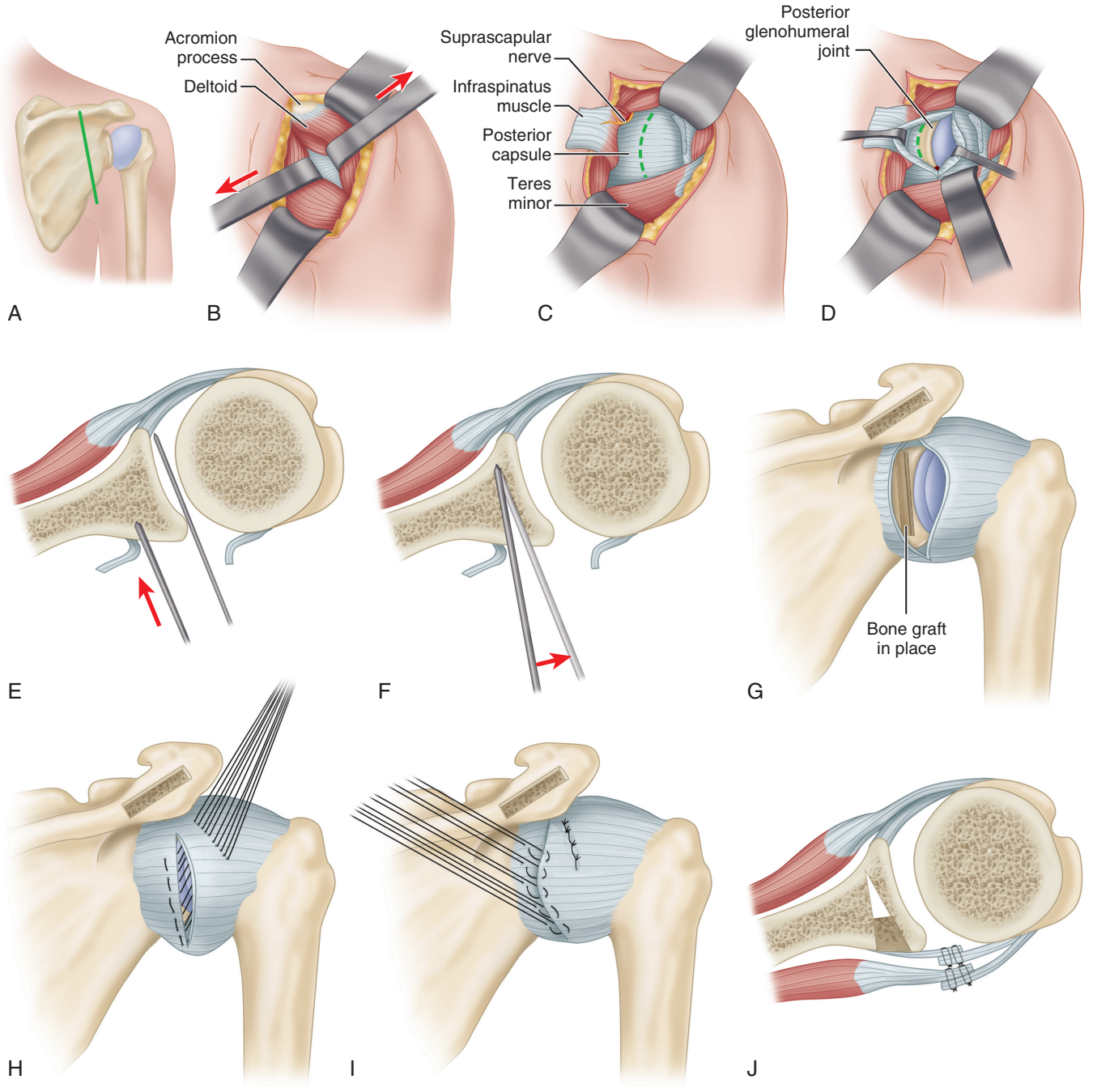

FIGURE 47.36 Rockwood technique of posterior shoulder reconstruction. **A,** Incision. **B,** Splitting of deltoid in line with its fibers. **C** and **D,** Capsular incision midway between humeral and glenoid attachments. **E,** Determination of angle of slope of glenoid. **F,** Glenoid osteotomy. **G,** Bone graft in place. **H,** Suture of medial capsule. **I,** Suture of lateral capsule. **J,** Suture of tendon to reduce laxity. **SEE TECHNIQUE 47.11.**

MCLAUGHLIN PROCEDURE

For recurrent posterior dislocation associated with a large anterior medial Hill-Sachs lesion, McLaughlin described transfer of the subscapularis tendon into the defect. Neer and Foster subsequently described transfer of the subscapularis with the lesser tuberosity into the defect and securing it with a bone screw. In a rare reverse Hill-Sachs lesion with involvement of 20% to 25% of the articular surface, transfer of the subscapularis with the tuberosity placed into the defect has been shown to produce satisfactory results in moderate-size defects; also, allografts in case reports involving larger lesions have provided satisfactory results.

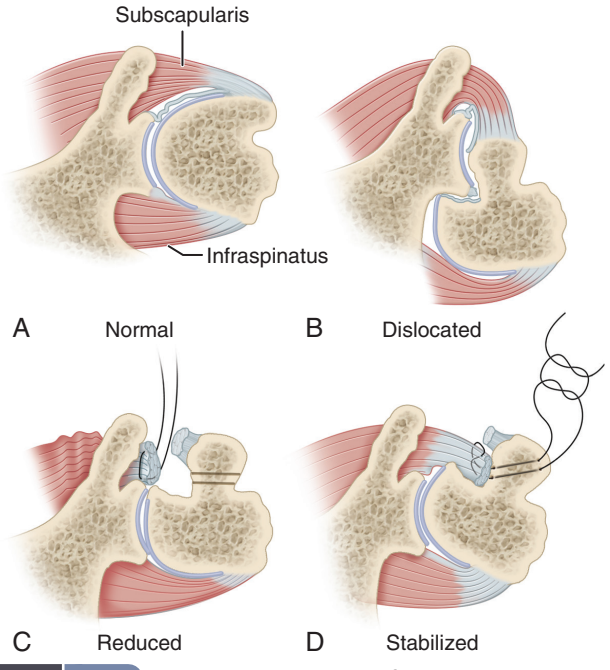

FIGURE 47.37 McLaughlin technique for posterior dislocation of shoulder. **A,** Cross section of left shoulder viewed from above. **B,** Deformity in posterior dislocation with engagement of posterior glenoid rim in defect of anterior aspect of humeral head. **C,** Dislocation has been reduced, but instability remains; redislocation occurs with internal rotation, flexion, or adduction. Subscapularis has been divided. **D,** Stabilization by medial transposition of subscapularis insertion into defect. **SEE TECHNIQUE 47.12.**

TECHNIQUE 47.12

(MCLAUGHLIN)

- Approach the shoulder anteriorly through the deltopectoral interval.
- Retract the conjoined tendon medially, exposing the subscapularis tendon. Divide the subscapularis tendon transversely as close to its insertion as possible.
- Alternatively, as described by Neer and Foster, osteotomize the lesser tuberosity with the insertion of the tendon. The added fragment of the lesser tuberosity helps fill the defect in the anteromedial humeral neck.
- Debride the surfaces of the defect in the anteromedial humeral neck.
- Reattach the subscapularis tendon to the humerus in the depths of the defect by mattress sutures passed through holes drilled in the bone (Fig. 47.37). Alternatively, as described by Neer and Foster, fix the lesser tuberosity together with the subscapularis tendon in the defect with a bone screw (Fig. 47.38).

POSTOPERATIVE CARE A shoulder immobilizer is applied. Pendulum exercises are started after the wound has healed, and gradual resumption of normal use is encouraged. The patient is protected from any forced external rotation forces for at least 3 months.

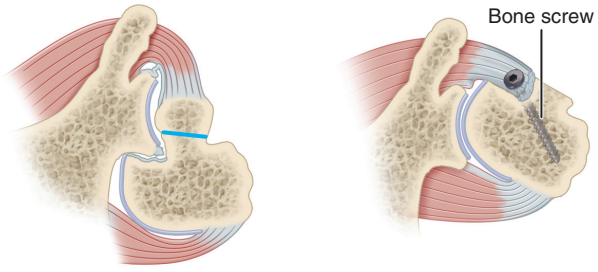

FIGURE 47.38 Neer and Foster modification of McLaughlin technique. Lesser tuberosity, with attached subscapularis tendon, is transferred into defect and fixed with bone screw. **SEE TECHNIQUE 47.12.**

BOX 47.3

Causes of Failure in Surgical Repair of Posterior Shoulder Instability

- Inadequate soft-tissue healing
- Ligamentous laxity
- Deficient capsule
- Deficient subscapularis
- Deficient glenoid
- Engaging Hill-Sachs lesion
- Overconstrained joint
- Nerve dysfunction

SURGICAL FAILURES

Causes of surgical failures are listed in Box 47.3. A thorough physical examination and 3D CT imaging are indicated to evaluate bony defects (see Fig. 47.17). Significant glenoid bone loss has been identified as a major factor in surgical failures, as have hyperlaxity and Hill-Sachs lesions. A Latarjet procedure, structural bone grafts, or remplissage procedures can be used as previously described for revision surgeries. Capsular deficiencies can be treated with a Latarjet procedure or soft-tissue allograft supplementation of the capsule with Achilles or posterior tibial tendon allografts. Subscapular deficiency is reconstructed with a pectoralis transfer. Finally, a careful search should be made to determine that a humeral avulsion of the glenohumeral ligament (HAGL lesion) is not present. Excessive loss of motion after arthroscopic procedures generally can be corrected by precision arthroscopic releases. Open procedures may be necessary when a previous open procedure was used.

ARTHROSCOPIC SURGERY

Arthroscopic repair of shoulder instability is an area of increasing interest and continued improvement. As experience increases with these techniques, the operative results have improved to be comparable to, and in some cases surpass, results obtained with more standard open techniques. Arthroscopic shoulder surgery is discussed in Chapter 52.

ELBOW

Acute dislocation of the elbow occurs relatively frequently, accounting for 28% of all injuries to the elbow. Elbow dislocation usually is a high-energy episode with severe soft-tissue injury, and residual loss of motion is common. Recurrent dislocation of the elbow is relatively rare, however, and usually is posterior. Persistence of posterolateral or medial instability is more common and, when symptomatic, should be surgically corrected in appropriate patients.

ANATOMY

The lateral ulnar collateral ligament of the elbow arises from the epicondyle and inserts on the annular ligament (Fig. 47.39). A separate band of the lateral ligamentous complex, the lateral ulnar collateral ligament, arises at the lateral epicondyle and blends with fibers of the annular ligament before inserting on the tubercle on the crest of the supinator of the ulna. This band has been described as the main lateral stabilizer, taut in flexion and extension, with disruption of this portion of the lateral complex resulting in posterolateral rotatory instability. The lateral collateral ligament contributes only 14% of the varus stability of the elbow with the joint in full extension and only 9% with the joint in 90 degrees of flexion. The remainder of the stability is contributed by the bony articular surfaces and the anterior capsule, with the bony surfaces supplying most of the stability.

The ulnar collateral ligament of the elbow is a well-developed ligament that can be described as three distinct portions (Fig. 47.40). In contrast to the lateral collateral ligament, the ulnar collateral ligament plays an important role in valgus stability. Valgus stability is divided equally among the ulnar collateral ligament, the anterior capsule, and the bony articulation with the elbow in full extension. At 90 degrees of flexion, the ulnar collateral ligament provides 55% of the stability to valgus stress, with the anterior bundle being the primary stabilizer.

PATHOPHYSIOLOGY

Elbow instability may be congenital, traumatic, or attritional. The primary stabilizers of the elbow are the anterior band of the medial ulnar collateral ligament and the lateral collateral ligament complex, consisting of the lateral collateral ligament, annular ligament, and the lateral ulnar collateral ligament. Secondary stabilizers consist of the capsule, the ulnohumeral and radiocapitellar articulations, and the dynamic stabilizers, consisting of all muscle-tendon units that cross the elbow joint (i.e., biceps, brachialis, triceps, wrist flexors, and wrist extensors). Insufficiency of one or more of the stabilizers may result in a spectrum of instability from subtle valgus or posterolateral rotatory instability to recurrent dislocation.

In a long-term follow-up study of simple elbow dislocations, Anakwe et al. found that 60% of patients had residual stiffness with loss of extension and residual pain. Only 8% had functional instability. When fractures are associated with the dislocation, resulting in loss of bony stability being provided by the greater sigmoid notch of the ulna or the radiocapitellar joint, greater instability and disability can be anticipated.

O'Driscoll et al. described the typical injury pattern for traumatic elbow dislocation, with the individual falling on a slightly flexed extremity and a valgus internal rotation force of the humerus on the pronated fixed position of the forearm. Structures are disrupted on the lateral side, progressing medially as more force is applied (Fig. 47.41). When recurrence or persistence in instability results, the posterolateral structures are most commonly affected, but the medial structures also can be involved and cause significant instability. A coronoid fracture in association with disruption of the posterior band of the ulnar collateral ligament can result in symptomatic posteromedial instability. Thus close evaluation of both primary stabilizers is warranted. Isolated medial side disruptions from valgus stress can result from football tackling, gymnastics, or throwing a javelin.

Valgus instability from attritional disruption of the anterior bundle of the medial ulnar collateral ligament is by far the most common form of recurrent elbow instability. The anterior bundle is divided into two nonisometric bands: an anterior band, which is taut at 0 to 60 degrees, and a posterior

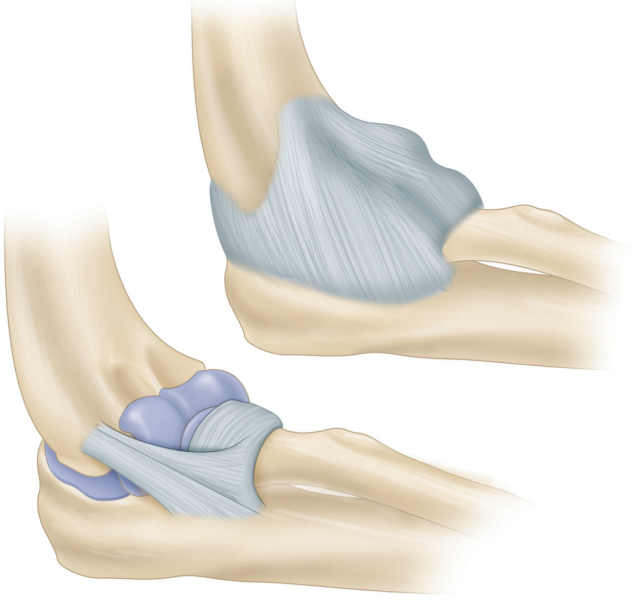

FIGURE 47.39 Lateral soft-tissue structures of elbow, including ulnar and radial part of lateral collateral ligament, annular ligament, and overlying capsule.

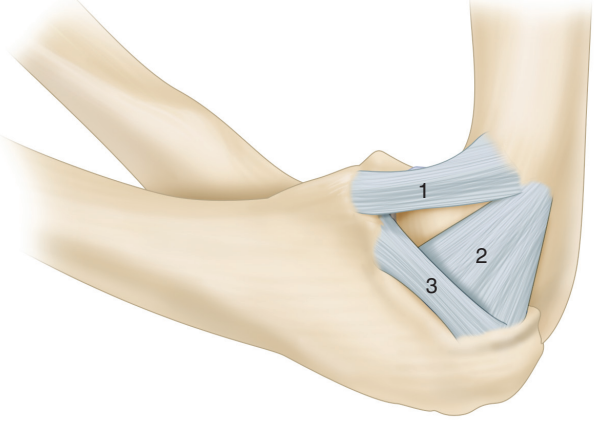

FIGURE 47.40 Medial elbow ligaments. *1,* Anterior oblique; *2,* posterior oblique; *3,* transverse oblique.

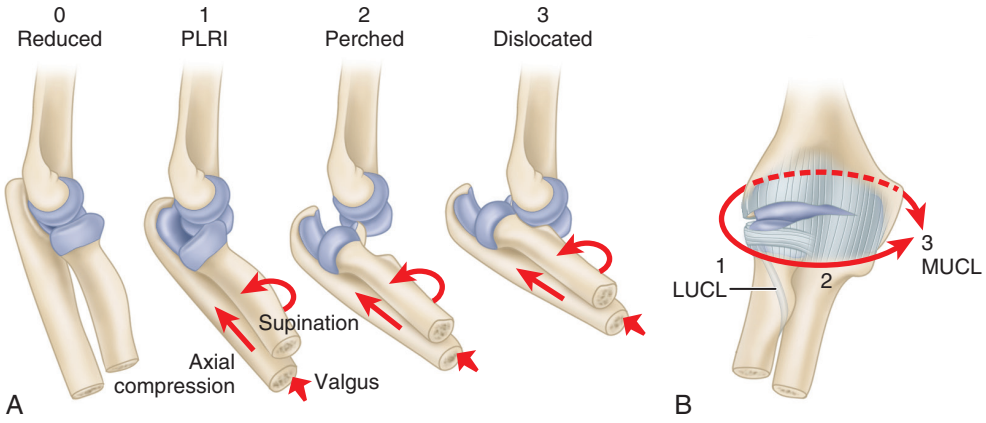

FIGURE 47.41 Injury pattern for traumatic elbow dislocation described by O'Driscoll et al. **A,** Three stages of elbow instability from subluxation to dislocation: stage 1, disruption of the ulnar part of the lateral collateral ligament; stage 2, disruption of the other lateral ligamentous structures and posterior capsule; stage 3A, partial disruption of the medial ulnar collateral ligament and posterior medial ulnar collateral ligament only; and stage 3B, complete disruption of the medial ulnar collateral ligament and posterior medial ulnar collateral ligament. **B,** Soft-tissue injury progresses in a circle from lateral to medial correlating with those shown in **A**. *LUCL*, lateral ulnar collateral ligament; *MUCL*, medial ulnar collateral ligament; *PLRI*, posterolateral rotatory instability

band, which is taut at 60 to 120 degrees. During the acceleration phase of throwing, up to 60 N of force is applied to the ligament, which is near its tensile failure point. Pitcher fatigue, poor mechanics, or repetition overuse can result in bundle fiber failure, partial tearing, and eventual complete disruption.

Failure of the primary stabilizer results in increased stress on secondary stabilizers, with resulting capsular contractures, chondromalacia, osteophytes, and loose bodies from compression of the radiocapitellar joint and shear forces to the posteromedial tip of the olecranon. Ulnar nerve symptoms may develop from traction, scarring, or osteophyte impingement.

PHYSICAL EXAMINATION

Examination of the elbow begins with a visual inspection for atrophy, swelling, or ecchymosis. The forearm circumference is measured 7 cm below the medial epicondyle to compare with the opposite extremity. Fluid can be detected in the soft spot posterolaterally. The flexor pronator mass, the ulnar collateral ligament, and the tip of the olecranon posteromedially are carefully palpated for the area of most tenderness. Tenderness and swelling 2 to 3 cm distal to the olecranon tip may indicate an olecranon stress fracture. Active and passive range of motion is recorded, and a valgus stress is applied to the elbow with the forearm in the supinated and the pronated positions and the elbow in about 30 degrees of flexion. The amount of medial opening, the firmness of the end point, and the production of medial pain should be noted when valgus is applied with the forearm pronated (Fig. 47.42).

The valgus extension overload test is done by maintaining a valgus stress on the elbow while the elbow is passively extended from 30 degrees down. Pain along the posteromedial aspect of the olecranon can be produced when subacute or chronic instability has resulted in posteromedial olecranon impingement. O'Driscoll described the active valgus extension overload test, which he thought was the most accurate test for ulnar collateral ligament competence. With the patient's shoulder abducted and externally rotated, a valgus stress is applied on the elbow as it is passively extended from 120 degrees down to 30 degrees and then flexed back in a rapid sequence.

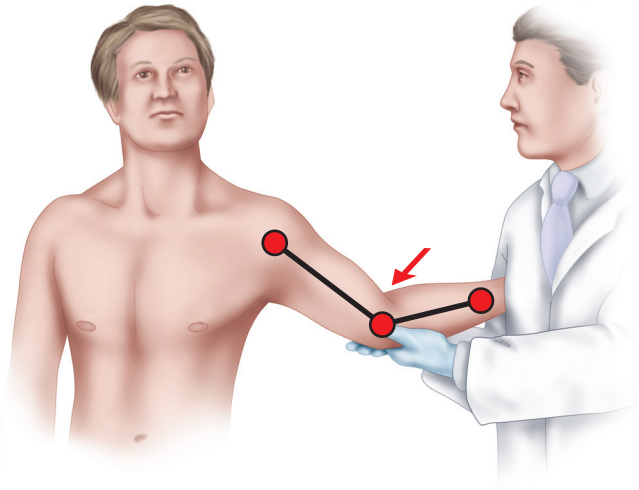

FIGURE 47.42 Test for elbow instability.

Generation of medial pain may indicate ligamentous incompetence. The milking maneuver is likewise performed by putting valgus stress on the elbow by pulling on the patient's thumb while stabilizing the arm and ranging the elbow between 30 and 120 degrees. Although valgus stress and compression are applied to the radiocapitellar joint, the forearm is pronated and supinated with the elbow in varying degrees of flexion to evaluate radiocapitellar crepitance or the production of pain, indicative of radiocapitellar chondromalacia.

The patient is placed prone, and the ulnar nerve is evaluated by the Tinel test. With the shoulder abducted to 90 degrees and the elbow flexed 90 degrees, the ulnar nerve is evaluated to see if it subluxes anteriorly from its groove with passive elbow motion or with manual stress on the nerve. Valgus stress again can be applied to the elbow when flexed greater than 30 degrees to detect medial instability.

Posterolateral instability can be evaluated by supinating the forearm and applying a valgus moment and axial force with the elbow flexed 20 to 30 degrees. A clunking sensation

may indicate posterolateral laxity. The same test can be done with the extremity over the patient's head and the shoulder fully externally rotated. With the forearm fully supinated and valgus stress applied, the elbow is moved from a fully extended position to a flexed position. As the elbow is flexed near 40 degrees, a posterolateral prominence is produced by subluxation of the radial head; as the joint is flexed further, a dimple in the soft spot area appears and eventually disappears as the radius and ulna snap back into place on the humerus (Fig. 47.43). A variation of this examination, which reproduces functional posterolateral instability, is the table or seat press-up test, which is performed by having the patient push up with the forearm supinated while the examiner feels and observes for radial head instability. Wall or floor push-ups with the forearm in supination accomplish the same objective.

Diagnostic radiographs should include anteroposterior and lateral views and two 45-degree oblique views to evaluate the radiocapitellar joint and the trochlear joint. In patients with chronic medial symptoms, a Jones view of the elbow is indicated to determine if posteromedial osteophytes are present. In the presence of recent elbow subluxation or dislocation, the drop sign, widening of the ulnohumeral joint, may represent significant capsular disruption and persistent subluxation. A gravity stress radiograph can be obtained with the patient supine, the shoulder abducted 90 degrees and externally rotated, the forearm supinated, and the elbow flexed 20 to 30 degrees. A lateral radiograph is obtained to show the opening of the medial side of the elbow to gravity stress. This is not a highly sensitive test, although a positive test does indicate a significant injury to the ulnar collateral ligament. Gadolinium-enhanced MR arthrograms or CT arthrograms are indicated to evaluate for complete or incomplete undersurface tears of the ulnar collateral ligament. Timmerman and Andrews described the *T sign* as a leak of contrast material around the humerus or ulna without extracapsular leakage. Currently the best test of ulnar collateral ligament instability is a gadolinium-enhanced MRI of the elbow to evaluate for extravasation of fluid (T sign) or degenerative changes in the ulnar collateral ligament. Edema of the soft tissues medial to the ulnar collateral ligament generally indicates ligamentous damage. Some centers use ultrasound to evaluate the ulnar collateral ligament in the relaxed and stressed positions. Nonetheless, MRI allows for better visualization.

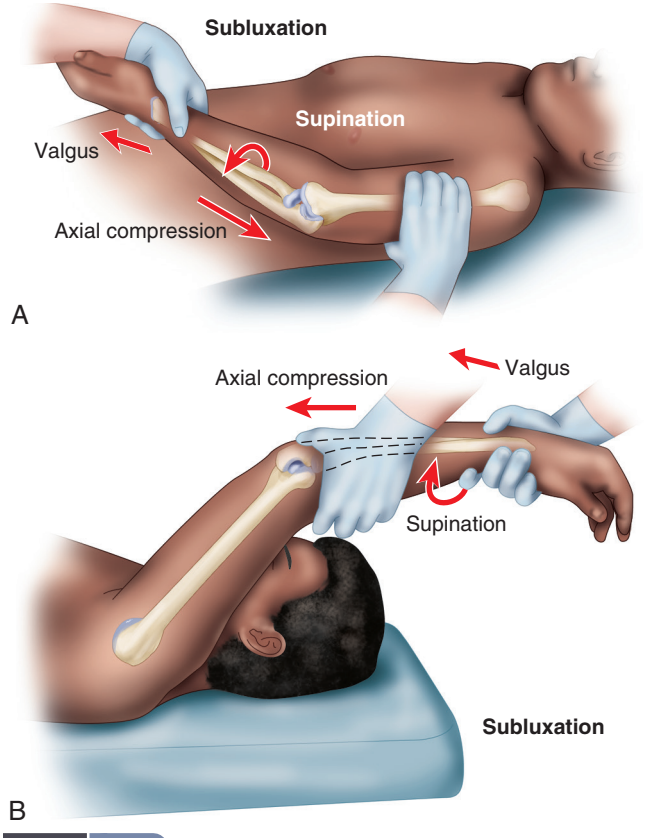

FIGURE 47.43 Test for posterolateral rotatory instability of elbow. **A,** With arm at side and forearm in supination, supination and valgus moments and axial forces are applied to elbow, which is flexed 20–30 degrees. Posterolateral subluxation is visibly and palpably reduced when elbow is flexed farther. **B,** Same procedure is done much more easily with patient's arm over his or her head. Full external rotation of shoulder provides counterforce for supination of forearm and leaves one of examiner's hands free to control valgus moments.

NONOPERATIVE TREATMENT

Acute complete simple dislocations are categorized as stable or unstable after reduction. For stable elbows, early range of motion is indicated. For unstable elbows, an elbow splint is used to control range of motion, blocking extension at 45 degrees for 1 week, 30 degrees for the next week, and allowing full motion thereafter. If a contracture of more than 30 degrees is still present after 6 weeks, an extension splint can be used to improve motion. For incomplete injuries that involve disruption of the medial side of the elbow, the forearm is placed in supination. Lateral injuries are treated by placing the forearm in pronation with the elbow flexed 70 degrees for 1 to 2 weeks, followed by use of an elbow brace. Repair and primary reconstruction with strong tendon grafts of the lateral or medial side, or both, depending on the instability pattern, are indicated when instability persists or recurs.

ARTHROSCOPY

Arthroscopy of the elbow can be used to confirm the presence of medial instability or loose bodies and to remove posteromedial osteophytes. Medial instability may be associated with chondromalacia of the radiocapitellar joint, synovitis of the medial capsule, or the formation of posteromedial olecranon osteophytes. Andrews et al. described a valgus stress test done arthroscopically with the patient under general anesthesia. Using the anterolateral portal to view the medial compartment, valgus stress is applied to the elbow, which is flexed to 70 to 90 degrees, and the opening between the ulna and trochlea is measured. An opening of more than 1 to 2 mm indicates medial instability. With high-resolution MRA, most surgeons forgo arthroscopy unless specifically indicated. A more complete description of elbow arthroscopy is given in Chapter 52.

SURGICAL TREATMENT

Surgery generally is not indicated for simple elbow dislocations unless the dislocation recurs despite immobilization. In these instances, examination and MRI evaluation are used to delineate the soft tissues and bony anatomy to identify all damaged structures. Surgical intervention is directed toward the side of greatest instability, generally the lateral side, or in the case of global instability, both the lateral and medial sides may need to be treated. Repair of the capsule, primary ligamentous

reconstruction, and reattachment of the tendon origins usually is necessary to obtain a stable joint. Significant fractures that result in joint instability must always be repaired.

The number of ulnar collateral ligament reconstructions has increased yearly for the past 2 decades. The procedure, first done in 1974 by Dr. Frank Jobe, has become a relatively common operation. Twenty-five percent of Major League Baseball pitchers and 15% of minor league pitchers have had ulnar collateral ligament reconstruction. The incidence of ulnar collateral ligament reconstruction in 15- to 19-year old players is 22 per 100,000 in the PearlDiver insurance database. With more primary procedures being done, more revisions also are performed. Athletes with primary reconstruction return to the same level of play 83% of the time, while those with revisions return 42% to 63% of time. After 21 months of rehabilitation, those with primary reconstructions generally return to play at about 13 months but continue to improve for an additional year; revisions tend to be associated with a decline in performance.

Ulnar collateral ligament tears have been associated with increased pitching velocity, innings, and pitches; a small repertoire of pitches; smaller stature; lack of rest within and between seasons; poor mechanics; and glenohumeral joint internal rotation deficit (GIRD). Revision failures are associated with increased workload. Results for the modified Jobe and docking techniques are similar. Ulnar nerve transfer results in neuropraxia in 12% of patients and some decrease in Conway (return-to-play) scores. Graft types have had comparable results for return-to-play, although symptomatic proximal graft heterotopic ossification occurs in about 0.6% of patients, and when the gracilis tendon is used, it occurs in 10% of patients. Ossification may require excision for persistent pain or loss of motion.

Suggested indications for ulnar collateral ligament reconstruction are an acute complete or high-grade partial rupture in a competitive throwing athlete who wishes to remain active and a partial tear with chronic pain or instability without improvement after at least 4 to 6 weeks of supervised conservative treatment. Conservative treatment consists of relative rest with forearm and shoulder strengthening exercises. Core strengthening and lower extremity and cardiovascular exercises are maintained. Medications and antiinflammatory agents are routinely prescribed. A short toss program is started at 4 to 6 weeks and progressed as the athlete tolerates. Recurrence of medial pain with throwing that prevents skillful progression of the athlete's monitored throwing program is indicative of ligamentous incompetence.

Jobe originally described the technique for reconstruction of the ulnar collateral ligament in 1986. Since that time, a number of modifications of the technique have been devised. In the original technique, the flexor mass was released from the epicondyle and open-ended tunnels were placed in the ulna and the medial humeral condyle (Fig. 47.44). A palmaris longus graft was used to reconstruct the ligament, and the ulnar nerve was transferred anteriorly under the flexor muscle mass. Jobe later modified the technique to involve splitting the common flexor mass to expose the ulnar collateral ligament tear, using a closed-ended tunnel in the medial epicondyle, and transferring the ulnar nerve only if heavy scar tissue is found around the nerve or if chronic changes are present in the ulnar nerve. Andrews et al. described dissection of the muscle belly of the flexor carpi ulnaris, retracting the muscle anteriorly to expose the ulnar collateral ligament. They did not detach the muscle from the epicondyle and used the

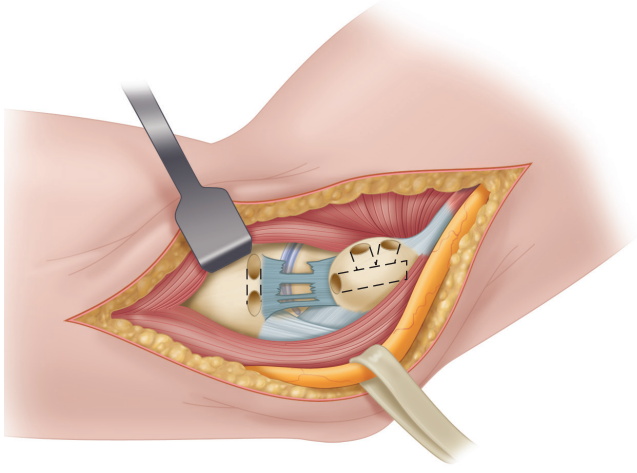

FIGURE 47.44 Jobe ulnar collateral ligament reconstruction. Medial aspect of right elbow before reconstruction showing remnant of ulnar collateral ligament and proper placement of bone tunnels in ulna and medial humeral condyle. Holes are drilled in ulna 5 mm from joint. Ulnar tunnel and closed-end tunnel in medial epicondyle are centered over bony attachments of ligament. Altchek et al. use same tunnel configuration, except anterior humeral tunnels are made with small drill bit for suture passage. **SEE TECHNIQUE 47.13.**

open-ended tunnels. The graft is sutured securely to the posterior epicondyle, and the soft-tissue graft is secured onto itself and the imbricated collateral ligament. The ulnar nerve is transferred anteriorly, where it is held by fascial slings. Cain et al. evaluated 743 athletes who had ulnar collateral ligament reconstruction with a minimum of 2 years' follow-up. Eighty-three percent returned to the same level or a higher level of competition at less than 1 year from surgical stabilization. In a statistical analysis of 147 Major League Baseball pitchers, Makhni et al. found that 67% were able to return to same competitive level as before their surgery. Overall, the group had a decline in performance comparable to age-matched controls. Reconstruction in immature athletes who progress to professional status has shown similar or slightly better results when compared with athletes who did not need surgery as an amateur.

Absence of the palmaris longus tendon occurs in 15% to 20% of individuals. When the palmaris longus tendon is present on one side only, it often has muscle extending distally, which usually is a short deficient tendon. One must be aware and prepared for the potential need of a hamstring graft, with the patient being informed of the possibility. Attritional tears with a bony ossicle in the ulnar collateral ligament also may be best treated with the larger hamstring graft.

A medial collateral ligament reconstruction done through a muscle-splitting approach and use of a single closed-end humeral tunnel was reported to allow 39 of 40 athletes to return to their previous level of competition. The benefits of this "docking procedure" include (1) reconstruction through a split in the muscle in a safe zone, (2) avoidance of obligatory nerve transfer, (3) placement of tendon grafts in bone tunnels, (4) reduction in number of humeral tunnels, and (5) simplification of graft tensioning (see Technique 47.15.) There has been interest in graft fixation with interference screws. Pullout studies have shown the use of a docking technique to be

superior to use of screws. With the potential for bone resorption around absorbable screws, at present we do not advocate the use of the interference screw.

Repair of ligamentous avulsions in otherwise healthy ligaments has been reported by Savoie et al. and O'Brien et al. to have 93% good-to-excellent results and return-to-play at 6 months. Repair and backing up with an internal brace was shown by Dugas et al. to have good results for earlier to return to play. Biomechanical studies have shown the augmented repair to be as strong as traditional graft reconstruction at time-zero, with more resistance to gapping. Dugas et al. recommended the use of collagen-coated fiber tape to augment avulsions and partial tears in athletes without degenerative ligamentous changes. In early reports, 102 of 111 patients were able to return to play at the same or higher level by 6.7 months. In a small group of professional pitchers, the Kerlan-Jobe Orthopaedic Clinic (KJOC) overhead athlete scores averaged 88. There currently are no long-term results reported because the initial procedure using this technique was done in 2013.

ULNAR COLLATERAL LIGAMENT RECONSTRUCTION—MODIFIED JOBE TECHNIQUE

Important technical points to remember when performing this procedure are (1) calcification should be removed from the ligament (Fig. 47.45); (2) drill holes must correspond to ulnar collateral ligament attachment sites; (3) the graft should not rub on the epicondyle or ulna, and the ends of the graft should be buried in the tunnels; (4) a figure-of-eight configuration of the graft ensures strength and approximates ulnar collateral ligament biomechanics; and (5) meticulous handling of medial antebrachial cutaneous and ulnar nerves, their branches, and their vasculature is essential.

FIGURE 47.45 Anteroposterior radiograph showing calcification of deficient ulnar collateral ligament.

TECHNIQUE 47.13

- Apply a pneumatic tourniquet. Place the arm on an arm board with the elbow extended, and put a rolled towel beneath it. If appropriate, prepare the contralateral arm and ipsilateral leg for graft harvest.
- Make a 10-cm incision over the medial epicondyle.
- Protect the medial antebrachial cutaneous nerve, and incise the common flexor pronator mass at the posterior third to expose the ulnar collateral ligament.
- Split the muscle, but do not take it down, and incise the ulnar collateral ligament to evaluate the quality of the ligament and joint.
- Lightly retract the ulnar nerve until it is off the bone to allow for drilling of the holes. Do not transfer the nerve.
- Using a 3.2-mm bit at slow speed with a tissue protector, drill anterior and posterior holes in the proximal ulna. Leaving a 1-cm bone bridge, drill the tunnel at the level of the coronoid tubercle (see Fig. 47.44). In the medial epicondyle, drill a common anterior hole at the origin of the ulnar collateral ligament for 1 cm, using a 4-mm drill, and then, with a 3.2-mm drill bit, make divergent tunnels (lazy "Y") exiting anterior to the intermuscular septum 0.5 cm apart (see Fig. 47.44).
- Obtain a graft 15 cm long from the palmaris longus tendon, plantaris tendon, or Achilles tendon. Place a 1-0 nonabsorbable suture through each end of the graft, and thread it through the tunnels in a figure-of-eight fashion.
- Remove the rolled towel from beneath the elbow, and tension and suture the graft with the elbow in neutral (varus-valgus) and 45 degrees of flexion. Evaluate the range of motion. Suture the graft to the remnants of the ulnar collateral ligament.
- If ulnar nerve symptoms and heavy scar tissue are found, transposition of the ulnar nerve may be necessary. Elevate the flexor pronator musculature, leaving a ring of soft tissue on the medial epicondyle. Decompress the nerve proximally to the arcade of Struthers and distally to the end of the intermuscular septum, avoiding devascularization. Transfer the nerve anterior to the epicondyle, and reattach the flexor pronator mass to the epicondyle superficial to the transferred nerve.
- Release the tourniquet, and obtain hemostasis. Bathe the nerve with dexamethasone (Decadron) solution, and perform routine subcutaneous and skin closure. Apply a padded posterior splint with the elbow in 90 degrees of flexion and neutral rotation, leaving the wrist and hand free.

POSTOPERATIVE CARE The elbow is immobilized in the posterior splint for 7 to 10 days. Gentle hand grip exercises are begun as soon as the patient is comfortable. Active range-of-motion exercises for the elbow and shoulder are started at 10 days, and exercises to strengthen the muscles of the wrist and forearm are begun at 4 to 6 weeks. After 6 weeks, elbow strengthening exercises are

begun, but valgus stress on the elbow is avoided until 4 months postoperatively.

Athletes can begin a progressive, supervised throwing program. They continue with a progressive strengthening program for the forearm and shoulder and a general conditioning program. They are allowed to return to competitive pitching in approximately 1 year.

ULNAR COLLATERAL LIGAMENT RECONSTRUCTION—ANDREWS ET AL. TECHNIQUE

The goal of the procedure described by Andrews et al. is to reconstruct the anterior bundle of the ulnar collateral ligament. They recommend transposition of the ulnar nerve in all ulnar collateral ligament reconstructions because (1) the nerve must be mobilized to expose the ulnar collateral ligament through the interval used; (2) during drilling of the humeral tunnels the drill is aimed directly at the ulnar nerve if it is left in situ; and (3) athletes often have ulnar nerve symptoms and ulnar collateral ligament pathology. Preoperatively, the presence or absence of the palmaris longus tendon should be documented. Alternative sources of tendon graft include the contralateral palmaris longus tendon and gracilis tendon.

TECHNIQUE 47.14

PALMARIS LONGUS GRAFT HARVEST

- After induction of general anesthesia, apply a nonsterile tourniquet to the upper arm. Prepare and drape the arm and then exsanguinate it with an Esmarch bandage. Inflate the tourniquet to 250 mm Hg.
- Harvest the palmaris longus tendon first. Because of the close proximity of the other flexor tendons and the median nerve, great care must be taken when harvesting this tendon.
- Make three transverse incisions, each 7-10 mm long, directly over the palmaris tendon.
- Make the first incision at the wrist flexion crease, directly over the palmaris tendon. Use a no. 15 blade to incise the skin and blunt dissection to isolate the tendon, which is immediately subcutaneous.
- Place a small hemostat around the tendon and pull to place tension on the tendon. This shows the course of the tendon along the length of the forearm.
- Make a second incision 3 to 5 cm proximal and parallel to the first, directly over the tendon. After the skin is sharply incised, deliver the tendon out of the second incision with a blunt hemostat.
- Make the final incision parallel to the others at the site of the musculotendinous junction, near the junction of the proximal and middle thirds of the forearm. Deliver the tendon out of the wound with a hemostat and confirm that the correct structure has been identified in all three locations.
- Cut the tendon at the most distal incision and use a no. 0 absorbable suture to whip stitch the exposed end.
- Deliver the tendon out of the proximal incision and cut it free at the musculotendinous junction (Fig. 47.46A).
- On a back table, remove any remaining muscle from the proximal end of the tendon, and whip stitch the end of the tendon with a no. 0 absorbable suture. Protect the tendon with a moist sponge.
- Close the three incisions with subcutaneous no. 2-0 absorbable and subcuticular 3-0 nonabsorbable sutures.

ULNAR NERVE EXPOSURE AND PROTECTION

- Make an incision over the medial elbow directly over the medial epicondyle, extending approximately 3 cm proximal and 6 cm distal to the medial epicondyle.
- Use blunt dissection to identify and protect the medial antebrachial cutaneous nerve. This nerve is variable in size and location and often has multiple branches at this location. It most commonly is located in the distal third of the incision (Fig. 47.46B).
- Once this nerve is protected, elevate full-thickness flaps to expose the medial epicondyle, the flexor/pronator mass, and the cubital tunnel.
- Open the cubital tunnel with a no. 15 blade or tenotomy scissors and identify the ulnar nerve. Release the ulnar nerve and mobilize it from as far proximal into the posterior compartment as can be safely reached (Fig. 47.46C).
- Sharply split the fascia of the flexor carpi ulnaris and then bluntly spread the muscle fibers overlying the ulnar nerve.
- Identify and protect the first motor branch to the flexor carpi ulnaris.
- Place a vessel loop around the ulnar nerve for gentle retraction during the procedure.
- Divide the medial intermuscular septum of the upper arm at the most proximal aspect of the incision. Take down the remaining distal septum from the medial humerus, leaving it attached distally to the superior edge of the medial epicondyle. This strip of tissue will be used as a sling at the end of the procedure to hold the ulnar nerve in its anteriorly transposed position.
- Coagulate blood vessels at the posterosuperior edge of the medial epicondyle to prepare for drilling of the humeral tunnels.
- If posteromedial olecranon osteophytes are present, make a small incision in the joint capsule to expose the posteromedial olecranon tip. With the ulnar nerve protected, remove osteophytes with a rongeur, osteotome, or 4-mm burr. Close the capsule with interrupted no. 0 absorbable sutures.

JOINT EXPOSURE

- Expose the injured ulnar collateral ligament. The native ulnar collateral ligament inserts on the sublime tubercle of the ulnar, which lies deep and anterior to the ulnar nerve. Once it is mobilized, the posterior fibers can be easily seen.
- Elevate the flexor digitorum profundus muscle, which overlies the anterior fibers of the ulnar collateral ligament, off the ligament with a no. 15 or no. 69 blade and a small periosteal elevator (Fig. 47.46D). Begin this dissection distally and carry it proximally up the humeral origin on the medial epicondyle. Depending on the location, severity, and chronicity of the injury, a defect in the ligament may be visible at this point.

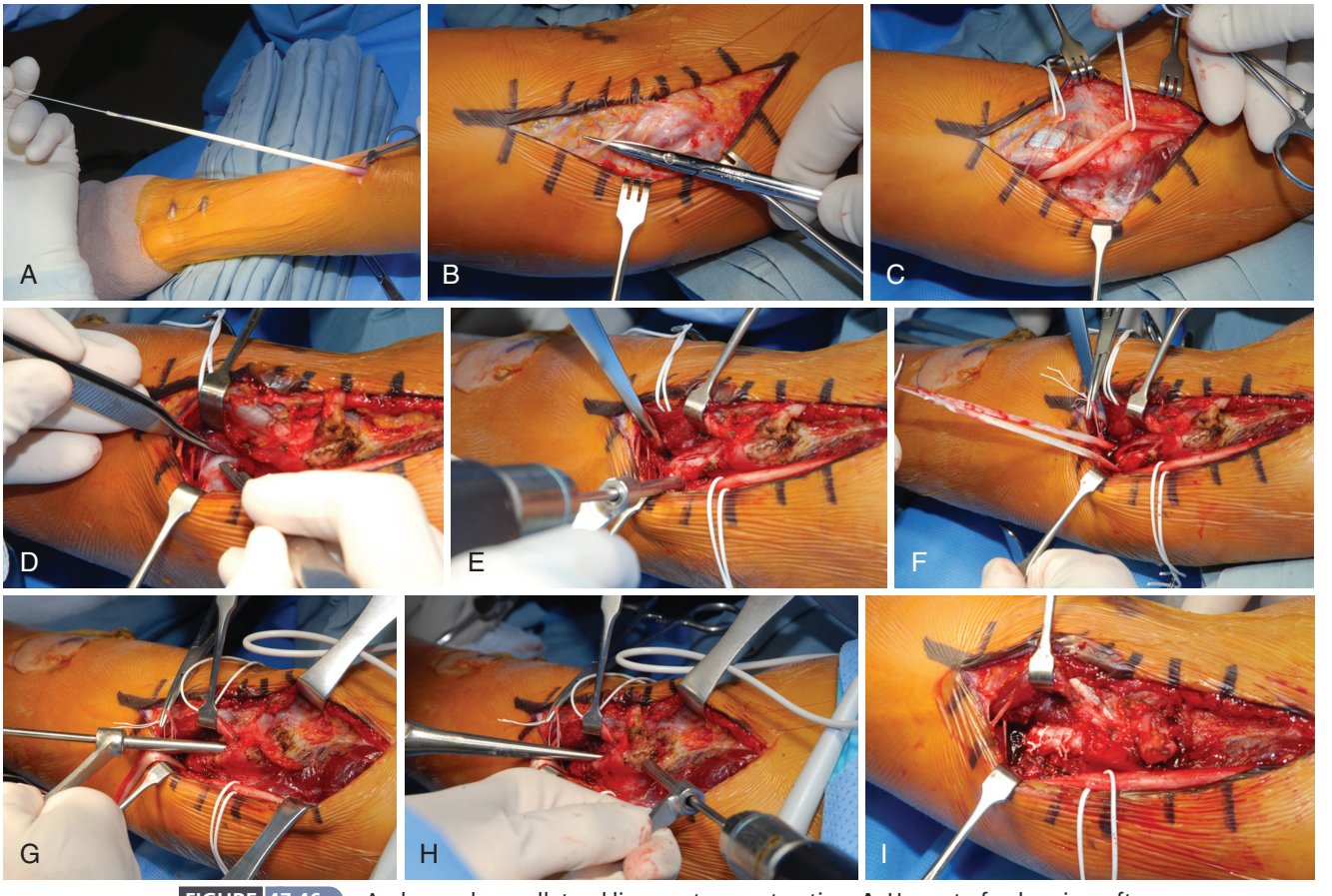

FIGURE 47.46 Andrews ulnar collateral ligament reconstruction. **A,** Harvest of palmaris graft. **B,** Medial antebrachial cutaneous nerve visible in distal third of exposure. **C,** Dissection of ulnar nerve from the cubital tunnel and mobilization with a vessel loop. **D,** Flexor digitorum profundus muscle belly elevated to expose the native ulnar collateral ligament, which is directly below the scalpel blade. **E,** Drilling of ulnar tunnels on either side of the sublime tubercle, perpendicular to the joint surface. **F,** Passage of graft through the ulnar tunnel. **G,** Drilling of the humeral tunnel from distal to proximal, starting at the native insertion of the ulnar collateral ligament onto the humerus. **H,** Placement of a curet in the first humeral tunnel while second tunnel is drilled. **I,** Graft sewn together between the humeral and ulnar tunnels to increase tension within the graft and re-create the course of the native ligament. (From Andrews JR, Jost PW, Cain EL: The ulnar collateral ligament procedure revisited: the procedure we use, *Sports Health* 4:438–441, 2012.) **SEE TECHNIQUE 47.14.**

- Split the remaining fibers of the injured ulnar collateral ligament longitudinally to expose the ulnohumeral articulation. Exposure of the joint surfaces provides a visual reference for proper ulnar tunnel position and allows inspection of partial undersurface ulnar collateral ligament tears.

TUNNEL PREPARATION AND GRAFT PASSAGE

- Use a 3.6-mm drill to make a hole at the posterior edge of the sublime tubercle, aiming anterior and parallel to the joint line (Fig. 47.46E).
- Place a hemostat in this hole and, with the same drill and starting at the anterior border of the sublime tubercle, make a second hole 1 cm distal to the joint line. When the drill is deep enough, it will hit the hemostat.
- Use angled curets to clean and connect the tunnels and to remove bone debris for easier graft passage. Wash away any remaining bone debris in the soft tissues to prevent heterotopic ossification.
- Bend a Hewson suture passer to fit through the curved tunnel and use it to pass the palmaris graft through the ulnar tunnels, leaving equal length of tendon on each side (Fig. 47.46F).
- Begin the humeral tunnels by placing a 3.6-mm drill at the humeral origin of the UCL and aiming it proximal and lateral to exit the posterosuperior border of the medial epicondyle (Fig. 47.46G). Take care to exit as close as possible to the medial border of the humeral shaft to leave the largest bone bridge possible. Place a no. 0 curet in the tunnel.
- Drill a second hole, starting at the medial prominence of the medial epicondyle and aiming toward the humeral insertion of the UCL. This creates a Y-shaped tunnel

configuration. The starting point of this second tunnel must be sufficiently distant from the exit point of the first tunnel to prevent fracturing of the bone bridge between them (Fig. 47.46H). The drill contacts the curet when it has reached the proper depth.

- Use straight and curved curets to clear bone debris from the tunnels.
- Pass a straight Hewson suture passer through one of the limbs of the Y-shaped humeral tunnel and use it to pass the suture on the end of the graft; place a clamp on the suture. Pass only the suture through the tunnel to allow adequate space for the Hewson suture passer to go through the tunnel a second time.
- Pass the suture passer through the second limb of the humeral tunnel and past the other end of the graft. Use the clamped suture to deliver the final limb of the graft through the remaining humeral tunnel.

GRAFT FIXATION

- With one assistant holding the elbow in 30 degrees of flexion and with a slight varus stress so that the articular surfaces of the ulnohumeral joint are in contact, and a second assistant holding tension on the two ends of the graft in an overlapping position on the posteromedial epicondyle, use no. 0 nonabsorbable, braided coated polyester to sew the two limbs to each other and to the underlying periosteum.
- Use three to five no. 0 nonabsorbable, braided coated polyester sutures to sew together the two limbs of the graft between the humeral and ulnar tunnels to increase tension within the graft and re-create the course of the native ulnar collateral ligament (Fig. 47.46I). Resect excess graft with a no. 15 blade.

ULNAR NERVE TRANSPOSITION

- Transfer the ulnar nerve anterior to the medial epicondyle and lay the sling of medial intermuscular septum over the nerve. Sew the end of the sling to the fascia of the flexor/pronator mass with no. 3-0 nonabsorbable, braided coated polyester sutures, taking care to leave the sling of septum very loose so that the ulnar nerve is not compressed under it and can move freely.

CLOSURE

- Close the flexor carpi ulnaris fascia and the fascia of the cubital tunnel with no. 0 absorbable suture.
- Release the tourniquet and obtain hemostasis with electrocautery.
- Irrigate the wound with normal saline and place a Hemovac drain in the dependent portion of the wound, exiting proximally.
- Close the wound with subcutaneous no. 2-0 absorbable and subcuticular no. 3-0 nonabsorbable suture, followed by Steri-Strips.
- Place sterile dressings and a posterior splint molded at 90 degrees of flexion.

POSTOPERATIVE CARE The splint is worn for 1 week; when it is removed, a functional brace set at 30 to 100 degrees is applied. Wrist gripping exercises are begun during the first week, and elbow isometric flexion and extension exercises are started during the second week. The brace is advanced from 15 to 110 degrees by week 3. Light isotonic exercises are started the fourth week, and full motion should be regained by 6 to 8 weeks. From 9 to 13 weeks, advanced strengthening exercises are begun, with eccentric elbow exercises and isometric and isotonic exercises. An interval throwing program is started during week 14, and return to competitive throwing is allowed in 22 to 26 weeks.

ULNAR COLLATERAL LIGAMENT RECONSTRUCTION

TECHNIQUE 47.15

(ALTCHEK ET AL.)

- If a reconstruction is planned, harvest the graft at this time. Usually the ipsilateral palmaris longus is harvested through a 5-mm to 1-cm incision placed in the distal wrist crease. Rather than make multiple incisions, use a tendon stripper specially made for this purpose.
- Place a no. 1 braided nonabsorbable suture using a curved needle in a Krackow fashion in one end of the tendon. After harvest, place the tendon on a moist sponge on the back table.
- To expose the medial collateral ligament, use a tourniquet to exsanguinate the arm.
- Make an incision from the distal third of the intermuscular septum across the medial epicondyle to a point 2 cm beyond the sublime tubercle of the ulna. While exposing the fascia of the flexor pronator, identify and preserve the antebrachial cutaneous branch of the median nerve, which frequently crosses the operative field.
- Incise the fascia of the flexor carpi ulnaris longitudinally, and split the underlying ligament (Fig. 47.47A).
- Place a deep, blunt, self-retaining retractor to maintain the exposure. Incise the anterior bundle of the medial collateral ligament longitudinally, exposing the joint. At this point, medial collateral ligament laxity can be confirmed by observing 2 mm or more separation of the joint surfaces with valgus stress (Fig. 47.47B).
- Expose the tunnel positions for the ulna. For the posterior tunnel, subperiosteally expose the posterior ulna at all times and meticulously protect the nerve. If the nerve subluxes anteriorly so that it cannot be protected, transpose it.
- Using a no. 3 burr, create tunnels anterior and posterior to the sublime tubercle so that a 2-cm bridge exists between them. Connect the tunnels using a small curved curet. Do not violate the bony bridge. Pass a looped no. 2-0 braided nonabsorbable suture using a curved needle.
- The humeral tunnel position is located in the anterior half of the medial epicondyle in the anterior position of the existing medial collateral ligament. Using a no. 4 burr, create a longitudinal tunnel up the axis of the

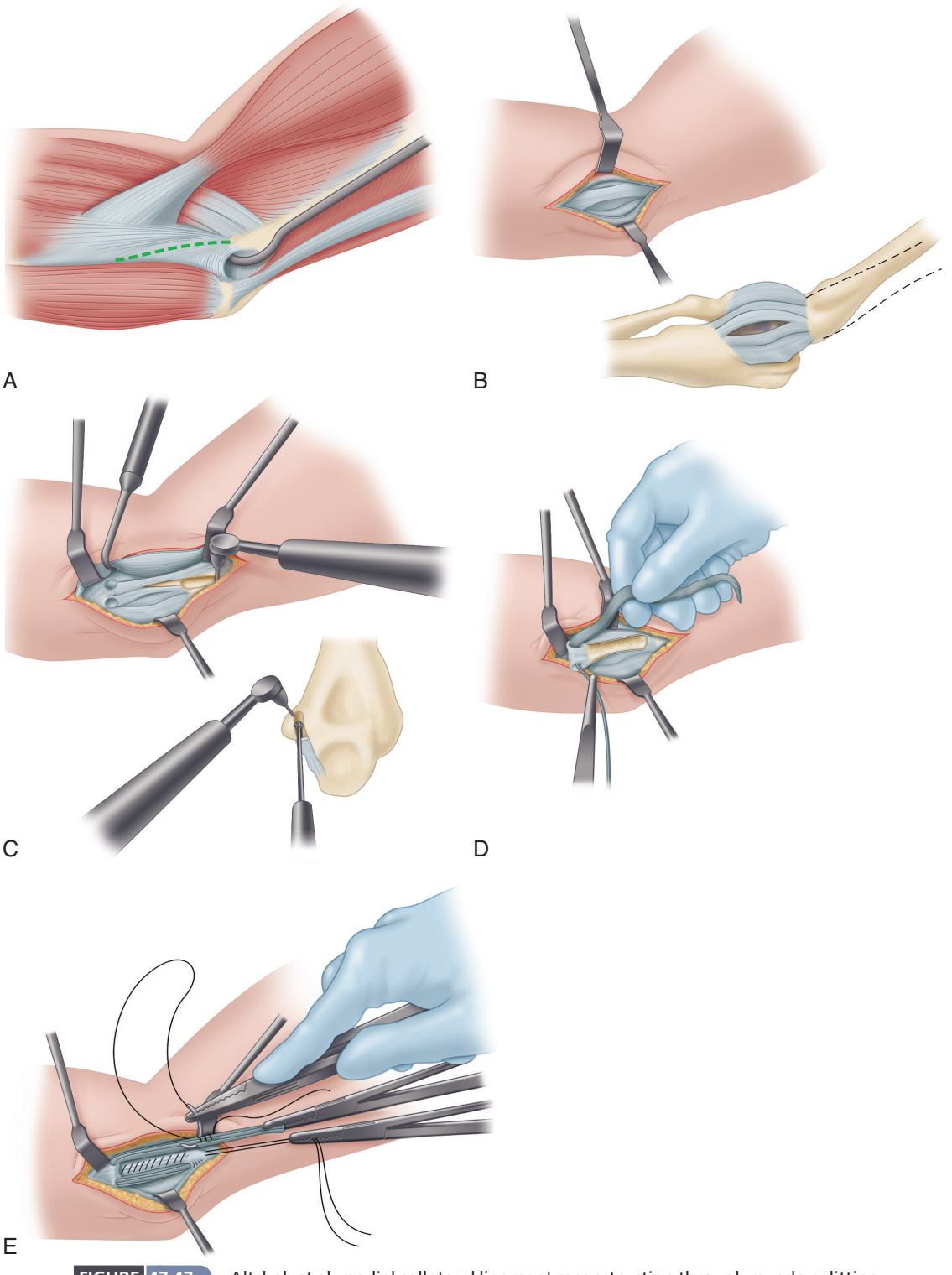

FIGURE 47.47 Altchek et al. medial collateral ligament reconstruction through muscle-splitting approach and using single closed-end humeral tunnel. **A,** Incision through flexor carpi ulnaris. **B,** Submuscular exposure of medial collateral ligament. **C,** Ulnar tunnel and single humeral tunnel and exit holes for two suture bundles. **D,** Graft passage through ulnar tunnel from anterior to posterior. **E,** Posterior limb of graft is docked in humeral tunnel. Elbow is reduced with varus stress; and after final tensioning of graft, Krackow stitch is placed in anterior limb of graft. **SEE TECHNIQUE 47.15.**

epicondyle to a depth of 15 mm. Expose the upper border of the epicondyle, just anterior to the intermuscular septum. Create two small tunnels separated by 5 mm to 1 cm with a dental drill with a small bit. This allows suture passage from the primary humeral tunnel (Fig. 47.47C). Use a suture passer from each of the two upper humeral tunnels to pass a looped suture for later graft passage.

- With the elbow reduced, repair the longitudinal incision in the medial collateral ligament with a 2-0 absorbable suture.
- Pass the graft through the ulnar tunnel from anterior to posterior (Fig. 47.47D). Pass the limb of the graft that has sutures already in place into the humeral tunnel exiting into one of the small superior humeral tunnels.
- With the first limb of the graft securely docked in the humerus, reduce the elbow with forearm supination and gentle varus stress. Maintain tension on the graft while flexing and extending the elbow to avoid potential creep within the graft.
- Measure the final length of the graft by placing the free limb of the graft adjacent to the humeral tunnel and visually estimating the length of the graft that can be tensioned within the humeral tunnel. Mark this point with dye, and place a no. 1 braided nonabsorbable suture in a Krackow fashion. Dock this end of the graft securely in the humeral tunnel with the sutures exiting the small superior humeral tunnel (Fig. 47.47E). The graft may be quadrupled and secured with one braided nonabsorbable suture in a Krackow fashion in the looped end, as well as in both tails. These are then folded over and secured on the docking position as described by Paletta et al.
- Perform final graft tensioning by moving the elbow through a full range of motion with varus stress placed on the elbow.
- When satisfied with graft tension, tie two sets of graft sutures over the bony bridge on the humeral condyle.
- Deflate the tourniquet, and copiously irrigate the wound.
- Approximate the flexor carpi ulnaris fascia, and perform subcutaneous and subcuticular closure.
- Place the elbow in a plaster splint at 60 degrees of flexion.

POSTOPERATIVE CARE The sutures are removed 1 week after surgery, and the elbow is placed in a hinged brace. Motion is allowed between 45 degrees of extension and 90 degrees of flexion. Over the next 3 weeks, motion is gradually advanced to full. A formal physical therapy program is begun at 6 weeks, and gradual strengthening of the forearm and shoulder is started. Care is taken to prevent a valgus load across the elbow during this phase of rehabilitation. At 12 weeks, the strengthening program is more vigorous, and bench-pressing with light-to-moderate weights is allowed. At 4 months, a throwing program is begun for throwing athletes.

For revision procedures or tunnel blow-out, a single ulnar tunnel with endobutton fixation can be used as a salvage procedure. A small interference screw can also be used, but generally poor bone quality makes this a less desirable fixation option.

ULNAR COLLATERAL LIGAMENT REPAIR WITH AN INTERNAL BRACE

TECHNIQUE 47.16

(DUGAS ET AL.)

- With the patient supine and the operative arm on a hand table, after anesthesia administration, examine the elbow with attention to any preoperative range of motion restrictions, particularly in extension.
- Make in incision from the posterior aspect of the medial epicondyle, extending distally.
- If ulnar nerve transposition is planned, extend the excision proximally and unroof and mobilize the ulnar nerve. Take care not to dissect the nerve proximally to prevent iatrogenic ulnar nerve instability.
- Elevate the flexor pronator mass off the ulnar collateral ligament and split the ulnar collateral ligament in line with its fibers.
- Visually examine the ligament for the location of the tear and the tissue quality. Midsubstance injuries, significant tissue degeneration, and/or tissue loss that prevents approximation of the ulnar collateral ligament to either the sublime tubercle or medial epicondyle are considered relative contraindications to repair.
- If repair is indicated, an InternalBrace (Arthrex) technique can be used.
- For most overhead throwing athletes, use 3.5-mm SwivelLock anchors (Arthrex). Larger anchors are available and can be used if required.
- Place the first anchor, loaded with collagen-dipped FiberTape and 0 FiberWire (Arthrex), in the location of the tear using a 2.7-mm drill and then tapping to the size of the anchor.
- Use a free needle to pass the FiberWire in a mattress fashion into the ulnar collateral ligament and tie this down to approximate the torn tissue to the ulnar collateral ligament footprint on the medial epicondyle or sublime tubercle.
- Close the remainder of the native ligament using 0 TiCron suture (Medtronic).
- Place the second anchor at the opposing attachment site with collagen-dipped FiberWire loosely tensioned. Allow enough slack on the brace to align the third thread on the anchor with a drill hole for the anchor.
- Dock the eyelet and advance the anchor to the aperture of the drill hole.
- Move the elbow through a range of motion to ensure adequate isometry and tension of the internal brace.
- To achieve isometry, choose a starting point for the medial epicondyle anchor in the center of the attachment point of the ulnar collateral ligament. Place the center of the sublime tubercle tunnel approximately 6 to 8 mm distal to the joint, slightly anterior on the ridge of the sublime tubercle. Drill the tunnel in a direction aimed slightly away from the articular surface of the ulna.
- Drill the medial epicondyle tunnel in a similar orientation to the tunnel created for ulnar collateral ligament reconstruction, proximally and slightly laterally toward the posterosuperior border of the medial epicondyle. This provides adequate tunnel length for anchor placement and avoids drilling into the cubital tunnel or olecranon fossa.

- If perfect isometry is not obtained, the brace may become taut at certain points during range of motion. If this occurs, remove the anchor and loosen the brace. If anisometry exists, laxity is preferred rather than overconstraint.
- Once the desired tension is achieved and the anchor is placed, suture the brace to the native ligament to prevent motion of the brace over the ligament and potential abrasion.
- Move the elbow through a range of motion to ensure full motion without overtensioning of the graft and to assess for instability of the ulnar nerve.

POSTOPERATIVE MANAGEMENT The patient is discharged home the same day. The splint is removed 5 to 7 days after surgery, and range-of-motion and strengthening exercises are begun in a protective hinged elbow brace. A supervised throwing program is initiated at 10 weeks, with the goal of returning to competition by 6 months after surgery.

LATERAL ULNAR COLLATERAL LIGAMENT RECONSTRUCTION FOR POSTEROLATERAL ROTATORY INSTABILITY

For posterolateral rotatory instability that persists because of disruption of the lateral ulnar collateral ligament and incompetence of the lateral capsular structures, Nestor, Morrey, and O'Driscoll described the use of a Kocher lateral incision for repair or reconstruction of the lateral side.

TECHNIQUE 47.17

(NESTOR, MORREY, AND O'DRISCOLL)

- Approach the elbow through a modified Kocher incision (see Technique 1.107).
- By sharp dissection, carefully elevate the common extensor origin, including a portion of the extensor carpi radialis, to reveal the origin of the radial collateral ligament complex at the lateral epicondyle.
- Distally, reflect the anconeus muscle posteriorly and the extensor carpi ulnaris anteriorly. Reflect the extension of the origin of the anconeus to the lateral aspect of the triceps fascia sufficiently to expose the ligament adequately. Identify the supinator crest of the ulna.
- Typically, a lax ulnar band of the radial collateral ligament is observed and the abnormal portion of the ligament is proximal to the annular ligament. The pivot-shift maneuver reveals laxity of the anterior part of the capsule over the radial head and of the posterior part of the capsule at the posterior aspect of the radiohumeral joint. The subluxation of the joint clearly shows the stretched ulnar part of the collateral ligament.
- Enter the joint, and inspect for loose bodies and abrasion of the articular surfaces.
- Tighten the anterior and posterior aspects of the capsule with plication sutures, but do not tie these sutures (Fig. 47.48A, *left*). If the radial collateral ligament complex appears intact but stretched or detached from its origin, imbricate and advance it with a Bunnell suture technique. Suture and plicate the ulnar and the radial parts of the radial collateral ligament complex. Advance the suture through holes placed in the bone at the humeral anatomic origin of the ligament (Fig. 47.48A, *right*).
- If the tissue of the collateral ligament is of poor quality, as is the usual case, reconstruct the ulnar part of the radial collateral ligament with an autogenous graft from the palmaris longus tendon.
- Pass the tendon through an osseous tunnel created by a small burr just posterior to the tubercle of the crest of the supinator. Make the entry holes about 7 mm apart to lessen the likelihood of rupture of the osseous tunnel roof. Thread the tendon through a humeral tunnel that emerges at the origin of the ligaments. Determine the location of the tunnel in the humerus by placing a temporary suture in the ulnar tunnel and holding the ends of the suture against the humerus with a hemostat while the elbow is moved. Reflect the tendon graft back onto itself, crossing the joint again, and attach it into its origin with 1-0 nonabsorbable sutures (Fig. 47.48B-D).
- If the tendon graft seems to be inadequate for the size of the arm or for the anticipated activity or stress, use an autogenous or allograft hamstring tendon to reinforce the reconstruction with the same sites of attachment to bone and crossing the joint twice.
- Tie all the sutures with the elbow flexed 30 degrees and with the forearm fully pronated.
- After completing the reconstruction, test the elbow for anterolateral rotatory instability. Allow the anconeus and triceps muscles to assume their normal positions, and close the interval between the anconeus and the extensor carpi ulnaris with absorbable sutures.
- Apply a splint with the forearm flexed 90 degrees and pronated.

We prefer to use a closed-end tunnel and docking technique in the humerus comparable to that used with the ulnar collateral ligament. When the palmaris is deficient, we use a 3.2-mm thick portion of the gracilis tendon. One hamstring may be split for medial and lateral reconstructions in the case of global instability after dislocation. The humeral tunnel is drilled at the point on the epicondyle where the line drawn along the anterior humeral cortex intersects a line through the center of the radiocapitellar axis between the 3- and 4:30-o'clock position on the epicondyle (Fig. 47.49). Stability and isometry are less affected by the location of the ulnar tunnels. Placement of drill holes 4 mm posterior to the radial head at the crista supinatoris and at the proximal aspect of the lesser sigmoid notch provides reproducible landmarks.

POSTOPERATIVE CARE With the forearm in full pronation, the elbow is placed in 70 to 80 degrees of flexion and held in this position for 10 to 14 days. Protected movement is allowed in a hinged brace 2 to 6 weeks after surgery. After 6 weeks, the hinged brace can be removed for light activity. The brace is discontinued completely at the end of an additional 6 weeks, but patients are encouraged to protect the elbow from heavy activity. Full activity is

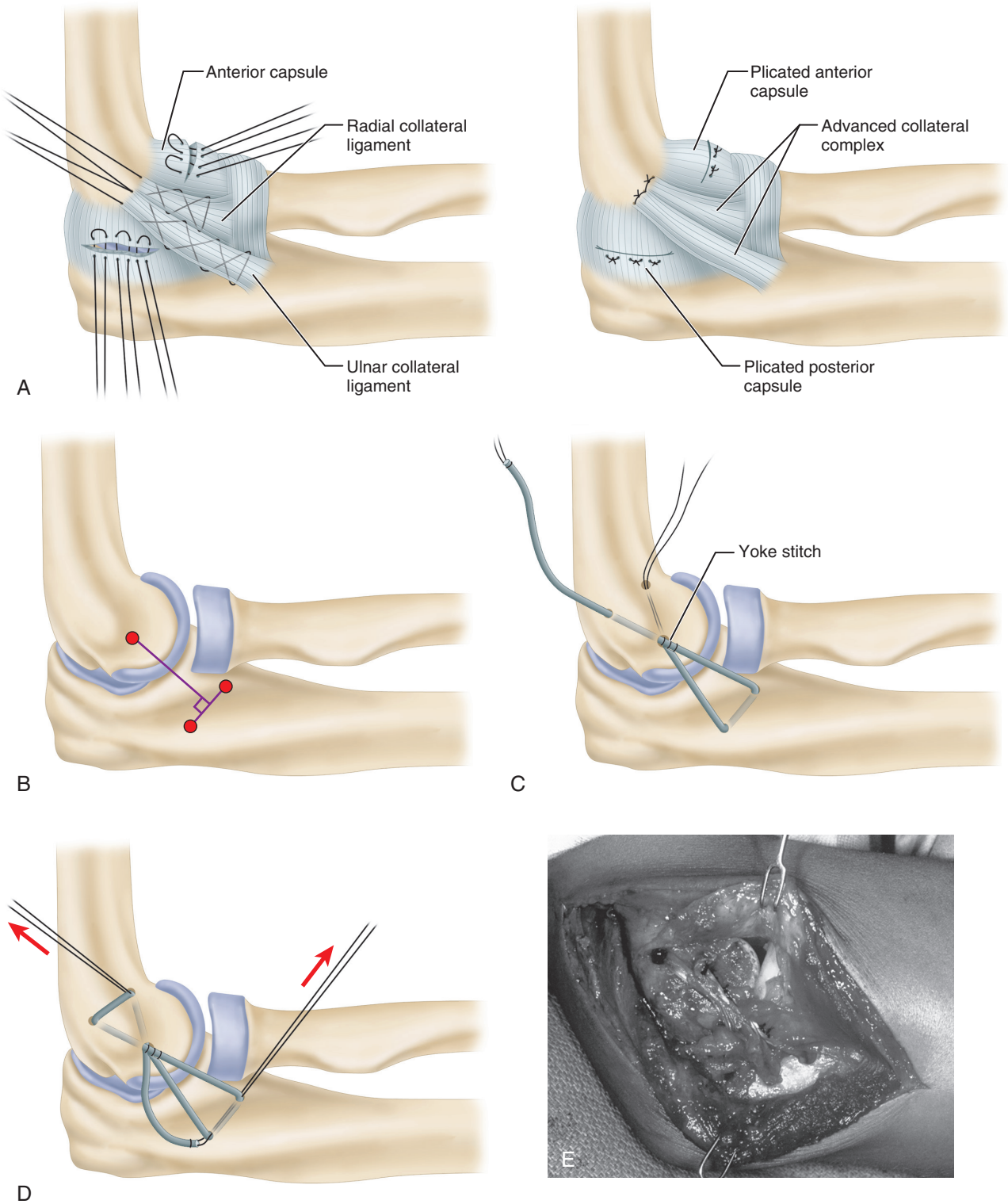

FIGURE 47.48 Technique of Nestor et al. **A,** Imbrication and advancement of ulnar band of radial collateral ligament and radial part of radial collateral ligament with Bunnell suture technique, accomplished by placing sutures through drill holes at anatomic origin of ligament in humerus. **B,** Ulnar tunnel placed in crista supinatoris tubercle and oriented to have optimal alignment with isometric point. **C,** Placement of graft into ulnar tunnel and creation of yoke stitch. **D,** Graft tensioning after introduction into humeral tunnels. **E,** Tunnel is made in humerus and expanded in posterosuperior direction to emerge posterior and superior to point of isometry. Second humeral tunnel exits posterior and inferior from common entry site. Palmaris longus tendon is drawn through ulnar and humeral tunnels and tied to itself after recrossing joint. **SEE TECHNIQUE 47.17.**

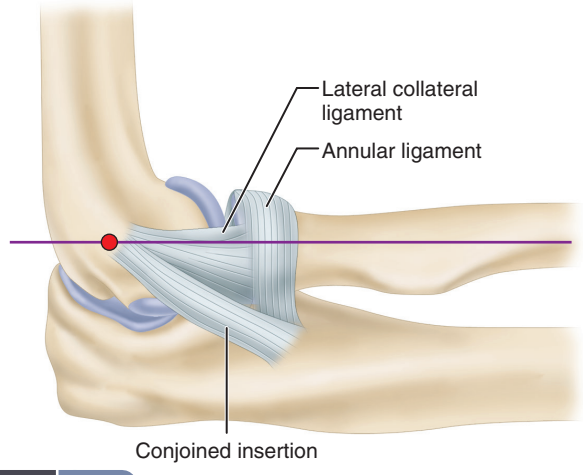

FIGURE 47.49 Lateral collateral and annular ligament complex of elbow. Lateral collateral ligament originates off humerus at axis point of ulnohumeral joint, which lies at intersection of anterior humeral line and radiocapitellar axis. Radial collateral ligament blends with annular ligament to insert in conjoined fashion onto proximal ulna. **SEE TECHNIQUE 47.17.**

allowed at 6 months, and participation in contact sports is allowed at 1 year. The patient is advised to protect the elbow from stresses during activities of daily living, such as lifting weights. We recommend that patients lift weights only in the plane of elbow flexion and extension, keeping the shoulder adducted and the elbow close to the body.

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