Anatomical Glenoid Reconstruction for Recurrent Anterior Glenohumeral Instability With Glenoid Deficiency Using an Autogenous Tricortical Iliac Crest Bone Graft

Jon J. P. Warner,* MD, Thomas J. Gill,* MD, James D. O'Hollerhan,* MD, Neil Pathare,* and Peter J. Millett,[†‡§] MD, MSc

*From *Harvard Shoulder Service, Massachusetts General Hospital, Boston, Massachusetts, [‡]Harvard Shoulder Service, Brigham & Women's Hospital, Boston, Massachusetts, and [§]Steadman Hawkins Clinic, Vail, Colorado*

Background: Anterior shoulder instability associated with severe glenoid bone loss is rare, and little has been reported on this problem. Recent biomechanical and anatomical studies have suggested guidelines for bony reconstruction of the glenoid.

Hypothesis: Anatomical glenoid reconstruction will restore stability in shoulders with recurrent anterior instability owing to glenoid bone loss.

Study Design: Case series; Level of evidence, 4.

Methods: Eleven cases of traumatic recurrent anterior instability that required bony reconstruction for severe anterior glenoid bone loss were reviewed. In all cases, the length of the anterior glenoid defect exceeded the maximum anteroposterior radius of the glenoid based on preoperative assessment by 3-dimensional CT scan. Surgical reconstruction was performed using an intra-articular tricortical iliac crest bone graft contoured to reestablish the concavity and width of the glenoid. The graft was fixed with cannulated screws in combination with an anterior-inferior capsular repair.

Results: At mean follow-up of 33 months, the mean American Shoulder and Elbow Surgeons score was 94, compared with a preoperative score of 65. The University of California, Los Angeles score improved to 33 from 18. The Rowe score improved to 94 from a preoperative score of 28. The mean motion loss compared with the contralateral, normal shoulder was 7° of flexion, 14° of external rotation in abduction, and one spinous process level for internal rotation. All patients returned to preinjury levels of sport, and only 2 complained of mild pain with overhead sports activities. No patients reported any recurrent instability (dislocation or subluxation). The CT scans with 3-dimensional reconstructions obtained 4 to 6 months postoperatively demonstrated union of the bone graft with incorporation along the anterior glenoid rim and preservation of joint space.

Conclusion: Anatomical reconstruction of the glenoid with autogenous iliac crest bone graft for recurrent glenohumeral instability in the setting of bone deficiency is an effective form of treatment for this problem.

Keywords: shoulder instability; bone graft; glenoid deficiency; glenoid reconstruction

Most traumatic anterior shoulder instability is associated with soft tissue lesions, and the typical finding is a Bankart lesion with or without capsular laxity.[‖] Numerous biomechanical studies have supported this observation.[3,8,15,39,44,48] Soft tissue repair, using either open or arthroscopic techniques, has been shown to have a very high rate of success.[2,6,9,16,20,33,37,49] In rare cases, significant bony lesions have been associated with recurrence of instability, although the incidence and recognition of such lesions remain variably reported.[¶]

Rowe et al[41] suggested that a 30% loss of the anterior glenoid was still amenable to a soft tissue Bankart repair. However, this was an observation based on qualitative visual

[†]Address correspondence to Peter J. Millett, MD, MSc, Steadman Hawkins Clinic, 181 West Meadow Drive, Vail, CO 81657 (e-mail: drmillett@steadman-hawkins.com).

Presented at the interim meeting of the AOSSM, San Francisco, California, March 2004.

No potential conflict of interest declared.

The American Journal of Sports Medicine, Vol. 34, No. 2
DOI: 10.1177/0363546505281798

[‖]References 5, 8, 11, 14, 18, 20, 33, 39, 47.
[¶]References 4, 7, 9, 10, 12, 21, 24, 29, 34, 46.

inspection and anecdotal experience. Burkhart et al[9,10] have observed that substantial bony loss of the anterior glenoid is associated with a very high recurrence rate after arthroscopic repair of instability. They developed a method of arthroscopic inspection to determine what constituted clinically relevant bone loss. Few other studies have drawn attention to the biomechanical relevance of stability afforded by glenoid depth and width.[12,21,24,29,30,35,36,46] Recently, Gerber and Nyffeler[18] have provided a method of quantitative assessment of glenoid bone loss and determined its importance to stability of the glenohumeral joint.

There is a paucity of literature available regarding operative treatment of anterior shoulder instability with significant glenoid bone loss. Options have included the Latarjet or Bristow procedures[#] and bone grafting, both intra-articular and extra-articular.[23,28] Procedures that transfer the coracoid process have been shown to carry the risk of loss of motion, development of arthritis, breakage of screws, and resorption or nonunion of the bone graft.[51] Anatomical reconstruction of glenoid depth and thus joint conformity may be difficult with these approaches as well. Furthermore, the result of such surgery is nonanatomical, and the scarring that may occur around the subscapularis tendon can complicate further surgery, if needed.

The purpose of this study was to report our experience with an intra-articular tricortical iliac crest bone graft for an anatomical reconstruction of glenoid insufficiency in the treatment of recurrent traumatic anterior instability. This technique is based on the assumption that anatomical restoration of glenoid depth and width is essential to restore stability to the shoulder. The extent of bony loss was determined based on criteria reported by Gerber and Nyffeler[18] in 2002. Our overall experience is reported in the context of the denominator of all instability surgeries treated by the senior author during the same time period.

METHODS

Patient Selection

Over a 3-year period (1999-2001), the senior author (J. J. P. W.) performed 262 surgeries for anterior shoulder instability; 138 of these cases were arthroscopic capsulorrhaphy procedures, and 23 were open repairs for capsular insufficiency or associated subscapularis tears. Eleven patients were identified who had marked loss of the anterior glenoid that was the primary biomechanical factor in their recurrent anterior instability (Table 1).

There were 10 men and 1 women with a mean age of 30 years (range, 19-41 years). Eight dominant and 3 nondominant shoulders were involved. In 9 of 11 cases, there was a prior operative procedure that had been unsuccessful. Four patients had previously undergone 1 or 2 open operative procedures, 1 had undergone 3 open operative procedures, 3 had undergone 1 arthroscopic and 1 open operative procedure, and 1 patient had undergone a single arthroscopic repair. All patients presented with multiple episodes of shoulder subluxation and dislocation, and in 7 cases, the patients had more than 10 episodes of dislocation (Table 1).

[#]References 1, 9, 19, 25-27, 38, 42, 43, 50.

All patients sustained their instability as a result of trauma, and in 4 cases, this trauma was a collision in a sporting event. There were 3 professional hockey players who developed their instability as a result of a collision during competition. In 5 cases, the patient had trauma as the initial injury. One patient had a fall while working on a construction job.

Suspicion of glenoid bone loss was based on the high number of recurrences, decreasing force required for instability, midrange symptoms of instability, and prior failed soft tissue repairs. Many patients reported that their recurrent episodes of instability required less and less force, so that simply reaching for something or rolling over in bed was sufficient to cause their shoulders to subluxate or dislocate.

Physical examination demonstrated profound apprehension with any attempt to move the patients' shoulders passively into abduction and external rotation, and the relocation maneuver[31,45] had a positive result in all patients. All patients had normal rotator cuff function, and no patient had associated subscapularis tendon injury.

In addition to preoperative plain radiographs, which included true AP glenoid views, axillary views, and Stryker-Notch views, all patients had a CT scan with intra-articular gadolinium. In most patients, standard radiographs were only suggestive of glenoid bone loss. Six of 11 patients had MRIs (performed elsewhere before consulting the senior author), and of these, 4 had intra-articular gadolinium. In all cases, there was suggestion of bony loss of the anterior glenoid rim (Figure 1). As we and others[22] believe, CT arthrogram more accurately reflects bone lesions; these results were obtained in all patients. The degree of bone loss was based on either an oblique sagittal reconstruction or a 3D reconstruction of the glenoid face. The length of the glenoid defect was measured along the anterior edge. Normally, this is a curved surface, but in these patients, the glenoid edge was straight. If the length of the defect, measured along this straight edge, was greater than half of the maximum AP diameter of the glenoid fossa, then the patient was considered to be a candidate for an anatomical glenoid reconstruction based on a biomechanical study performed by Gerber and Nyffeler[18] (Figure 2). In cases in which there is significant anterior erosion, the superoinferior axis of the glenoid is established first, and the radius is then measured from this line posteriorly to the margin of the glenoid.

Surgical Technique

The patient was positioned on a full-length beanbag with the head of the bed elevated to 30° and the ipsilateral iliac crest exposed. The beanbag was then contoured to ensure the shoulder was freely mobile and the iliac crest was exposed. Examination under anesthesia was performed to confirm degree and direction of instability. The shoulder, arm, and ipsilateral iliac crest were prepared and draped in the standard sterile fashion. The patient received intravenous antibiotics for preoperative prophylaxis against infection. An anterior deltopectoral incision was made with a standard approach through the deltopectoral interval

TABLE 1
Patient Demographics[a]

						Preoperative Score				Postoperative Score			
No.	Age	Sex	Injury	No. Dislocations/ Subluxations	Prior Surgery	ASES	UCLA	Rowe	Follow-up, mo	ASES	UCLA	Rowe	Sport
1	33	Female	Fall in tennis	10/> 100	2 open	40	17	20	60	100	35	100	Tennis, swimming
2	37	Male	Motor vehicle accident	10/> 50	2 open	40	12	20	38	83	31	90	No sports
3	26	Male	Contact sport	5/multiple	1 + 1 scope/open	73	18	15	36	100	35	95	Professional hockey
4	25	Male	Contact sport	0/multiple	1 + 1 scope/open	82	25	45	32	87	34	85	Professional hockey
5	25	Male	Contact sport	100/100	2 open	47	12	15	30	95	32	90	Recreational hockey
6	19	Male	Fall	> 10/0	1 scope	83	24	45	30	100	35	100	Swimming, tennis, golf
7	38	Male	Fall	18/multiple	None	60	60	25	29	95	33	100	Golf, manual labor
8	23	Male	Fall	> 40/multiple	None	77	19	30	29	100	35	100	Golf
9	41	Male	Collision	12/multiple	3 open	65	15	25	24	75	22	75	Light duty work
10	28	Male	Contact sport	0/5	1 + 1 scope/open	80	24	40	24	100	35	95	Professional hockey
11	32	Male	Fall in tennis	1/1	1 open	67	21	30	31	97	35	95	All sports

[a]ASES, American Shoulder and Elbow Surgeons; UCLA, University of California, Los Angeles.

Figure 1. An MRI showing significant loss of anterior-inferior glenoid rim (white arrow) in a professional hockey player with multiple anterior dislocations after 2 failed instability repairs.

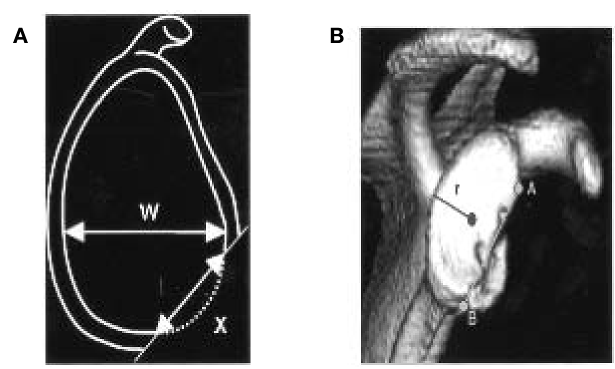

Figure 2. Quantitative method for assessing glenoid bone defect. A, schematic illustration, where X is the length of the defect and W is the maximum anteroposterior diameter. If the length of the defect is greater than the radius (W/2), then the dislocation resistance decreases to no more than 70% of the value of an intact joint. B, this is a 3D CT reconstruction from a patient with an anterior glenoid erosion in which the length of the defect (A-B) exceeds the maximum anteroposterior radius (r).

down to the clavipectoral fascia. The circumflex vessels were identified and ligated, and the subscapularis tendon was removed from the underlying capsular layer. The axillary nerve was identified in all cases and protected during the dissection with a retractor. The capsule was then released from the humeral neck and split down to the glenoid through the rotator interval region, creating an inverted L-shaped capsulotomy (Figure 3). This procedure permitted more extensive visualization of the glenoid and mobilization of the capsule-periosteal sleeve from the anterior scapular neck. A periosteal elevator was then used to strip the periosteal sleeve from the anterior scapular neck to fully

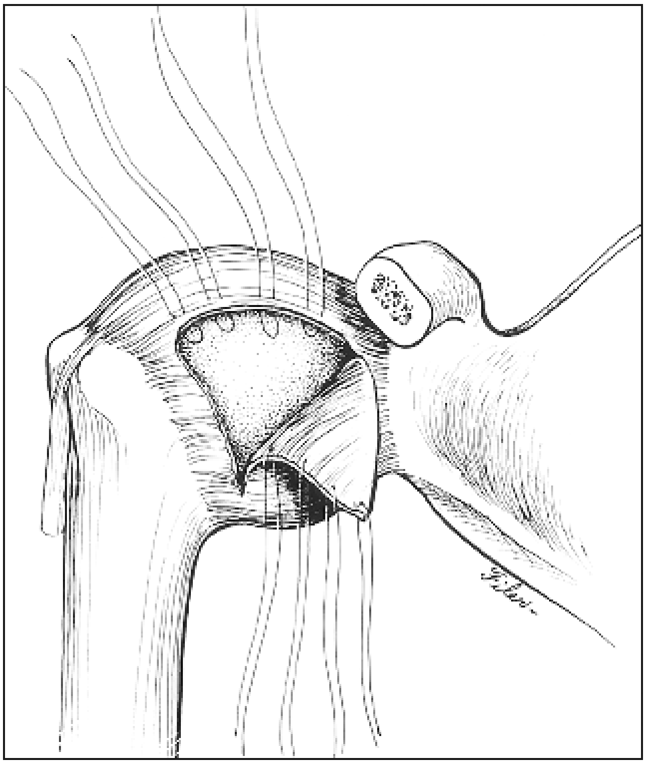

Figure 3. An inverted L-shaped capsulotomy is created through the rotator interval so that the capsule can be opened to expose the glenoid.

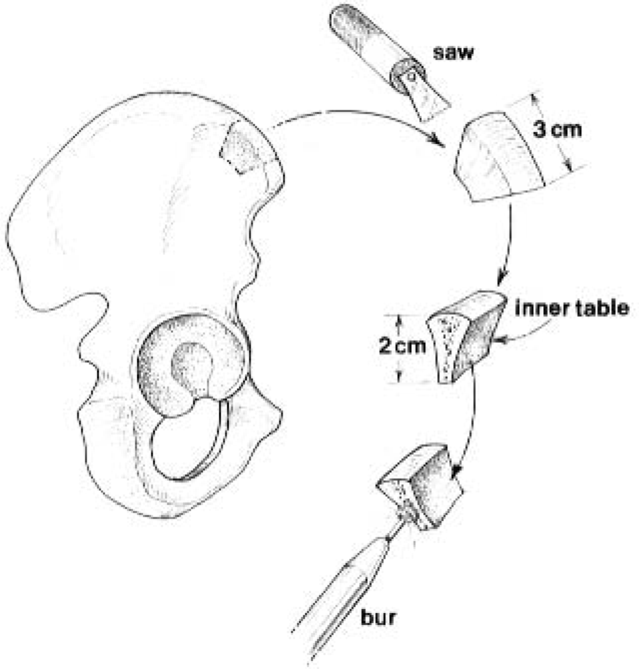

Figure 4. Harvesting and preparing the tricortical iliac crest bone graft. See text for further explanation.

expose the glenoid. The anterior glenoid was thus exposed, and a bony defect could be visualized as a straight line rather than the convex contour of a normal anterior glenoid. A curved, blunt retractor was used to retract the soft tissues medially while a humeral head retractor exposed the glenoid. The length of the defect was measured and compared with the maximum AP radius of the glenoid to quantify the extent of bony loss (Figure 2). This measurement also formed the basis for determining the size of the bone graft needed.

The iliac crest was exposed with an incision posterior to the anterosuperior iliac spine. The superior iliac crest with the inner and outer tables was exposed, and blunt retractors were used to maintain this exposure. An oscillating saw and osteotomes were used to remove a tricortical wedge-shaped graft that was approximately 3 cm in length by 2 cm in width (Figure 4). This graft was contoured using a small saw and bur so that it fit onto the anterior glenoid in a fashion that added width and depth to the glenoid surface. The inner table is concave and was used to re-create the articulation. The angle of the bony interface of the graft with scapula was inclined so as to add the correct concavity to the joint (Figure 5). Too acute an angle results in a vertical graft placement, which may impinge on the humeral head, whereas too horizontal an angle makes the graft sit flat on the scapula so that glenoid depth (concavity) is not restored.

Once the graft had been contoured to match the desired dimensions to approximate a normal joint surface, it was fixed in place using terminally threaded K-wires from the stainless steel AO 4.0-mm cannulated screw set (AO/Synthes, Paoli, Pa). Usually, 3 wires were placed. The wires were oriented medially and parallel to the joint surface so that the screw heads sat medially, as far away from the humeral articular surface as possible. Two to 3 cannulated screws were then placed over these wires with a standard technique. Before fully seating each screw, a single No. 2 braided polyethylene suture was placed around the shaft of the screw so that when the screw was completely tightened down onto the graft, the suture remained well fixed. This part became a suture anchor that could then be used to repair the capsule-periosteal sleeve to the edge of the graft (Figure 6). The interface between the graft and the remaining glenoid was then visualized and palpated to confirm a smooth transition and restoration of glenoid depth. If necessary, a small bur was used to contour this interface. The humeral retractor was then removed, and the positioning of the humeral head on the newly reconstructed glenoid was assessed by rotating the arm to confirm joint congruity and joint stability. The capsule-periosteal sleeve was then repaired to the edge of the graft using horizontal mattress sutures with the No. 2 braided suture material fixed underneath each screw.

Lateral repair of the capsule was sometimes limited because of the width of the graft and the paradoxical shortening of the capsule that occurs with chronic bone loss. In cases in which the capsule could not be reattached to the neck of the humerus with the arm in at least 30° of external rotation, the lateral portion of the subscapularis tendon was used as an extension of the capsule so that the capsule became tensioned in external rotation through this attachment (Figure 6). In such cases, the capsule was sewn into the undersurface of the subscapularis tendon using horizontal

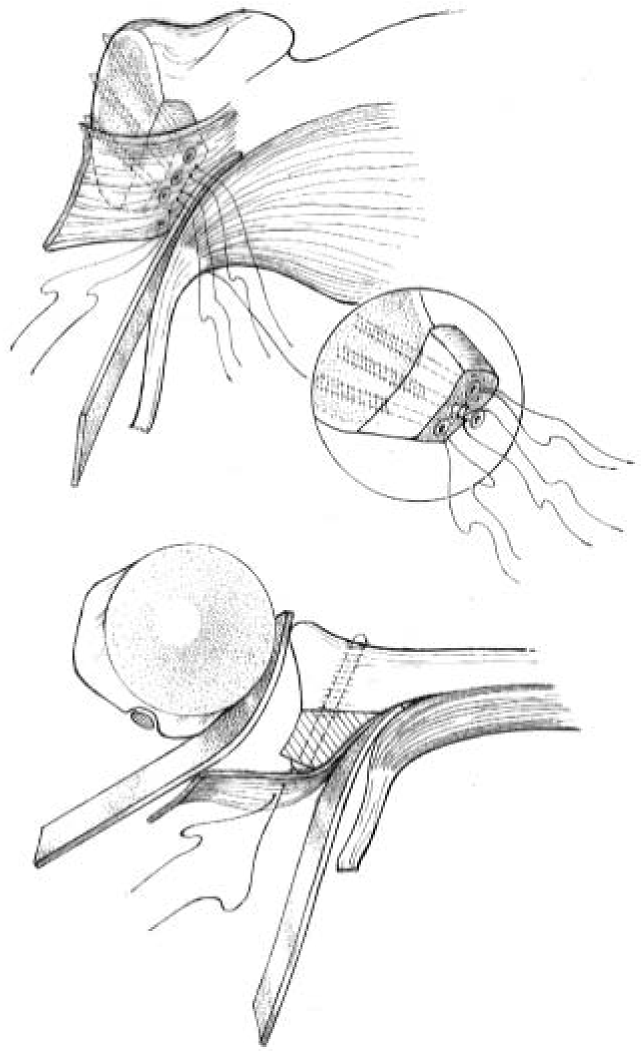

Figure 5. The graft is shaped so that it restores the normal concavity contour of the anterior glenoid, and it is fixed in place with 2 to 3 cannulated 4.0-mm screws around which No. 2 braided, nonabsorbable suture has been placed (top). The capsule-periosteal sleeve is then fixed to the edge of the graft using these sutures (bottom).

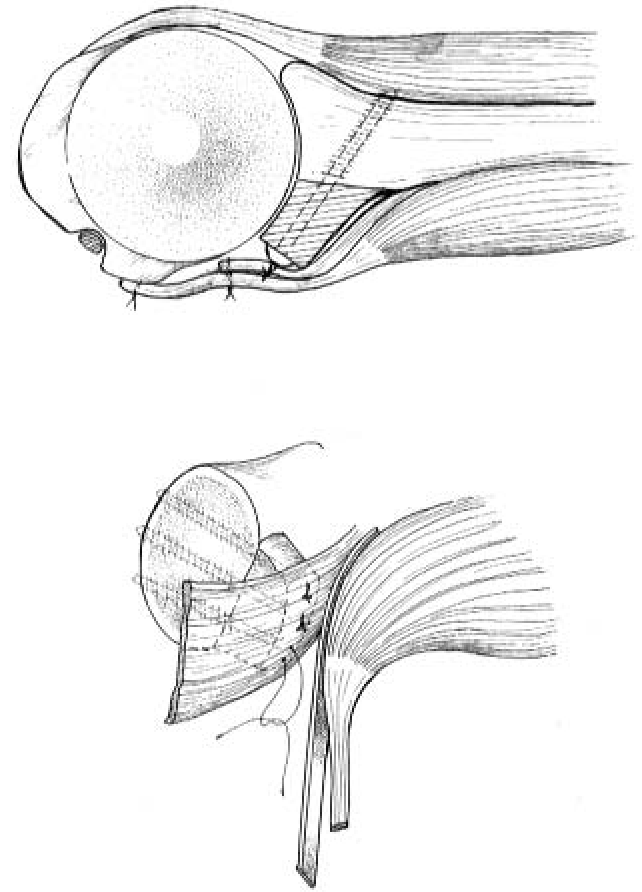

Figure 6. The capsule is fixed over the edge of the graft, and then the capsule is lengthened using the lateral portion of the subscapularis tendon (top). The subscapularis tendon is then reinserted anatomically to ensure that the shoulder can be externally rotated (bottom). See text for more details.

mattress sutures of No. 2 braided nonabsorbable material, and then the subscapularis tendon was reattached to its insertion using the same suture material with direct fixation to bone with suture anchors (TwinFix AB anchors, Smith & Nephew, Mansfield, Mass). The remainder of the incision was then closed in layers with a subcuticular resorbable 3-0 monofilament suture and Steri-Strips. The incision was then dressed with sterile bandages, and the shoulder was placed into a shoulder immobilizer.

Postoperative Care

The shoulder was maintained in a shoulder immobilizer for 4 weeks, although pendulum exercises were permitted after the first week. After the fourth week, patients began supervised physical therapy to regain motion and were allowed to use their arms for activities of daily living. Active-assisted and passive-assisted motion was commenced, and water therapy was encouraged. After 3 months, strengthening was allowed. At 4 months postoperatively, patients were permitted use of their arms for overhead recreational sports such as golf, tennis, or swimming, although collision and contact sports were not permitted until at least 8 months after surgery.

Evaluation

All patients were evaluated using the American Shoulder and Elbow Surgeons (ASES) self-assessment score[40]; the University of California, Los Angeles, score[13]; and the Rowe shoulder score.[41] In addition, all patients were evaluated postoperatively by one observer (J. J. P. W.). Measurement of range of motion was performed with a goniometer with the patient supine for internal and external rotations and with the patient standing for flexion. Strength was measured by manual testing. No patient had weakness of internal rotation

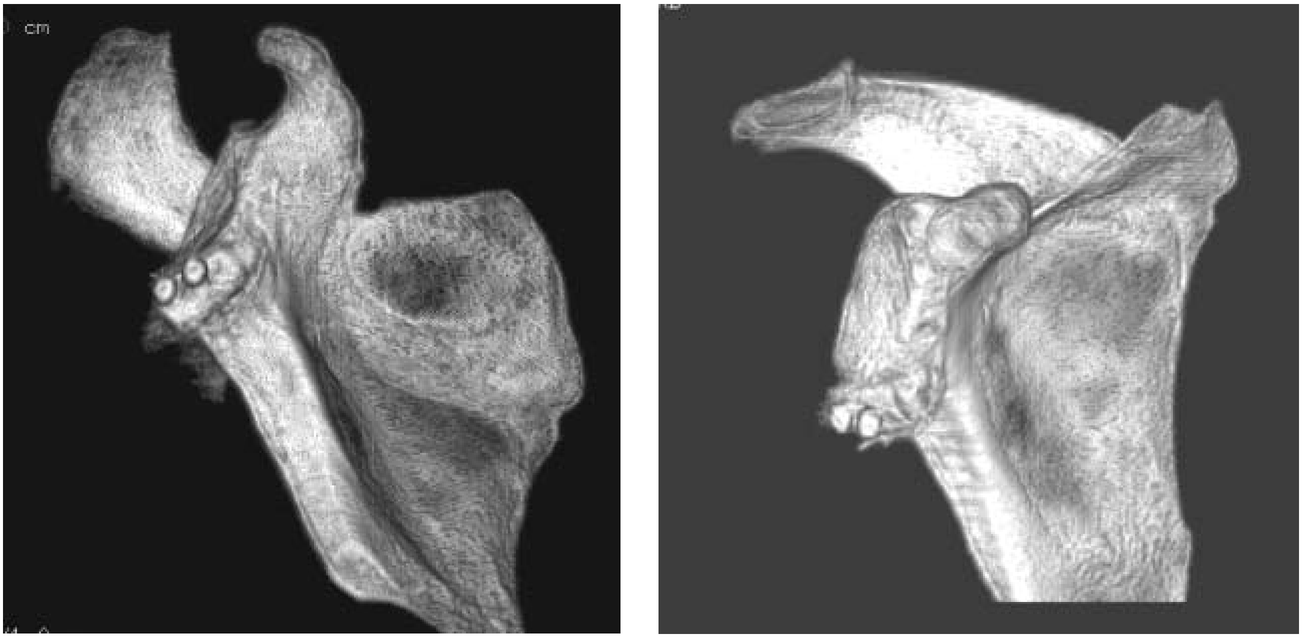

Figure 7. Postoperative 3D CT scans from different angles showing incorporation of the bone graft at 4 months after surgery. The screw heads appear as circles at the anteroinferior portion of the graft.

or a positive belly-press test result or lift-off sign.[17] Anterior apprehension and relocation were measured according to principles described by Jobe et al.[32] The patient was supine, and the arm was abducted and externally rotated. No patient in this series had either finding. At 4 to 6 months after surgery, all patients underwent a CT scan with 3D reconstruction in addition to plain radiographs to confirm osseous union, maintenance of glenoid concavity, concentric glenohumeral articulation, and hardware position (Figure 7).

RESULTS

Radiographic Findings

At the time of surgery, all patients were found to have biomechanically relevant glenoid defects according to the criteria developed by Gerber and Nyffeler,[18] as previously noted (Figure 2). In all cases, the length of the glenoid defect was larger than the maximum AP radius of the glenoid. Hill-Sachs lesions were present in all patients; they were small in 3, medium in 3, and large in 5 cases, in which a large size involved more than a third of the posterolateral humeral head, medium size involved approximately one fourth, and small included anything smaller, such as a small divot.

Operative Findings

During examination under anesthesia, all patients were found to have shoulders with grade 3+ anterior instability (dislocated and remained locked out) that could easily be dislocated under anesthesia. Many patients had shoulders that appeared to statically rest out of the glenoid, requiring manual manipulation to restore placement of the humeral head back into the glenoid. At the time of exposure of the joint, severe bony loss of the glenoid was observed in all cases. In many cases, our subjective impression was that the anterior half of the glenoid was absent. The length of the glenoid defect ranged from 18 to 35 mm, and this range correlated closely with our preoperative CT measurements.

In all cases, the quality of the subscapularis tendon was good, and the capsular quality was robust. However, in 7 of 11 cases, the capsule was shortened, and lengthening by attachment to the undersurface of the subscapularis tendon was required, as described previously.

Clinical Outcomes

At a mean follow-up of 33 months (range, 24-60 months), the mean ASES score was 94 (range, 75-100), compared with a preoperative ASES score of 65 (range, 40-83). The postoperative University of California, Los Angeles, score improved to 33 (range, 31-35) from a preoperative value of 18 (range, 12-25). The postoperative Rowe score averaged 94 (range, 75-100), compared with a preoperative score of 28 (range, 15-45). No patient showed signs of apprehension or complained of instability, and only 2 described mild pain with overhead sports activities. All patients returned to their preinjury levels of sports activity (Table 1), including 3 professional hockey players. Mean motion loss compared with the nonoperative side was 7° of flexion (range, 0°-30°), 14° of external rotation in abduction (range, 0°-45°), and 1 intervertebral level (range, 0-2) for active internal rotation. The patient with a 45° loss of external rotation in abduction had multiple prior surgeries and a subscapularis tendon that was stiff and short as a result of scarring. Motion loss of this nature is inherent to many revision surgeries and, in this case, was not directly related to the glenoid bone defect but instead to the quality of the remaining subscapularis tendon.

Follow-up Radiographic Analysis

Postoperative plain radiographs and CT scans at 4 to 6 months confirmed that the graft appeared to incorporate along the anterior glenoid rim and restored glenoid contour in all patients. In addition, there was no evidence of joint space narrowing, no observable resorption or subsidence of the graft, and no articular impingement on the screws in any of the patients (Figure 7). Although most patients reported discomfort over the bone graft donor site, none had complaints of pain at this area 6 months after surgery.

DISCUSSION

Over a 3-year period, we observed a 4% (11/262) incidence of biomechanically relevant, severe glenoid insufficiency in the setting of recurrent anterior instability after trauma in our patient population. The incidence of this problem has not been clearly reported in prior literature. Patients were suspected to have glenoid insufficiency if they had failed prior operative treatment, in which conventional Bankart repair had been performed (as did 9/11 in this study); if they had multiple instability episodes with decreasing force necessary for each episode; or if they had both findings. This study further supports experimental biomechanical observations on the relevance of the normal anterior glenoid contour and how its loss leads to instability.[12,18,21,29,35,36]

Historically, the qualitative assessment of one-third glenoid bone loss of Rowe et al[41] as a basis for deciding about soft tissue repair was used as the surgeon's best method. This factor might be expected to underestimate the degree of glenoid loss and cause the surgeon to err on the side of a biomechanically weak reconstruction using a conventional Bankart repair technique. Indeed, Burkhart and DeBeer[9] observed a failure rate of more than 80% in athletically active individuals who had anterior glenoid erosion treated with arthroscopic Bankart repair.

Although Burkhart et al[10] have presented arthroscopic criteria for determination of anterior glenoid bone loss with the observation of an inverted-pear glenoid, the process requires intraoperative decision making to determine if an open or arthroscopic method of repair is most appropriate. We have observed that CT scan imaging of patients suspected of having severe glenoid bone loss can identify candidates for glenoid reconstruction preoperatively, as our intraoperative measurements correlated with our preoperative CT scan measurements. We believe this may be a more practical method for determining needs before surgery and allowing informed discussion with the patient.[22] As the intraoperative procedure and the postoperative course are significantly different, it is helpful to know this information preoperatively so that appropriate planning and counseling can occur.

As the incidence of significant glenoid bone loss that requires treatment is relatively low, there are few reports in the literature that outline a management plan. The Bristow-Helfet and the Latarjet procedures involve transfer of the coracoid process and conjoined tendon through the subscapularis tendon and onto the anterior scapular neck. Although these techniques have been recommended as methods for the treatment of traumatic anterior instability, they have also been recommended for treatment of significant glenoid erosion.** The mechanisms of stability with coracoid process transfers are through the creation of an anterior bone block as well as both the passive sling effect and active stabilizing effect of the conjoined tendon. Although several series have reported very satisfactory outcomes with these techniques, some have observed significant problems, including loss of motion, hardware impingement and loosening, nonunion of the bone graft, and arthritis. Furthermore, revision surgery can be very challenging because of scarring and distortion of the anatomy around the subscapularis muscle and the brachial plexus.[51]

The technique of anatomical reconstruction of the deficient anterior glenoid using a tricortical autogenous iliac crest bone graft was developed in response to some of the limitations seen with the coracoid process transfer procedures and has been very successful in our experience. The long-term effects of an intra-articular graft are yet to be seen, but in the short term, placing the bone graft intra-articularly seems to lead to a high rate of successful union and stability, as evidenced by our study. Given the severity of the bone loss in some of the subjects, it will be difficult to determine whether joint arthrosis is the result of the initial trauma and loss of articular congruity or whether it is owing to the humeral head articulating with the neoglenoid that is formed with the bone graft. Although it is possible to place the bone graft extra-articularly, there are no peer-reviewed publications on the outcomes using that technique, and such constructs may inhibit bone union. In the present study, the subjective outcome was satisfactory in all patients, and all were able to return to sports participation, including 3 professional hockey players who all underwent this bone graft procedure as a revision surgery.

In this series, the biomechanical rationale defined by Gerber and Nyffeler[18] to show significant loss of the glenoid concavity and articular surface served as the basis for determining the need for bone graft reconstruction of the glenoid, regardless of revision or primary status. Therefore, we conclude that this method of quantifying bone loss is useful clinically and, furthermore, that this surgical technique for addressing anterior glenoid bone loss is a reasonable alternative to coracoid transfer procedures for treatment of the relatively rare condition of anterior glenoid insufficiency. Long-term results await further follow-up.

REFERENCES

1. Allain J, Goutallier D, Glorion C. Long-term results of the Latarjet procedure for the treatment of anterior instability of the shoulder. *J Bone Joint Surg Am*. 1998;80:841-852.
2. Altchek DW, Warren RF, Skyhar MJ, Ortiz G. T-plasty modification of the Bankart procedure for multidirectional instability of the anterior and inferior types. *J Bone Joint Surg Am*. 1991;73:105-112.
3. Apreleva M, Hasselman CT, Debski RE, Fu FH, Woo SLY, Warner JJP. A dynamic analysis of glenohumeral motion after simulated capsulolabral injury: a cadaver model. *J Bone Joint Surg Am*. 1998;80:474-480.

**References 1, 9, 10, 19, 25-27, 38, 42, 43, 50.

4. Aston JW Jr, Gregory CF. Dislocation of the shoulder with significant fracture of the glenoid. *J Bone Joint Surg Am*. 1973;55:1531-1533.
5. Bankart ASB. The pathology and treatment of recurrent dislocation of the shoulder joint. *Br J Surg*. 1938;26:23-29.
6. Bigliani LU, Kurzweil PR, Schwartzbach CC, Wolfe IN, Flatow EL. Inferior capsular shift procedure for anterior-inferior shoulder instability in athletes. *Am J Sports Med*. 1994;22:578-584.
7. Bigliani LU, Newton PM, Steinmann SP, Connor PM, McIlveen SJ. Glenoid rim lesions associated with recurrent anterior dislocation of the shoulder. *Am J Sports Med*. 1998;26:41-45.
8. Bigliani LU, Pollock RG, Soslowsky U, Flatow EL, Pawluk RJ, Mow VC. Tensile properties of the inferior glenohumeral ligament. *J Orthop Res*. 1992;10:187-197.
9. Burkhart SS, DeBeer JF. Traumatic glenohumeral bone defects and their relationship to failure of arthroscopic Bankart repairs: significance of the inverted-pear glenoid and the humeral engaging Hill-Sachs lesion. *Arthroscopy*. 2000;16:677-694.
10. Burkhart SS, DeBeer JF, Tehrany AM, Parten PM. Quantifying glenoid bone loss arthroscopically in shoulder instability. *Arthroscopy*. 2002; 18:488-491.
11. Cole BJ, Millett PJ, Romeo AA, et al. Arthroscopic treatment of anterior glenohumeral instability: indications and techniques. *Instr Course Lect*. 2004;53:545-558.
12. Edelson JG. Bony changes of the glenoid as a consequence of shoulder instability. *J Shoulder Elbow Surg*. 1996;5:293-298.
13. Ellman H, Hanker G, Bayer M. Repair of the rotator cuff: end-result study of factors influencing reconstruction. *J Bone Joint Surg Am*. 1986;68:1136-1144.
14. Field LD, Boker DJ, Savoie FH. Humeral and glenoid detachment of the anterior inferior glenohumeral ligament: a cause of anterior shoulder instability. *J Shoulder Elbow Surg*. 1997;6:6-10.
15. Flatow EL, Warner JJP. Instability of the shoulder: complex problems and failed repairs, part I: relevant biomechanics, multidirectional instability, and severe bone of the glenoid and humeral bone. *J Bone Joint Surg*. 1998;80:122-140.
16. Gartsman GM, Roddey TS, Hammerman SM. Arthroscopic treatment of anterior-inferior glenohumeral instability: two to five year follow-up. *J Bone Joint Surg Am*. 2000;82:991-1003.
17. Gerber C, Krushell RJ. Isolated rupture of the tendon of the subscapularis muscle: clinical features in 16 cases. *J Bone Joint Surg Br*. 1991;73:389-394.
18. Gerber C, Nyffeler RW. Classification of glenohumeral joint instability. *Clin Orthop Relat Res*. 2002;400:65-76.
19. Gerber C, Terrier F, Ganz R. The Trillat procedure for recurrent anterior instability of the shoulder. *J Bone Joint Surg Br*. 1988;70:130-134.
20. Gill T, Micheli L, Gebhard F, Binder C. Bankart repair for anterior instability of the shoulder: long-term outcome. *J Bone Joint Surg*. 1997;79: 850-857.
21. Greis PE, Scuderi MG, Mohr A, Bachus KN, Burks RT. Glenohumeral articular contact areas and pressures following labral and osseous injury to the anteroinferior quadrant of the glenoid. *J Shoulder Elbow Surg*. 2002;11:442-451.
22. Griffith JF, Antonio GE, Tong CWC, Ming CK. Anterior shoulder dislocation: quantification of glenoid bone loss with CT. *AJR Am J Roentgenol*. 2003;180:1423-1430.
23. Haaker RG, Eickhoff U, Klammer HL. Intraarticular autogenous bone grafting in recurrent shoulder dislocations. *Mil Med*. 1993;158:164-169.
24. Habermeyer P, Gleyze P, Rickert M. Evolution of lesions of the labrum-ligament complex in posttraumatic anterior shoulder instability: a prospective study. *J Shoulder Elbow Surg*. 1999;8:66-74.
25. Hovelius L, Körner L, Lundberg B, et al. The coracoid transfer for recurrent dislocation of the shoulder. *J Bone Joint Surg Am*. 1983;65: 926-934.
26. Hovelius L, Sanstrom B, Sundgren K, Saeboe M. One hundred eighteen Bristow-Latarjet repairs for recurrent anterior dislocation of the shoulder prospectively followed for fifteen years: Study 1–Clinical Results. *J Shoulder Elbow Surg*. 2004;13:509-516.
27. Hovelius LK, Sandström BC, Rösmark DL, Saebö M, Sundgren KH, Malmqvist BG. Long-term results with the Bankart and Bristow-Latarjet procedures: recurrent shoulder instability and arthropathy. *J Shoulder Elbow Surg*. 2001;10:445-452.
28. Hutchinson JW, Neumann L, Wallace WA. Bone buttress operation for recurrent anterior shoulder dislocation in epilepsy. *J Bone Joint Surg Br*. 1995;77:928-932.
29. Itoi E, Lee SB, Amrami KK, Wenger DE, An KN. Quantitative assessment of classic anteroinferior bony Bankart lesions by radiography and computed tomography. *Am J Sports Med*. 2003;31:112-118.
30. Itoi E, Lee SB, Berglund LJ, Berge LL, An KN. The effect of glenoid defect on anteroinferior stability of the shoulder after Bankart repair: a cadaver study. *J Bone Joint Surg Am*. 2000;82:35-46.
31. Jobe FW, Bradley JP. The diagnosis and nonoperative treatment of shoulder injuries in athletes. *Clin Sports Med*. 1989;8:419-438.
32. Jobe FW, Kvitne RS, Giangarra CE. Shoulder pain in the overhand or throwing athlete: the relationship of anterior instability and rotator cuff impingement. *Orthop Rev*. 1989;18:963-975. Erratum: *Orthop Rev*. 1989;18:1268.
33. Kim SH, Ha KI, Cho YB, Ryu BD, Oh I. Arthroscopic anterior stabilization of the shoulder: two to six year follow-up. *J Bone Joint Surg Am*. 2003;85:1511-1518.
34. Kummel BM. Fractures of the glenoid causing chronic dislocation of the shoulder. *Clin Orthop Relat Res*. 1970;69:189-191.
35. Lazarus MD, Sidles JA, Harryman DT II, Matsen FA III. Effect of chondral-labral defect on glenoid concavity and glenohumeral stability: a cadaveric model. *J Bone Joint Surg Am*. 1996;78:94-102.
36. Lippitt SB, Vanderhooft JE, Harris SL, Sidles JA, Harryman DT II, Matsen FA III. Glenohumeral stability from concavity-compression: a quantitative analysis. *J Shoulder Elbow Surg*. 1993;2:27-35.
37. Millett PJ, Clavert P, Warner JJP. Arthroscopic management of anterior, posterior, and multidirectional shoulder instability: pearls and pitfalls. *Arthroscopy*. 2003;19(suppl 1):86-93.
38. Nielsen AB, Nielsen K. The modified Bristow procedure for recurrent anterior dislocation of the shoulder. *Acta Orthop Scand*. 1982;53: 229-232.
39. Pollack RG, Wang VM, Bucchieri JS, et al. Effects of repetitive subfailure strains on the mechanical behavior of the inferior glenohumeral ligament. *J Shoulder Elbow Surg*. 2000;9:427-435.
40. Richards RR, An KN, Bigliani LU, et al. A standardized method for assessment of shoulder function. *J Shoulder Elbow Surg*. 1994;3: 347-352.
41. Rowe CR, Patel D, Southmayd WW. The Bankart procedure: a long-term end result study. *J Bone Joint Surg Am*. 1978;60:1-16.
42. Schauder KS, Tullos HS. Role of the coracoid bone block in the modified Bristow procedure. *Am J Sports Med*. 1992;20:31-34.
43. Singer GC, Kirkland PM, Emery RJH. Coracoid transposition for recurrent anterior instability of the shoulder: a 20 year follow-up study. *J Bone Joint Surg Br*. 1995;77:73-76.
44. Speer KP, Deng X, Borrero S, Torzilli PA, Altchek DA, Warren RF. Biomechanical evaluation of a simulated Bankart lesion. *J Bone Joint Surg Am*. 1994;76:1819-1826.
45. Speer KP, Hannafin JA, Altchek DW, Warren RF. An evaluation of the shoulder relocation test. *Am J Sports Med*. 1994;22:177-183.
46. Sugaya H, Moriishi J, Dohi M, Kon Y, Tsuchiya A. Glenoid rim morphology in recurrent anterior glenohumeral instability. *J Bone Joint Surg Am*. 2003;85:878-884.
47. Warner JJP, Beim GM. Combined Bankart and HAGL lesion associated with anterior shoulder instability. *Arthroscopy*. 1997;13:749-752.
48. Warner JJP, Caborn DNM, Berger R, Fu FH, Seel M. Dynamic capsuloligamentous anatomy of the glenohumeral joint. *J Shoulder Elbow Surg*. 1993;2:115-133.
49. Warner JJP, Johnson D, Miller MD, Caborne DNM. A technique for selecting capsular tightness in repair of anterior-inferior shoulder instability. *J Shoulder Elbow Surg*. 1995;4:352-364.
50. Wredmark T, Tornkvist H, Johansson C, Brobert B. Long-term functional results of the modified Bristow procedure for recurrent dislocation of the shoulder. *Am J Sports Med*. 1992;20:157-161.
51. Young CD, Rockwood CA Jr. Complications of a failed Bristow procedure and their management. *J Bone Joint Surg Am*. 1991;73:969-981.