Arthroscopic anatomic glenoid reconstruction using an autologous iliac crest bone grafting technique

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Background: Open bone block procedures for glenohumeral stabilization have been used for a long time. With the advancement of arthroscopic techniques and the development of sophisticated instruments and implants, the insertion of the bone block can be performed by an all-arthroscopic approach. The purpose of this study was to evaluate the clinical and radiologic results after an arthroscopic anatomic glenoid reconstruction using an all-arthroscopic, autologous tricortical iliac crest bone grafting technique.

Materials and methods: Fifteen patients (1 female and 14 male patients; mean age, 31.4 years [range, 17-49 years]) underwent reconstruction of significant glenoid defects in cases of recurrent shoulder instability by the aforementioned technique. The patients were followed up clinically (range of motion, Constant score, Rowe score, Subjective Shoulder Value, and Western Ontario Shoulder Instability Index) and radiographically (with true anteroposterior and axillary views, as well as 2-/3-dimensional computed tomography [glenoid configuration, signs of graft resorption, bone consolidation, and glenoid index]).

Results: After a mean follow-up period of 20.6 months (range, 12-65 months), the Constant score averaged 85.0 points (range, 73-98 points; contralateral side, 89.6 points [range, 78-96 points]); the Rowe score averaged 88.0 points (range, 65-100 points), the Subjective Shoulder Value averaged 84.5% (range, 50%-100%), and the Western Ontario Shoulder Instability Index averaged 76.7% (range, 46%-93%). No recurrent subluxations or dislocations were observed. Radiographically, computed tomography imaging showed a consolidated autograft in all cases. The glenoid index increased from a mean of 0.77 preoperatively to 1.16 immediately postoperatively; at the time of last follow-up, the glenoid index decreased to 1.04.

Conclusion: The arthroscopic reconstruction of anteroinferior glenoid defects re-creates the pear-shaped anatomy of the anteroinferior glenoid and leads to good to excellent early clinical results.

Level of evidence: Level IV, Case Series, Treatment Study.

Keywords: Shoulder instability; glenoid defect; arthroscopic stabilization; bone block procedure

 Bone block procedures initially were described as a treatment option for ligamentous shoulder instability as a mechanical dislocation barrier. Because of a better understanding of pathomechanisms and pathophysiology, soft-tissue repair became the main stabilization procedure...
for acute instability. Until recently, open bone graft techniques were used in cases of chronic recurrent shoulder instability, especially those with significant glenoid defects.\textsuperscript{1,4,12,21,24} Recently published clinical and radiologic studies were able to show that an anatomic reconstruction of the glenoid concavity using a pre-shaped iliac crest autograft represents an effective and durable treatment option for glenoid-deficient anterior shoulder instability.\textsuperscript{11,12,20} With the advancement of arthroscopic techniques and the development of sophisticated instruments and implants, bone block grafting can now be performed by an all-arthroscopic approach.\textsuperscript{1,12,23}

Thus far, 3 different techniques have been published in the literature. Besides an anatomic intra-articular tricortical iliac crest bone grafting technique,\textsuperscript{19} Taverna et al\textsuperscript{23} described extra-anatomic extracapsular positioning of the bone block using a pulling technique. The J-graft technique, established as an open technique by Resch et al,\textsuperscript{14} has recently been described using an all-arthroscopic implant-free technique, which requires transglenoid drilling.\textsuperscript{1} Up to now, no clinical or radiologic results of a case series have been published.

The aim of this study was to evaluate the clinical and radiologic results after an anatomic glenoid reconstruction using an autologous tricortical iliac crest bone grafting technique through an all-arthroscopic approach.

**Material and methods**

From April 2007 to November 2010, 15 patients (1 female and 14 male patients; mean age, 31.4 years [range, 17.7-49.7 years]) with a glenoid defect were treated by an arthroscopic iliac crest bone grafting technique. During the study period, no patient was excluded after treatment was indicated. The indication for treatment was based on a previously published classification of glenoid defects.\textsuperscript{20} At our institution, an arthroscopic iliac crest bone graft is indicated in cases of acute glenoid injury if a non-reconstructible multifragmentary situation (type Ic) is present. Furthermore, it is indicated in chronic fragment-type defects (type II) in which the fragment is too small for anatomic reconstruction in comparison with the osseous defect and in erosion-type defects without any fragment if the defect size exceeds 25%. In patients with an erosion-type defect of less than 25% (type IIIa), an iliac crest bone graft can be indicated if prior arthroscopic stabilization failed.

In our patient group, there were 5 type II, 1 type IIIa, and 9 type IIIb cases. In 8 shoulders, the dominant side was affected. On average, patients had shoulder dislocation 6.2 times (range, 1-30 times) before undergoing surgery. Patients underwent, on average, 1.5 previous arthroscopic or open stabilization procedures (range, 0-4 procedures). One patient underwent 3 open stabilizations and 1 arthroscopic stabilization before surgery.

The diagnosis of recurrent anteroinferior shoulder instability was established by history, physical examination, standard radiographs (true anteroposterior and axillary views), and 2-/3-dimensional computed tomography (CT). The glenoid rim lesion was diagnosed preoperatively on 2-/3-dimensional CT.

**Surgical technique**

Under general anesthesia with perioperative antibiotics, the patient is placed in the lateral decubitus position. The arm and the ipsilateral iliac crest are prepared and draped in a sterile fashion. The arm is placed in a STAR Sleeve (Arthrex, Naples, FL, USA) in 30° of abduction and 20° of external rotation with 5 kg of horizontal and 3 kg of vertical traction applied (Fig. 1).

A standard posterior portal and anterosuperior, anteroinferior, and deep anteroinferior portals are necessary to perform the procedure. A diagnostic arthroscopy is performed through a standard posterior portal. Concomitant lesions such as rotator cuff tears, biceps tendon pathologies, and capsulolabral lesions should be addressed after the graft attachment to avoid additional soft-tissue swelling. An anteroinferior working portal is created superior to the subscapularis tendon by an outside-in technique, and a transparent 8.25-mm × 7-cm Twist-In Cannula (Arthrex) is inserted. After creation of an anterosuperior viewing portal, the camera is placed anterosuperiorly by use of a switching stick. Next, a second transparent Twist-In Cannula is inserted into the posterior portal under direct visualization. The anterior and anteroinferior glenoid rim and the capsuloligamentous complex can now be evaluated thoroughly. If significant bony defects are present, a so-called inverted-pear glenoid or banana-shaped glenoid may be found. The next step of the procedure depends on the pathology and morphology of the defect. If an anterior labroligamentous periosteal sleeve avulsion (ALPSA) lesion is found in combination with an erosion-type glenoid defect, the labrum is mobilized from the glenoid neck up to the 6-o’clock position, using either a rasper or electrothermic instruments (Fig. 2, A). If a chronic fragment-type lesion is present, any further steps depend on the size and position of the fragment. Smaller fragments are resected to create a flat surface for the bone graft on the scapular neck. Alternatively, the fragment may be mobilized and reattached together with the capsuloligamentous complex at a later stage. Larger fragments that are healed in a medial position (>1 cm) are left in place, and the labrum is mobilized alone. After placement of the bone block anterior to the scapular neck, those fragments may provide support against a medial dislocation of the graft and facilitate temporary K-wire stabilization, as well as definitive screw fixation. In rare cases of non-reconstructible multiligamentous glenoid fractures, loose osteochondral fragments are resected whereas fragments attached to the labrum are left in place and reattached against the bone block later.

Next, the glenoid rim and the scapular neck are prepared using a motorized burr to ensure adequate bony healing (Fig. 2, B). Adjacent chondral defects are debrided with a shaver and, if necessary, undergo microfracture at the end of the procedure. Afterward, a deep anteroinferior portal is created through the inferior parts of the subscapularis. A spinal needle is used for correct portal direction. The skin is incised with the needle in place, and a switching stick is introduced parallel to it. The switching stick is inserted into the glenohumeral joint through the subscapularis under direct visualization. An 8.25-mm × 9-cm transparent Twist-In Cannula is inserted (Fig. 2, C).

Next, a 2.5- to 3-cm × 1- to 1.5-cm × 1- to 1.5-cm tricortical iliac crest bone block is harvested and appropriately contoured (Fig. 3, C). After hemostasis and insertion of a drain, the wound is closed in a standard fashion. Meanwhile, the graft is cleaned of soft tissue and contoured (Fig. 3, B).
The arthroscope is again inserted into the glenohumeral joint through the posterior portal. The Twist-In Cannula in the rotator interval is temporarily removed and the skin incision enlarged approximately 1 cm to allow passage of the graft. Under direct visualization, the passage of the graft is dilated either with expending scissors or bluntly using the surgeon’s index finger. The pre-shaped bone block is inserted with a straight clamp and placed between the scapular neck and subscapularis and...

Figure 1  Lateral decubitus position with arm and iliac crest prepared and draped. (Reprinted with permission from Springer.)

Figure 2  (A) Release of capsulolabral complex from scapular neck. (B) Preparation of scapular neck using motorized burr. (C) Deep anteroinferior portal through inferior part of subscapularis tendon.
capsuloligamentous complex. Again, the arthroscope is introduced in the anterosuperior portal, and the Twist-in Cannula is reinserted in the anteroinferior portal using a switching stick. The incision is closed near the cannula to avoid its loosening during further instrumentation using a No. 3-0 Ethilon suture (Ethicon, Somerville, NJ, USA). Now, the graft is placed anatomically on the scapular neck (Fig. 4, A). The level of the bone block in relation to the glenoid surface is ensured with the aid of a switching stick introduced through the posterior portal. A significant lateral step-off has to be corrected using a burr after definitive graft fixation. After correct positioning of the bone block, a special drill sleeve (Twist-Drill Guide; Arthrex) is introduced through the deep anteroinferior portal and placed at the caudal end of the graft. The integrated K-wire placement sleeve has to lie at the transition of the distal to the medial third of the bone block point superiorly. The Twist-Drill Guide is pressed onto the graft, and a 1.0-mm K-wire is driven in as far as the posterior cortical wall of the scapular neck for temporary bone block fixation. Another 1.0-mm K-wire is placed through the actual drill sleeve. To ensure parallel placement, the K-wire may be placed with the cannulated drill. If necessary, a 1.6-mm K-wire can be placed through the anteroinferior portal or percutaneously to guarantee rotational stability of the bone block. The inferior K-wire is overdrilled using a cannulated drill under direct visualization (Fig. 4, B). Next, the thread cutter is inserted manually over the K-wire. The K-wire is removed, and the first 3.0-mm to 3.7-mm × 26-mm Bio-Compression screw (Arthrex) is inserted and placed 1 to 2 mm below glenoid level (Fig. 4, C).

The Twist-Drill Guide is now rotated 180° clockwise (right shoulder) or counterclockwise (left shoulder), with the first K-wire remaining in the K-wire placement sleeve as a rotational center (Fig. 5, A). The second drill hole is placed parallel and superior to the first drill hole in the same way, and the second Bio-Compression screw can be inserted parallel to the first screw (Fig. 5, B). The graft surface can be smoothed with a shaver, and if necessary, a lateral step-off may be removed and the bone block made level with the glenoid surface. The capsuloligamentous complex is penetrated inferior to the bone block with a 25° SutureLasso (Arthrex), and a No. 2 FiberWire (Arthrex) is brought in as a loop. First, the anteroinferior labrum is reattached to the
original glenoid rim using a knotless 2.9 × 15.5-mm PushLock anchor (Arthrex). Two additional knotless anchors are used for reconstruction of the anterosuperior labrum so that the anterior part of the graft is partly covered (Fig. 5, C).

After glenoid rim reconstruction, other accompanying lesions such as chondral defects, rotator cuff tears, biceps tendon pathologies, or humeral avulsion of the glenohumeral ligament (HAGL) lesions can be addressed. Finally, the arthroscopic portals are closed in a standard fashion.

Postoperative management

Postoperative management includes immobilization in a sling (UltraSling ER 15; DJO, Vista, CA, USA) for 6 weeks. Physical therapy involves passive range-of-motion exercises during that time. Flexion in internal rotation is limited to 90°, and external rotation in adduction is limited to 20°. At week 7, active range-of-motion exercises are initiated. After 12 weeks, an intensive strengthening program including the deltoid, rotator cuff, and scapulothoracic muscles is started.

Clinical evaluation

All patients are routinely evaluated preoperatively, postoperatively within 3 weeks, and at 6 and 12 months postoperatively. At the time of final follow-up, all individuals undergo a complete physical examination of both shoulders. The active range of flexion, abduction, glenohumeral abduction, and external rotation in 0° and 90° of abduction are measured and compared with the contralateral side. Signs of persisting instability such as recurrent dislocation or a positive apprehension sign are noted as well. The clinical evaluation is performed by a single surgeon who is not the operating surgeon. The overall function of the shoulder is assessed by the Constant score, Rowe score, Subjective Shoulder Value, and Western Ontario Shoulder Instability Index.

Radiologic evaluation

True anteroposterior and axillary views are used at the latest follow-up to assess the presence of glenohumeral osteoarthritis and the sclerotic glenoid line sign.15 Signs of osteoarthritis are graded according to the classification of Samilson and Prieto.16 Two- and three-dimensional CT imaging is performed preoperatively, postoperatively after 6 and 12 months; and where applicable, at the latest follow-up. Preoperatively, the maximum glenoid width (GW), maximum glenoid length (GL), and maximum glenoid area (GA), as well as the glenoid index (GI) according to Chuang et al.3 are measured (Fig. 6, A and B). During the follow-up CT scans, the aforementioned measures, as well as the area of the bone graft (AG), are obtained (Fig. 6, C). In addition, the glenoid configuration and any signs of graft resorption and bony union are evaluated.

Results

Patient population

After a mean follow-up period of 20.6 months (range, 12-65 months), 15 patients (1 female and 14 male patients; mean age, 31.4 years [range, 17-49 years]) were included in this study. During arthroscopy, 8 Hill-Sachs lesions (1 type I, 1 type II, and 6 type III according to Calandra et al.2) and 9 anterior labroligamentous periosteal sleeve avulsion (ALPSA) lesions were found. None of these required a change in procedure or additional treatment. Intra-articular concomitant lesions consisted of 1 posterior HAGL lesion, 1 superior labrum anterior-posterior lesion (type IV), and 1 partial tear of the long head of the biceps. The posterior HAGL lesion was reconstructed with suture anchors.
a mattress-stitch configuration. The superior labrum anterior-posterior type IV lesion was reattached with PDS sutures (Ethicon). The partial tear of the long head of the biceps was treated with arthroscopic suture anchor tenodesis.

**Clinical results**

At the final follow-up, the mean active range of flexion was 177° (range, 160°-180°) on the affected side compared with 179° (range, 170°-180°) on the contralateral side (P = .90). The mean active range of abduction was 174° (range, 160°-180°) on the affected side compared with 177° (range, 170°-180°) on the contralateral side (P = .95). The mean active range of glenohumeral abduction was 95° (range, 90°-110°) on the affected side compared with 98° (range, 90°-110°) on the contralateral side (P = .92). The mean active range of external rotation was 52° (range, 30°-85°) on the affected side compared with 74° (range, 50°-90°) on the contralateral side (P = .08). The mean active range of external rotation in 90° of abduction was 70° (range, 30°-90°) on the affected side compared with 75° (range, 45°-90°) on the contralateral side (P = .23). No recurrent subluxations or dislocations were observed. The score results are presented in Figure 7.

**Radiologic results**

In 8 patients, no signs of glenohumeral osteoarthritis could be detected. Two patients had grade I and one patient had grade II osteoarthritis according to Samilson and Prieto. In the remaining 4 shoulders, pre-existing arthritis (grade I) showed no signs of progression during the time of follow-up. Complete re-formation of the anterior sclerotic glenoid line could be detected in 13 shoulders. Two shoulders had an incomplete re-formation of the sclerotic glenoid line.

CT imaging obtained at final follow-up showed a consolidated autograft in all cases. Preoperative CT scans showed a mean GW of 22.1 mm (range, 18.2-25.6 mm), GL of 39.3 mm (range, 32.8-46.0 mm), GA of 734 mm² (range, 481-957 mm²), and GI of 0.78 (range, 0.69-0.83) on the affected side. The contralateral side reached, on average, a GW of 28.3 mm (range, 22.4-31.8 mm) (P < .001), GL of 39.4 mm (range, 31.8-44 mm) (P = .23), and GA of 837 mm² (range, 532-978 mm²) (P = .008). After a mean of 3.9 days (range, 1-12 days) postoperatively, the affected side showed a mean GW of 32.4 mm (range, 25.6-38.3 mm), GL...
of 39.0 mm (range, 32.7-46.1 mm), GA of 997 mm$^2$ (range, 634-1,344 mm$^2$), and GI of 1.15 (range, 1.04-1.39). In comparison with the contralateral side, all measures except GL were significantly larger (GW, $P < .001$; GL, $P = .14$; GA, $P = .006$; and GL, $P < .001$). The mean AG was 247.5 mm$^2$ (range, 139.5-335.2 mm$^2$). Six months postoperatively, the GW was 30.9 mm (range, 27.6-34.0 mm), the GL was 40.0 mm (range, 34.7-44.8 mm), the GA was 964 mm$^2$ (range, 854-1,159 mm$^2$), and the GI was 1.09 (range, 0.94-1.43). In comparison with the contralateral side, this still showed a significant difference for some measures (GW, $P = .04$; GL, $P = .48$; and GA, $P = .032$). The GI showed a significant difference compared with preoperatively ($P < .001$). However, there was no significant difference between the GI postoperatively and that after 6 months ($P = .095$). The AG was measurable in 2 patients only (175.0 mm and 229.3 mm).

After 12 months, the GW measured 28.8 mm (range, 22.8-37.0 mm), the GL was 39.3 mm (range, 31.8-46.0 mm), the GA was 859 mm$^2$ (range, 532-1,193 mm$^2$), and the GI was 1.07 (range, 0.95-1.22). These differences were not statistically significant anymore (GW, $P = .97$; GL, $P = .90$; and GA, $P = .91$). At the latest follow-up after 20.6 months (range, 12-65 months), the GW was 28.8 mm (range, 22.8-36.5 mm), the GL was 38.9 mm (range, 31.8-45.1 mm), the GA was 850 mm$^2$ (range, 532-1,050 mm$^2$), and the GI was 1.04 (range, 0.94-1.16) (Figs. 8-11). We found these results to resemble an extracapsular partial resorption of the bone graft in terms of anatomic glenoid remodeling close to the contralateral healthy side (Fig. 12).

**Complications**

The only neurologic deficit was hypoesthesia of the iliac crest in 1 patient. A second patient complained of a “loose” shoulder 8 months postoperatively and was treated with plication of the capsule. The shoulder has been stable since. During arthroscopy, partial chondral coverage of the bone graft was noted.

**Discussion**

Re-establishing the bony buttress to accommodate the axial and shear forces present in the glenohumeral joint is the
ultimate goal in the treatment of anteroinferior glenoid deficiency. Different open and arthroscopic surgical techniques for approaching glenoid rim defects have been reported in the literature.1,4,5,8,12,14,19,21,23,24 Clinical studies using open stabilization surgery indicate that anterior approaches to the shoulder using a subscapularis tendon takedown or incision techniques may impair subscapularis recovery. This may cause irreversible changes of the muscle—in particular, fatty infiltration—with or without failure of the tendon repair, all of which may result in permanent loss of subscapularis function.10,13,15,17,22 In addition to the possible general advantages of arthroscopy, including better cosmesis, lower risk of infection, less scar formation, the possibility to allow a rapid return home, and an accelerated rehabilitation program, it has been shown that an all-arthroscopic approach does not significantly compromise subscapularis function and the structural integrity of the subscapularis musculotendinous unit.22

To date, 3 arthroscopic stabilization techniques using a free bone graft have been published in the literature.1,19,23 This study confirmed the good to excellent clinical results and the stable shoulder function equivalent to that seen with an open procedure.21,23,24 However, radiologically, we found an extracapsular partial resorption of the bone graft in terms of an anatomic glenoid remodeling that resembled the contralateral healthy side. In concordance with Wolff’s law, we think that bone that is not loaded is resorbed.6,7 In this study, Bio-Compression screws were used for graft fixation. However, some authors have used metallic screws in the past.4,24 The problem of bone resorption and resulting screw prominence with consecutive joint damage and osteoarthritis might thus evolve. Whether resorption of the Bio-Compression screws leads to osteolysis and insufficiency of the bone block remains to be shown in future studies.

A limitation of our study is that the case series was small and there was no cohort for comparison. However, indications for arthroscopic iliac crest bone grafting at our institution are non-reconstructible multifragmentary acute glenoid defects (type II), chronic fragment-type glenoid defects (type III), and erosion-type glenoid defects (type III), which are not common injuries.

**Conclusion**

The all-arthroscopic reconstruction of anteroinferior glenoid defects using an autologous iliac crest bone grafting technique re-creates the anatomy of the anteroinferior glenoid and leads to good to excellent early clinical results while preserving the integrity of the insertion of the subscapularis tendon.

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