LONG-TERM RESULTS OF TOTAL SHOULDER ARTHROPLASTY FOLLOWING BONE-GRAFTING OF THE GLENOID

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Background: The marked loss of glenoid bone volume or alteration of glenoid version can affect glenoid component fixation in patients undergoing total shoulder arthroplasty. The purpose of this study was to evaluate the long-term results associated with the use of bone-grafting for restoration of glenoid volume and version at the time of total shoulder arthroplasty.

Methods: Twenty-one shoulders received an internally fixed, corticocancellous bone graft for the restoration of peripheral glenoid bone stock at the time of total shoulder arthroplasty between 1980 and 1989. Grafting was indicated when glenoid bone stock was insufficient to maintain adequate version or fixation of the prosthesis. Seventeen shoulders were available for follow-up; the average duration of follow-up for the thirteen shoulders that did not have prosthetic failure within the first two years was seventy months. Total shoulder arthroplasty was performed because of osteoarthritis in five shoulders, chronic anterior fracture-dislocation in five, capsulorrhaphy arthropathy in three, inflammatory arthritis in two, recurrent dislocation in one, and failure of a previous arthroplasty in one. All patients had some form of anterior or posterior instability preoperatively. There were five anterior and twelve posterior glenoid defects. Bone from the resected humeral head was used for grafting in fifteen shoulders, and bicortical iliac-crest bone was used in two.

Results: The average glenoid version after grafting was 4° of retroversion, with an average correction of 33°. The graft failed to maintain the original correction in three shoulders due to nonunion, dissolution, or shift. Five total shoulder replacements failed, necessitating glenoid revision at two to ninety-one months postoperatively. The failures were associated with recurrent massive cuff tears (one shoulder), persistent instability (two shoulders), improper component placement (one shoulder), and loss of graft fixation (one shoulder). There were no humeral component failures. According to the criteria of Neer et al., the functional result was rated as excellent in three shoulders, satisfactory in six, and unsatisfactory in eight.

Conclusions: Despite the finding that eight shoulders had an unsatisfactory functional result at the time of long-term follow-up, corticocancellous grafting of the glenoid successfully restored glenoid version and volume in fourteen of the seventeen shoulders in the present study. Patients with glenoid deficiency often have associated glenohumeral instability, which may affect the results of total shoulder arthroplasty. Bone-grafting of the glenoid is a technically demanding procedure that can restore bone stock in patients with structural defects.

Total shoulder replacement was introduced by Neer in 1974 for the treatment of arthritic conditions involving the glenoid and humeral articular surfaces[1]. Several authors have reported excellent pain relief and improved motion in association with this procedure[2-12].

The glenoid component has been the object of much scrutiny and is the most common source of failure of total shoulder arthroplasty. Asymmetric glenoid wear or loss of bone stock can contribute to common complications involving the glenoid component. The reported rate of glenoid component loosening, defined as dislocation, migration, or a complete progressive radiolucent line measuring ≥2 mm in width, is approximately 10% (seventy-eight of 761 reported cases)[2-13]. Inadequate glenoid bone stock and a lack of congruent component contact have been associated with an increased rate of component loosening[14-16]. The rate of glenohumeral instability after shoulder arthroplasty has been reported to be approximately 3% (sixteen of 498 reported cases)[3,6-9,11,13]. Improper glenoid component version due to asymmetric bone wear can be a source of joint instability[16-20].

Several conditions result in abnormal glenoid fossa wear[16]. Rheumatoid arthritis most commonly results in central glenoid erosion. Primary osteoarthritis is typically associated with progressive posterior glenoid wear. Arthropathy related to recurrent or chronic dislocation of the shoulder can result in excessive anterior or posterior wear, depending on the direction of the instability. Severe erosion can make proper seating of the glenoid component difficult. Tech-

TABLE I Data on the Patients

Case	Sex, Age at Surgery *(yr)*	Duration of Follow-up *(mo)*	Diagnosis	Previous Surgery	Glenoid Defect			
					Location	Version *(deg)*	Extent *(% of glenoid surface)*	Depth *(mm)*
1	F, 33	60	Chronic dislocation		Anterior	50	57	14
2*	M, 35	†	Failure of previous arthroplasty	Total shoulder arthroplasty	Posterior	22	100	10
3*	M, 30	91	Recurrent dislocation		Posterior	30	61	15
4	F, 84	34	Chronic dislocation		Anterior	42	33	10
5	M, 75	50	Osteoarthritis	Distal clavicular resection	Posterior	26	80	13
6	M, 46	87	Osteoarthritis		Posterior	18	100	10
7	M, 63	95	Osteoarthritis		Posterior	32	100	10
8	F, 79	25	Inflammatory arthritis		Posterior	50	100	15
9	F, 66	60	Chronic dislocation		Anterior	47	40	25
10	F, 48	108	Capsulorrhaphy arthropathy	Putti-Platt	Posterior	30	100	13
11	M, 65	77	Osteoarthritis		Posterior	35	100	15
12	F, 56	134	Chronic dislocation	Humeral head replacement	Anterior	45	40	25
13	M, 37	†	Capsulorrhaphy arthropathy	Magnuson-Stack	Posterior	20	100	10
14	M, 61	†	Osteoarthritis	Distal clavicular resection	Posterior	8	80	4
15	M, 48	68	Capsulorrhaphy arthropathy	Putti-Platt	Posterior	25	100	15
16	F, 69	†	Chronic dislocation		Anterior	52	29	15
17	M, 64	24	Inflammatory arthritis		Posterior	28	100	15

*Cases 2 and 3 pertain to the right and left shoulders of the patient who had a bilateral procedure. †Prosthetic failure occurred less than twenty-four months postoperatively. ‡0 = no radiolucency around the component, 1 = radiolucency at the superior and/or inferior flange only, 2 = incomplete radiolucency at the keel, 3 = complete radiolucent line with a width of ≤2 mm around the component, 4 = complete radiolucent line with a width of >2mm around the component, 5a = complete translation or shift, and 5b = dislocation of the component from bone. §RCT = rotator cuff tear.

niques that can be used to compensate for lesser degrees of bone loss include changing the humeral component version, reaming to lower the elevated side of the glenoid margin, and using an augmented glenoid component. These techniques may be used alone or in combination, depending on the degree of erosion. Larger defects may preclude the use of a glenoid component or require the use of internally fixed bone grafts to restore glenoid fossa volume and version. Although abnormal glenoid wear is common, the percentage of patients requiring correction with internally fixed bone grafts has ranged from only 4% (twenty of 463) to 10% (nine of eighty-nine)[16,21]. The purpose of this study was to evaluate the long-term results associated with the use of internally fixed bone grafts for the reconstruction of glenoid deficien-

TABLE I (continued)

Glenoid Graft Result			Radiographic Classification[23] of Glenoid Component at Follow-up Evaluation†	Glenohumeral Stability		Functional Result[11]	Cause of Failure or Unsatisfactory Result§	Complications§
Outcome	Postoperative Version	Change in Version *(deg)*		Pre-operative	Post-operative			
Union	Neutral	50	3	Fixed dislocation	Normal	Excellent		
Union	Neutral	22	1	Recurrent dislocation	Recurrent subluxation	Failed at 21 months	Massive RCT, persistent instability	Instability, RCT, axillary nerve injury, failure
Union	22° anteversion	52	5a	Recurrent dislocation	Recurrent subluxation	Failed at 91 months	Persistent instability	Failure
Union	Neutral	42	3	Fixed dislocation	Superior migration	Unsatisfactory	Recurrent RCT	Recurrent massive RCT
Union	12° retroversion	14	3	Fixed subluxation	Normal	Satisfactory		
Union	4° retroversion	14	1	Fixed subluxation	Normal	Satisfactory		
Union	Neutral	32	0	Fixed subluxation	Normal	Satisfactory		
Union	30° retroversion	20	3	Fixed subluxation	Normal	Satisfactory		
Union	10° retroversion	57	0	Fixed dislocation	Superior migration	Excellent		
Union	10° retroversion	20	2	Fixed subluxation	Normal	Excellent		
Union	5° retroversion	30	3	Fixed subluxation	Normal	Satisfactory		
Union	7° retroversion	52	1	Fixed dislocation	Superior migration	Unsatisfactory	Recurrent RCT	Recurrent massive RCT
Nonunion	Dissolution	Failed	5a	Fixed subluxation	Recurrent subluxation	Failed at 8 months	Persistent instability	Failure
Nonunion	Dissolution	Failed	5a	Fixed subluxation	Superior migration	Failed at 2 months	Improper glenoid component placement	Failure
Union	15° anteversion	40	2	Fixed subluxation	Normal	Satisfactory		
Shift		Failed	5b	Fixed dislocation	Recurrent dislocation	Failed at 2 months	Loss of graft fixation	Failure
Union	10° retroversion	18	2	Fixed subluxation	Normal	Unsatisfactory	Limited motion	

cies at the time of total shoulder arthroplasty.

Materials and Methods

One hundred and thirty-two unconstrained total shoulder arthroplasties were performed between 1980 and 1989. Twenty-one shoulders (16%) received a large, internally fixed bone graft for the reconstruction of a glenoid deficiency at the time of shoulder replacement. Three patients were lost to follow-up before a minimum of two years, and one died of unrelated causes. Seventeen shoulders in sixteen patients (nine men and seven women) were available for follow-up examination; the average duration of follow-up for the thirteen shoulders that did not have prosthetic failure within the first two years was seventy months (range, twenty-four to 134 months). The average age at the time of the operation was fifty-six years (range, thirty to eighty-four years). Total shoulder replacement was performed on the right side in nine patients, on the left in six, and bilaterally in one. Ten shoulder replacements were on the dominant side.

Total shoulder replacement was performed because of primary osteoarthritis in five shoulders, chronic anterior fracture-dislocation in five, capsulorrhaphy arthropathy in three, inflammatory arthritis in two, arthritis secondary to recurrent dislocation in one, and failure of a previous replacement

in one. Seven shoulders had undergone previous surgery. Two of the three patients with capsulorrhaphy arthropathy had been treated with a Putti-Platt stabilization procedure and one, with a Magnuson-Stack procedure. Two patients had had a previous resection arthroplasty of the distal part of the clavicle. One patient with an anterior fracture-dislocation had had a prior humeral head replacement for a three-part proximal humeral fracture. One patient had a failed total shoulder replacement due to persistent instability (Table I).

Patients were evaluated preoperatively and postoperatively for pain, motion, strength, stability, and function according to the system of the American Shoulder and Elbow Surgeons[22]. All patients were considered to have some form of instability before the operation (Table I). Five shoulders had a fixed anterior dislocation. One patient had bilateral recurrent posterior dislocations. The remaining ten shoulders had a fixed posterior subluxation. This was represented by the humeral head being posteriorly displaced due to the lack of glenoid bone support resulting from the defect. Thus, the center of the humeral head was displaced posterior to the true central axis of the glenoid (Fig. 1). Six shoulders had an associated rotator cuff tear, three of which were classified as massive (involving two or more tendons). All cuff tears were diagnosed and repaired at the time of the index procedure.

All shoulders were evaluated preoperatively with an axillary radiograph, and ten had an adjunctive evaluation with computerized tomography (Table I). The axillary radiograph was standardized so that the space between the posterior margin of the coracoid and the anterior part of the glenoid rim was equal to the space between the posterior part of the glenoid rim and the scapular spine. Three factors were used to evaluate the glenoid defect: (1) the version of the defect, measured relative to the normal glenoid surface version; (2) the extent of the defect relative to the entire glenoid surface, expressed as a percentage; and (3) the maximal depth of the defect at the glenoid margin, measured in millimeters (Fig. 1, Table I). The normal glenoid contour was extrapolated from radiographs of the uninvolved shoulder (fifteen shoulders) or from an average glenoid retroversion of 5° (two shoulders in one patient). All measurements were made on plain radiographs. A computerized tomographic scan was used, if available, to corroborate the measurements. In general, the plain radiographic measurements correlated well with those obtained by computerized tomography. Five shoulders, in the five patients with chronic anterior dislocation, had an anterior glenoid defect. These anterior defects had an average anteversion of 47° (range, 42° to 52°), accounted for an average of 40% (range, 29% to 57%) of the entire glenoid surface, and had an average maximal depth of 18 mm (range, 10 to 25 mm). Twelve shoulders, in eleven patients, had a posterior glenoid defect. Five of these patients had primary osteoarthritis, three had capsulorrhaphy arthropathy, two had inflammatory

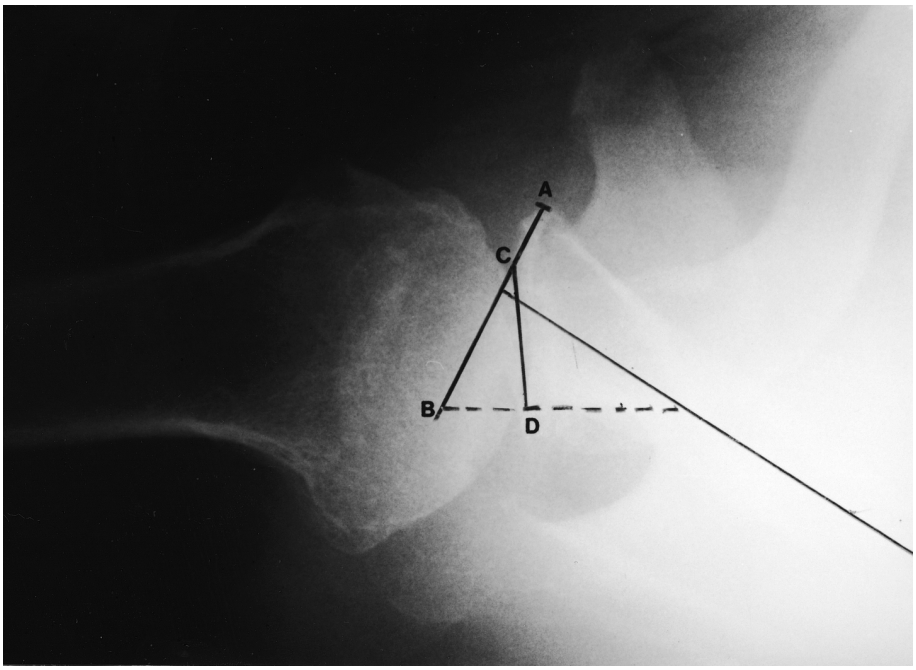

Fig. 1

Axillary radiograph depicting posterior glenoid bone deficiency. Line A-B defines the extrapolated original subchondral glenoid articular surface and lies 5° posteriorly retroverted relative to the axis of the scapula. Line C-D defines the current articulating glenoid surface. Note that the center of the humeral head lies posterior to the axis of the glenoid and scapula, representing posterior subluxation. The extent of involvement of the defect, relative to the entire glenoid surface, is expressed as a percentage of the difference in the distance between lines A-B and C-B. The version of the defect is measured as the angle between lines C-D and A-B. The maximal depth of the defect is measured from point D to point B with use of the extrapolated original contour of the glenoid articular surface.

arthritis, and one had bilateral involvement (recurrent dislocation on one side and failure of a previous arthroplasty on the other). These posterior defects had an average retroversion of 27° (range, 8° to 50°), accounted for an average of 93% (range, 61% to 100%) of the glenoid surface, and had an average maximal depth of 12 mm (range, 4 to 15 mm).

Glenoid insufficiency was defined as glenoid bone loss that met one of three criteria: (1) cortical penetration of the glenoid neck by the glenoid component keel or peg, (2) incomplete peripheral contact of the glenoid component flange, or (3) >20° of retroversion or anteversion of the glenoid component surface with complete seating. Thus, the indication for glenoid bone-grafting was (1) insufficient bone stock for appropriate component fixation or (2) peripheral wear that was severe enough to result in component malpositioning that could not be corrected by glenoid reaming or a change in humeral component version. These situations typically could be predicted preoperatively by templating a true axillary radiograph of the glenohumeral joint. If the keel of the component clearly penetrated the cortex as a result of either excessive version or decreased volume, grafting was anticipated.

All shoulders were treated with the Neer-II prosthesis (Kirschner Medical, Fair Lawn, New Jersey). The humeral component was fixed with cement in three shoulders and was press-fit in fourteen. The humeral component was placed in the standard 30° to 40° of retroversion in fifteen shoulders, and it was placed in neutral version in two (Cases 3 and 10). An all-polyethylene glenoid component was used in five shoulders, and a metal-backed component was used in twelve. All glenoid components were fixed with cement.

The glenoid defect was prepared and grafted as described by Neer and Morrison[16]. There were five anterior and twelve posterior glenoid bone grafts. Bone from the resected humeral head was used for grafting in fifteen shoulders, and bicortical iliac-crest bone was used in two (Cases 3 and 12). No allograft bone was used. The graft was transfixed with screws in sixteen shoulders; in the seventeenth shoulder, an attempt was made to insert the graft without fixation by wedging it in a fissure created by an osteotomy along the glenoid neck.

Fourteen shoulders required one or more supplemental procedures in addition to the index operation. Six shoulders required a rotator cuff repair, six required lengthening of the subscapularis tendon, one required an anterior capsular release because of an internal rotation contracture, and two required a posterior capsulorrhaphy.

The result at the most recent follow-up examination was graded according to the criteria described by Neer et al.[11]. A standard radiographic evaluation was performed with use of anteroposterior and lateral radiographs of the glenohumeral joint relative to the scapular plane as well as an axillary radiograph. Radiographs were made preoperatively, immediately postoperatively, at three and six months, and yearly thereafter. Postoperative radiographs were analyzed with the method described by Amstutz et al.[13]. Fixation of the glenoid component was classified according to the criteria described by Franklin et al.[23] (Table I).

Results

The arthroplasty failed in five shoulders (Cases 2, 3, 13, 14, and 16) (Table I). All failures were associated with symptomatic loosening of the glenoid component; there were no humeral component failures. The patient with bilateral involvement (Cases 2 and 3) had bilateral failure. The right shoulder (Case 2) had had a previous total shoulder arthroplasty for the treatment of arthritis secondary to recurrent dislocation. The revision, which involved insertion of a posterior bone graft to correct glenoid version, failed twenty-one months postoperatively due to excessive polyethylene wear in the glenoid component secondary to persistent instability and development of a rotator cuff tear. The procedure in the left shoulder (Case 3) failed ninety-one months postoperatively due to persistent instability. The third failure (Case 13) occurred eight months postoperatively due to persistent instability that resulted in nonunion of the graft and shifting of the component. The fourth failure (Case 14) occurred because the glenoid component had been placed too inferiorly, resulting in superior subluxation of the humerus and shifting of the glenoid component two months postoperatively. The fifth failure (Case 16), which involved the only shoulder in which the graft was not fixed with a screw, occurred when the glenoid component and bone graft became dislodged two months postoperatively. All failures were definitively treated with removal of the glenoid component. Glenoid version and peripheral bone volume were noted to be well restored after removal of the component from two (Cases 2 and 3) of the five shoulders.

Functional Evaluation

The twelve patients who did not have prosthetic failure had marked relief from pain at the time of the most recent follow-up. All twelve had had marked or disabling pain preoperatively. At the time of the most recent follow-up examination, ten patients had slight or no pain, one had moderate pain with activity, and one had moderate pain at rest. The average total elevation at the time of the latest evaluation was 107° (range, 30° to 165°), with an average postoperative improvement of 19° (range, –40° to 90°). Three patients had less than 90° of elevation postoperatively. The average external rotation was 28° (range, –15° to 90°), and the average internal rotation was to the twelfth thoracic level (range, the sacrum to the sixth thoracic vertebra); the average improvement in these values was 28° and four spinal levels, respectively. Nine patients obtained full strength. The strength deficit in two patients (Cases 4 and 12) was due to the recurrence of a massive rotator cuff tear after repair. Glenohumeral stability returned to normal in nine of the twelve patients (Table I). In three patients (Cases 4, 9, and 12), the original anterior-posterior instability was corrected but superior migration of the humeral head subsequently developed. The average preoperative functional score was 23 points (range, 4 to 39 points), and the average postoperative improvement was 20 points (range, 2 to 41 points). All twelve patients were satisfied with the procedure, with eight patients stating that they

were much better and four stating that they were better.

When the twelve patients who did not have prosthetic failure were evaluated according to the criteria of Neer et al.[11], the functional result was rated as excellent in three shoulders, satisfactory in six, and unsatisfactory in three. The unsatisfactory results were related to recurrence of a rotator cuff tear (Cases 4 and 12) and to limited postoperative motion (Case 17).

Radiographic Evaluation

Fourteen of the original seventeen bone grafts, including two grafts in shoulders in which the glenoid component failed, healed in proper position. Graft-healing was determined during the revision operation in the shoulders with component failure. Three grafts failed in association with failure of the glenoid component: two (Cases 13 and 14) failed as a result of nonunion caused by persistent glenohumeral instability or improper placement of the glenoid component, and one (Case 16) failed as a result of loss of graft fixation (Table I). The average glenoid version after grafting was 4° of retroversion, with a range of 22° of anteversion to 30° of retroversion. The average correction in version of the glenoid surface, excluding the three failures, was 33°.

The initial postoperative radiographs demonstrated periprosthetic radiolucency around nine of the seventeen glenoid components. The final radiographic evaluation of the twelve components that did not fail revealed no radiolucency around two components, radiolucency limited to the area of the flange of two components, incomplete radiolucency at the keel of three components, and a complete radiolucent line with a width of <2 mm around five components. The final radiographic evaluation of the five components that failed demonstrated that three had grossly shifted and one had dislocated (Table I). The radiographic evaluation of the fifth component that failed showed radiolucency limited to the area of the flange; although this component did not demonstrate severe loosening, it was revised because of excessive polyethylene wear.

The final radiographic evaluation demonstrated no radiolucent lines around twelve of the seventeen humeral components. A radiolucent line with a thickness of ≤1 mm was observed in one or more zones around five humeral components. Two of these five components were associated with global radiolucency, two were associated with radiolucency in the medial and lateral metaphyseal regions, and one was associated with radiolucency that was isolated to the lateral metaphyseal region. No humeral component was associated with progressive radiolucency on serial radiographs.

Discussion

Total shoulder replacement has provided good long-term results, with a satisfactory outcome reported after 72% (263) of 366 reported procedures[2,7,8,10,11]. Revision of the glenoid component because of loosening has been reported after approximately 2% to 3% of primary shoulder replacements[14,23,24]. Glenoid bone loss can be a contraindication to glenoid resurfacing. Bone-grafting can restore glenoid volume and version. Neer and Morrison[16] reported that only 4% (twenty) of 463 shoulders required a large, internally fixed bone graft for the treatment of glenoid deficiency at the time of total shoulder arthroplasty.

The indications for bone-grafting in a patient with glenoid deficiency include (1) uneven wear that cannot be accommodated by small changes in glenoid or humeral component version and (2) insufficient volume to support the glenoid component[16]. Friedman et al.[25] recommended bone-grafting if the retroversion of the glenoid surface exceeded 15° as determined by computerized tomography. Lesser degrees of bone loss can be compensated for by changing the humeral component version, lowering the high side of the glenoid with reaming, or using an augmented glenoid component. Alternatively, the surgeon may decide not to resurface the glenoid but to perform a humeral hemiarthroplasty. It is our opinion that the need for grafting can be predicted preoperatively by evaluating glenoid volume and version on a true axillary radiograph or with computerized tomography. Grafting is required if the component would penetrate the cortex of the glenoid neck after corrections in glenoid version are made.

There are few reports on the results of glenoid bone-grafting in patients undergoing total shoulder replacement. Neer and Morrison[16] evaluated nineteen shoulders after an average duration of follow-up of fifty-two months. All nineteen shoulders had a satisfactory result, and all grafts healed. Six of the nineteen glenoid components were associated with an incomplete radiolucent line that measured <1 mm in width. Two screws broke, and one screw was worn because of contact with the humeral component. Hulsey and Norris[26] reported on the first fourteen patients in the present study at an average duration of follow-up of thirty-six months. There were three reported failures. In the present study, there was one late failure that occurred since the time of the initial evaluation and another failure that occurred in a patient who was not involved in the initial evaluation. Thus, the failure rate in the present study (five of seventeen) was higher than that in the study by Neer and Morrison (zero of nineteen)[16]. The major difference between the two studies was in the use of metal-backed glenoid components. A metal-backed component was used in five of the nineteen shoulders in the study by Neer and Morrison[16] as opposed to twelve of the seventeen shoulders in the present study.

Fourteen of the seventeen glenoid bone grafts in the present study healed in a proper position, which was maintained during an average follow-up period of 5.8 years despite failure of the glenoid component in two of the fourteen shoulders in which the graft healed. All shoulders had some form of preoperative instability, and nine of the seventeen had a return to normal stability with the aid of grafting. Prosthetic failure occurred in five of the seventeen shoulders. All five failures involved the glenoid component, and all were treated with removal of the component. The failure was related to persistent instability in two shoulders and to recurrent rotator cuff tear, improper inferior placement of the glenoid component, and inadequate fixation of the graft in one shoulder each. A satis-

factory functional result was obtained in nine of the seventeen shoulders. The eight unsatisfactory functional results were related to prosthesis failure (five shoulders), recurrence of a large rotator cuff tear (two), and postoperative stiffness (one). Three of six shoulders had a recurrence of a rotator cuff tear that had been repaired at the time of the arthroplasty; the recurrence was associated with component failure in one of the shoulders and with a poor functional outcome in two.

There were differences in the morphology of the anterior and posterior defects. All anterior defects were related to fracture-dislocation, chronic dislocation, or recurrent anterior dislocation. The anterior defects involved a smaller proportion of the glenoid surface than did the posterior defects (average, 40% compared with 93%). However, the average version and depth of the anterior defects (47° and 18 mm, respectively) were greater than those of the posterior defects (27° and 12 mm, respectively). The grafts that were used for posterior defects were technically more difficult to place and transfix than were those used for anterior defects. One of the five components that had been inserted with an anterior graft failed, compared with four of the twelve components that had been inserted with a posterior graft. One anterior graft and two posterior grafts failed to maintain the original correction.

In conclusion, bone-grafting for patients with glenoid deficiency is a technically demanding procedure. Patients who require glenoid bone-grafting at the time of primary total shoulder replacement have a tenfold higher rate of glenoid component failure than those who have adequate glenoid version and volume. Patients with glenoid deficiency frequently have preoperative glenohumeral instability. The present long-term study demonstrated that glenoid bone-grafting has the potential to restore and maintain volume and version in patients undergoing total shoulder arthroplasty. When early failure is avoided, there does not appear to be any tendency for the graft to resorb or to predispose the glenoid component to early loosening. Glenoid bone-grafting can facilitate the restoration of normal glenohumeral stability when combined with appropriate soft-tissue balancing procedures. In the present study, failure of this procedure was related to recurrence of glenohumeral instability, rotator cuff tears, loss of graft fixation, or improper component placement. These same factors also have been shown to adversely affect the results of primary total shoulder replacement. ■

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