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ORIGINAL ARTICLE

Glenoid bone grafting in primary reverse total shoulder arthroplasty

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Background: Severe glenoid bone loss remains a challenge in patients requiring shoulder arthroplasty and may necessitate glenoid bone grafting. The purpose of this study was to determine results, complications, and rates of failure of glenoid bone grafting in primary reverse shoulder arthroplasty.

Methods: Forty-one shoulders that underwent primary reverse arthroplasty between 2006 and 2013 with a minimum follow-up of 2 years (mean, 2.8 years; range, 2-6 years) were reviewed. Thirty-four (83%) received corticocancellous grafts and 7 (17%) structural grafts.

Results: Active range of motion and pain levels were significantly improved ($P < .001$), with mean American Shoulder and Elbow Surgeons score of 77, Simple Shoulder Test score of 9, and patient satisfaction of 93% at the most recent follow-up. Preoperative severe glenoid erosion and increasing body mass index were significantly associated with worse American Shoulder and Elbow Surgeons scores ($P = .04$).

On radiographic evaluation, 7 patients (18%) had grade 1 or grade 2 glenoid lucency. Glenoid bone graft incorporation was observed in 31 patients (78%). Twelve patients (30%) suffered from grade 1 or grade 2 scapular notching. All of the patients with structural grafts showed graft incorporation and no signs of glenoid lucency.

Conclusion: Although glenoid lucency, glenoid graft resorption, and scapular notching were present at short-term to midterm follow-up, none of the patients needed revision surgery. Primary reverse shoulder arthroplasty with glenoid reconstruction using bone graft relieved pain and restored shoulder function and stability.

Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Shoulder; reverse; arthroplasty; glenoid; bone; graft

Reverse shoulder arthroplasty (RSA) has become an accepted treatment option for patients suffering from glenohumeral arthritis combined with significant glenoid bone loss.[8] However, in primary or revision shoulder arthroplasty, glenoid bone loss is associated with inferior results,[3,4,11] and significant glenoid bone loss may even be considered a contraindication to implantation of a glenoid component.[4]

Hill and Norris[10] stated that unconstrained total shoulder arthroplasty combined with glenoid bone grafting has a 10-fold

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Investigation performed at the Mayo Clinic, Rochester, MN, USA.

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higher failure rate than in procedures where glenoid bone quality is adequate. Because of the inherent stability of RSA while moving the center of rotation medially and distally to increase deltoid function but also its destabilizing force,[2,3] stress at the bone-implant interface might be increased, with increased failure rates of glenoid bone grafting with a reverse design prosthesis. However, results of previous studies with smaller cohorts of 9 and 22 patients, respectively, who underwent glenoid bone grafting in primary RSA are promising.[13,19]

The purpose of this study was to evaluate the short-term to midterm outcome associated with glenoid bone grafting in primary RSA. We aimed to analyze the overall success and to elicit any predicting factors for worse outcomes.

Methods

The study sample was identified using our institutional joint registry,[1] in which all patients who undergo total joint arthroplasty are documented prospectively.

Population of patients

Between May 2006 and March 2013, primary RSA was performed in 810 consecutive patients at our institution. There were 107 patients (13.2%) who received glenoid bone grafts when undergoing RSA implantation. In 27 of these shoulders, RSA was implanted for treatment of an acute fracture or neoplasia, and these were excluded from analysis. Of the remaining 80 patients (9.9%), 41 had a minimum follow-up of 2 years, with an average of 2.8 years (range, 2-6 years). Thirty-nine of those excluded did not have 2 years of follow-up. Baseline characteristics are summarized in Table I. Cuff tear arthropathy was the primary diagnosis in 33 (80%) patients, whereas 10 (30%) patients had a history of failed rotator cuff repair. Five (12%) patients suffered from degenerative joint disease, 1 (2%) patient from rheumatoid arthropathy, 1 (2%) from chronic dislocation, and 1 (2%) from neuropathic arthropathy. Among these 8 shoulders, all had an intact rotator cuff. In addition to those with a previous rotator cuff repair, prior surgeries included open reduction and internal fixation of a proximal humeral fracture (1), arthroscopic débridement and synovectomy for septic arthritis (1), and open distal clavicle excision and secondary open acromioplasty (1).

The surgeons followed the treatment algorithm, as previously described.[24] We attempt to achieve between 30% and 50% contact between the implant and host bone. In specific instances of superior bone loss, the graft is used to promote inferior tilt of the implant. In the setting of posterior or anterior defects, the graft is used to restore glenoid version. Cancellous graft is used in the setting of lesser defects. In larger glenoid deficiencies, the use of structural grafts is considered. The final decision for glenoid bone grafting was made intraoperatively.

Table I Characteristics of the patients

Variable	Finding
N	41
Age, years	73.5 ± 8.4
BMI, kg/m^2	27.4 ± 5.7
Female	28 (68)
RSA implantation on dominant side	28 (68)
Smokers	3 (7)
Diabetes mellitus type 2	7 (17)
Laborer	5 (12)

BMI, body mass index; *RSA*, reverse shoulder arthroplasty.
Categorical variables are presented as number (%). Continuous variables are presented as mean ± standard deviation.

Operative details and surgical findings

To obtain secure fixation of the implant and bone graft, at least 2 of the glenoid baseplate screws were placed to capture the medial cortex of the scapular neck. Operative details including glenoid bone graft source and location and size of the defects are detailed in Table II. None of the patients required bone grafting of the humerus.

Implanted components were from 3 different companies, including 32 (78%) Comprehensive Reverse Shoulder Prosthesis (Biomet, Warsaw, IN, USA), 6 (15%) Delta Xtend (DePuy Orthopedics, Warsaw, IN, USA), and 3 (7%) Encore Reverse Shoulder (DJO Surgical, Austin, TX, USA). A lateral offset glenosphere was implanted in 6 (15%) shoulders, including the Comprehensive (+3 mm offset) and the Encore (+4 mm offset) design. The remaining 35 (85%) implants had a medial center of rotation (Comprehensive and Delta Xtend; no offset).

Clinical and radiographic assessment

Complications after RSA were analyzed. All 41 patients were evaluated preoperatively and postoperatively for pain and active shoulder range of motion by the treating surgeon. Internal rotation was measured by the highest spinal segment that could be reached with the thumb. Pain levels were graded on a 5-point scale: 1, no pain; 2,

Table II Operative details

Variable	Finding
Mean humeral retroversion (degrees)	29
Cemented humeral components	7 (17)
Graft source*	
Autograft (humeral head or 1 iliac crest)	39 (95)
Allograft (CanPac or femoral head)	2 (5)
Type of graft	
Corticocancellous	34 (83)
Structural (allograft or autograft)	7 (17)
Main defect location	
Superior	24 (59)
Posterior	12 (29)
Anterior	3 (7)
Inferior	2 (5)
Intraoperative fracture	
Humeral side	2 (5)
Glenoid bone	1 (2)

Data are presented as number (%) unless otherwise indicated.
* CanPac is manufactured by AlloSource (Centennial, CO, USA).

mild pain; 3, occasional moderate pain with vigorous activity; 4, moderate pain; 5, severe pain. All patients completed postoperative functional evaluation questionnaires, including American Shoulder and Elbow Surgeons (ASES) score,[16] Simple Shoulder Test (SST),[15] Subjective Shoulder Value (SSV), and satisfaction regarding operative result and postoperative function and pain.

Of the 41 included patients, 1 patient had to be excluded for radiographic assessment because no late postoperative radiograph was available. Radiographic follow-up averaged 2.2 years (range, 2-5 years), and the assessment was conducted on preoperative and postoperative radiographs by 2 independent shoulder surgeons, both blinded of the clinical results. These included an anteroposterior view in internal and external rotation and an axillary view. Preoperative radiographs were assessed for the grade of glenoid erosion. Outcome measures evaluated on the postoperative radiographs were scapular notching, glenoid bone graft resorption, periprosthetic radiolucency, and component shift in position. According to the classification by Sperling et al,[22] glenoid erosion was classified as mild, moderate, and severe in the respective direction on radiographs in the frontal plane and axillary view. Mild glenoid erosion was considered if bone loss was confined to the peripheral part of the glenoid; moderate glenoid erosion was defined as erosion extending from the periphery of the glenoid to its midline; and severe glenoid erosion was considered if there was erosion extending beyond the midline of the glenoid. Inferior scapular notching was assessed according to Sirveaux et al on anteroposterior radiographs.[21] Periprosthetic radiolucency was defined as follows: grade 0, no radiolucent line; grade 1, incomplete 1-mm line; grade 2, complete 1-mm line; grade 3, incomplete 1.5-mm line; grade 4, complete 1.5-mm line; grade 5, 2-mm-wide lucent line and complete.[6,22] A glenoid component was considered to be "at risk" for clinical loosening if there was migration or tilt of the component or glenoid lucency of grade 4 or higher.[17] Glenoid graft resorption was quantified from 0% to 100%.

Statistical analysis

The Kolmogorov-Smirnov test was employed to test all variables for normal distribution. Normally distributed variables were compared using the dependent Student's *t*-test and non-normally distributed data using the Wilcoxon signed-rank test. For comparison of categorical data, the Fisher exact test was employed. To analyze correlations between parameters, the Pearson correlation or the Spearman rank correlation coefficient was calculated. The rate of survival free of postoperative complications was assessed using the Kaplan-Meier method. All *P* values were 2 tailed, and the a level was set to .05.

Interobserver reliability was measured by means of the intraclass correlation coefficient for absolute agreement, with 1 indicating perfect reliability.

Results

Clinical outcomes

All of the 41 patients were improved in pain levels ($P < .001$), active shoulder abduction ($P < .001$), and external ($P < .001$) and internal rotation ($P < .001$) and achieved good ASES and SST scores as well as excellent SSV and satisfaction scores (Table III). Factors associated with worse clinical outcome are depicted in Table IV. Increasing age, structural vs. corticocancellous graft, and a glenoid component with a lateral offset were not significantly associated with any clinical outcome. Also, there were no significant statistical differences in any clinical outcome measure between patients with incorporated glenoid bone graft and patients with bone graft resorption.

Table III Clinical and radiographic outcomes

Outcome measure	Result	*P* value
Moderate or severe pain		<.001
Preoperative	41 (100)	
Postoperative	2 (5)	
Mean shoulder abduction (degrees)		<.001
Preoperative	59	
Postoperative	149	
Mean ASES score	77	
Mean SST score	9	
Improvement in SST from preoperative score	37 (90)	
Mean SSV	90	
Satisfaction	38 (93)	
Radiographic outcomes		
Glenoid lucency (grade 1 or 2)	7 (18)	
Graft resorption	9 (23)	
Graft incorporation	31 (78)	
Scapular notching (grade 1 or 2)	12 (30)	
Humeral lucency	1 (3)	

ASES, American Shoulder and Elbow Surgeons; *SST*, Simple Shoulder Test; *SSV*, Subjective Shoulder Value.
Data are presented as number (%) unless otherwise indicated.

Table IV Factors with significant influence on outcome measure

Outcome measure with affecting factors*	*P* value
Improvement in pain	
Severe glenoid erosion	.041
ASES score	
Severe glenoid erosion	.035
Increasing BMI	.021
Radiographic outcomes†	
Graft resorption	
Laborer	.018
Scapula notching	
Laborer	.022

ASES, American Shoulder and Elbow Surgeons; *BMI*, body mass index; *SST*, Simple Shoulder Test; *SSV*, Subjective Shoulder Value.
* No factor significantly influenced one of the following clinical outcome measures: shoulder abduction, SST score, improvement in SST from the preoperative score, SSV, and the level of satisfaction.
† No factor significantly affected one of the following radiographic outcome measures: glenoid and humeral lucency.

Radiographic outcomes

Moderate to severe glenoid erosion was present in 39 patients (98%), among which 21 (53%) had severe glenoid erosion in the superior (14 [66%]), posterior (5 [24%]), and anterior (2 [10%]) directions. All patients (7 [100%]) with a structural glenoid bone graft presented with moderate to severe glenoid erosion: 1 in anterior, 1 in inferior, 1 in posterior, and 4 in superior direction.

The radiographic outcomes are summarized in Table III. The graft source of all patients with radiographic glenoid lucency and glenoid graft resorption was corticocancellous humeral head autograft (Fig. 1), and none received a structural bone graft or a glenoid implant with a lateral offset.

Factors with significant influence on radiographic outcomes are listed in Table IV. With the data available, severity of preoperative glenoid erosion, structural vs. corticocancellous graft, and a glenoid component with a lateral offset were not significantly associated with any radiographic outcome (Fig. 2).

There was excellent interobserver reliability for preoperative glenoid erosion ($R = 0.93$; 95% confidence interval [CI], 0.86-0.96), graft resorption ($R = 0.91$; 95% CI, 0.84-0.96), and glenoid loosening ($R = 0.95$; 95% CI, 0.91-0.98) and very good interobserver reliability for scapular notching ($R = 0.84$; 95% CI, 0.71-0.92).

Complications

Although 5 patients (12%) suffered from 7 postoperative complications, none of the included patients had revision surgery. Postoperative complications included scapular spine fractures (2), broken humeral tray (1), post-traumatic fragmentation of the posterior aspect of the greater tuberosity (1), proximal humeral bone resorption (1), postoperative instability (1), and heterotopic ossification leading to deltoid pain (1). The patient with postoperative instability had severe anterior glenoid erosion grafted with a structural graft. Treatment included closed reduction and immobilization in a sling for 6 weeks. At the final follow-up, the patient presented with a stable shoulder and an ASES score of 62 points. Average time to a postoperative complication was 23 months (range, 1-48 months).

The rate of survival free of postoperative complications at 2 and 5 years was 93% and 77%, respectively. Patients with postoperative complications presented with worse postoperative abduction ($P < .001$), internal rotation ($P = .022$), ASES and SST scores ($P = .025$ and $P = .007$), and SSV ($P < .001$) and worse improvement in pain ($P = .033$).

Discussion

Patients with cuff tear arthropathy often present with severe glenoid erosion and an off-centered humeral head.[8,9,18,21] Preoperative arthritic changes of the glenoid in the setting of primary or revision shoulder arthroplasty are associated with worse short-term to midterm outcome.[4,10,19,20,23,24] Because of glenoid malposition, graft resorption, and glenoid component loosening, total shoulder arthroplasty may subsequently fail. Wagner et al[24] reported in a case-control study about revision RSAs that failure rates are increased and implant survival rates are decreased in patients with glenoid bone grafting compared with those without. In the present study, none of the included patients were revised. However, in 5 patients (12%), a total of 7 postoperative complications were recorded, and 1 patient suffered from a broken humeral tray and was considered failed RSA. The rate of survival free of postoperative complications at 2 and 5 years was 93% and 77%. The calculated 5-year-rate for postoperative complications is high, and one might assume that shoulders requiring glenoid bone grafting are more complex cases in general. In 1 case, the recorded complication might be associated with the extent and location of glenoid bone loss, as this patient had severe anterior glenoid erosion treated with structural bone graft and suffered from postoperative instability. In case of severe anterior glenoid bone loss, the use of structural bone

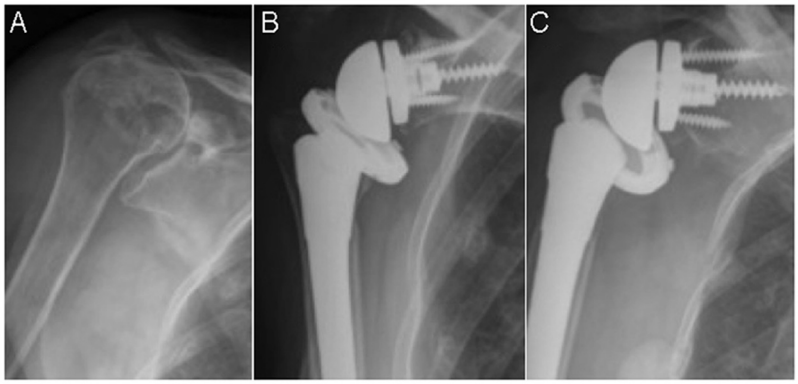

Figure 1 (**A**) Radiograph of a 71-year-old patient showing primary cuff tear arthropathy with superior glenoid erosion and humeral head subluxation. (**B**) Immediate postoperative radiograph showing reverse shoulder arthroplasty in place with superior corticocancellous glenoid bone graft being secured with the glenoid component baseplate only. (**C**) At 30 months postoperatively, graft resorption in the superior portion of the glenoid is evident.

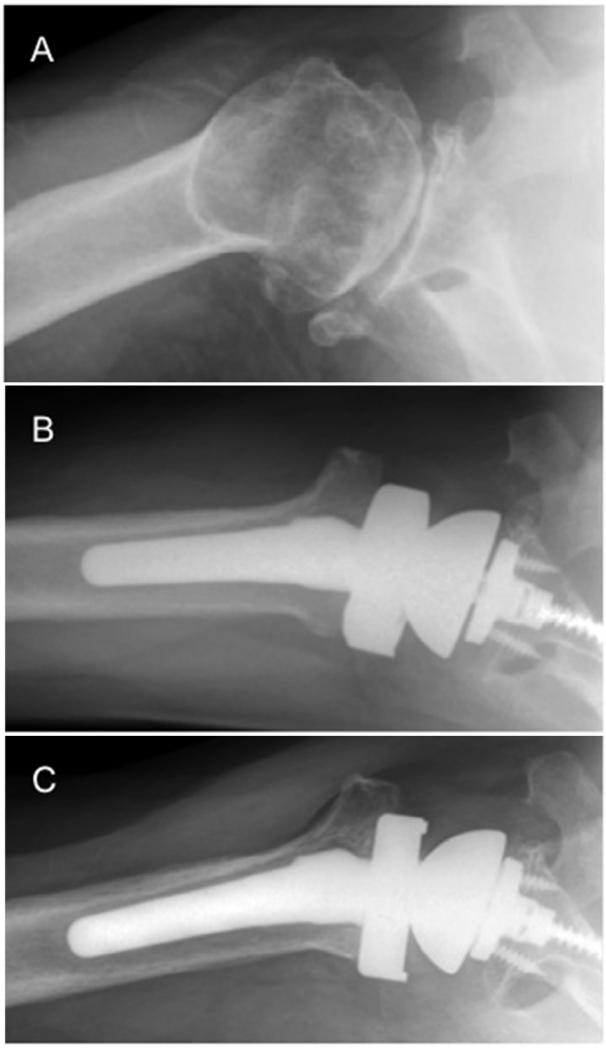

Figure 2 (**A**) A 79-year-old patient with posterior glenoid erosion. (**B**) Immediate postoperative radiograph after reverse shoulder arthroplasty implantation and posterior glenoid bone grafting with a structural humeral head autograft. (**C**) At 24 months after surgery, graft incorporation occurred without any signs of loosening or glenoid component migration.

graft with an additional epiphyseal extension should be considered.

In our study, significant improvement in postoperative pain levels, satisfaction, and functional scores was observed. Although the rate of graft resorption was relatively high, clinical results were comparable to studies reporting on primary RSA without glenoid bone grafting.[7,13] Klein et al reported that the presence of significant glenoid bone loss requiring bone grafting is not a contraindication to implantation of a reverse design prosthesis.[13] In their series of 141 patients undergoing primary RSA with a minimum follow-up of 2 years, 56 glenoids were classified as abnormal on the basis of glenoid bone defects. Twenty-two (39%) of the abnormal glenoids received a bone graft. All outcome measures improved significantly postoperatively, whereas no significant difference was observed between the group with and those without glenoid bone loss. Accordingly, Jones et al observed in their study about structural glenoid bone grafting in primary and revision RSA in 44 patients an improvement in functional outcome scores.[12] Neyton et al reported on 9 patients who underwent glenoid bone grafting in the setting of primary RSA.[19] After a minimum of 2 years of follow-up, patients presented with good pain relief. However, postoperative functional scores were low compared with the results of the present study.

Several factors influenced the clinical results. Preoperative severe glenoid erosion was associated with worse ASES scores and improvement in pain. On the other side, clinical outcome was associated with neither the use of structural grafts nor the type of graft used (allograft or autograft). Another factor to consider regarding surgical technique is the use of a lateralized implant. This increases shear forces on the baseplate, which might in turn deteriorate initial fixation and glenoid graft incorporation.[3] However, lateralization of the implant had no influence on functional results. Moreover, none of the patients who were found to have radiographic glenoid lucency and glenoid graft resorption had had a lateralized implant. Therefore, increased compressive forces due to a lateralized offset could improve bone graft incorporation,[5] although these results must be taken with caution as only 6 of 41 patients (15%) received a glenoid component with a lateral offset. Of the potentially modifiable risk factors, only increasing body mass index was associated with worse function scores. Moreover, patients with reported postoperative complications had worse shoulder function, SSV, and improvement in pain.

Regarding radiologic outcomes in the described study, the rate of glenoid lucency, glenoid graft resorption, and scapular notching is relatively high. Seven patients (18%) presented with grade 1 and grade 2 glenoid lucency at the latest follow-up. Glenoid bone graft resorption was observed in 9 patients (23%) and was graded between 10% and 30%. However, none of the glenoids were assessed as being at risk for clinically relevant glenoid loosening, and there were no significant statistical differences in any clinical outcome measure between patients with incorporated glenoid bone graft and patients with bone graft resorption. Moreover, the severity of glenoid bone defect had no influence on any radiologic outcome. Notwithstanding, all structural grafts were implanted in case of moderate to severe glenoid erosion and were determined intraoperatively to have more complex glenoid disease. Although the type of graft had no influence on any radiologic outcome, all of the structural grafts were incorporated, and no signs of glenoid lucency were present at the latest follow-up. Structural grafts therefore potentially improve graft incorporation and reduce glenoid loosening.

In the present study, laborers had increased rates and higher grades of graft resorption. The rate of mild grade scapular notching was also increased in laborers. A demanding shoulder activity profile is therefore associated with worse radiologic outcome. However, mild grade or asymptomatic scapular notching is present in the majority of patients with RSA.[21] Therapeutic consequence in light of scapular notching is

profoundly deliberated. Component characteristics like a lateral offset and the type of glenoid bone graft were not associated with glenoid lucency, graft resorption, or scapular notching.

In general, the type of graft did not have a significant influence on loosening, resorption, scapular notching rates, or any other radiologic or clinical outcome measure. According to Klika et al, clinical outcomes after structural bone grafting in primary anatomic total shoulder arthroplasty are favorable.[14] However, 40% of the glenoid implants were deemed to be at risk for clinically relevant loosening. Also, almost 25% of the grafts did not incorporate. Jones et al, who reported in their study about structural bone grafting in primary and revision RSA that in almost 20% the graft was not incorporated, observed similar results. Wagner et al[24] established an algorithm to address glenoid deficiency in the revision setting of RSA. Besides considering the ability to achieve implant contact with the host bone of 30% to 50%, the location of glenoid bone loss needs to be considered in decision-making. All of the patients in the present study with structural grafts presented with moderate to severe glenoid bone defects affecting the glenoid rim, and postoperatively, all of these structural grafts were incorporated without signs of glenoid lucency. Regarding surgical technique, the use of structural grafts in cases of complex glenoid disease resulting in reduced inferior tilt or reduced version in anterior or posterior direction should be considered. However, given the low number of structural grafts used (7 [17%]), it is difficult to definitely identify the ideal type of graft in primary RSA. Furthermore, radiographic changes not evident after 2 years may be present in the long term.

Several limitations should be considered. We did not compare our results to a control group consisting of patients with primary RSA without glenoid bone grafting. Therefore, it is difficult to identify the role of bone grafting in clinical and radiologic outcome. Besides the observed satisfying results after short-term to midterm follow-up, it is warranted to determine the longevity of the implant and bone graft in the long term. Another limitation is the use of almost only corticocancellous grafts. This might have led to worse results than if more structural grafts had been used. Further limitations involve the variability in surgical indications and 3 different types of implants used in this study. Last, the assessment of preoperative glenoid erosion as well as graft incorporation and radiographic lucency was conducted on high-quality radiographs rather than with computed tomography scans.[25] Nevertheless, the interobserver reliability was excellent or very good for all radiographic measurements.

Strengths of our study include the use of consistent data collection methods and radiographs over time, our institutional total joint registry allowing prospective collection of the clinical and radiographic outcomes data in a standardized manner, and the extensive experience at our institution with patients having complex diseases like glenoid bone loss in the setting of total shoulder arthroplasty. Finally, this is the first study reporting a large number of patients requiring glenoid bone grafting in primary RSA with an analysis of multiple questions regarding the operative technique, including the source and type of graft, as well as the influence of the patient's characteristics on outcome measures.

Conclusion

In spite of the presence of glenoid lucency, glenoid graft resorption, and scapular notching at short-term to midterm follow-up, none of the included patients needed revision surgery. Furthermore, glenoid reconstructive surgery with glenoid bone graft in primary RSA was able to relieve pain as well as to restore shoulder function and stability. Given the majority of corticocancellous grafts and the low number of structural grafts used, it is difficult to definitely identify the ideal type of graft in primary RSA.

Disclaimer

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