Surgical Management of Complex Proximal Humerus Fractures—A Systematic Review of 92 Studies Including 4500 Patients

Anil K. Gupta, MD, MBA, Joshua D. Harris, MD, Brandon J. Erickson, MD, Geoffrey D. Abrams, MD, Benjamin Bruce, MD, Frank McCormick, MD, Gregory P. Nicholson, MD, and Anthony A. Romeo, MD

Objectives: To compare the outcomes of open reduction and internal fixation (ORIF), closed reduction and percutaneous pinning, hemiarthroplasty (HA), and reverse shoulder arthroplasty (RSA) for proximal humerus fractures.

Data Sources: The search was performed on September 9, 2012 using an explicit search algorithm in the following databases: Medline, SportDiscus, CINAHL, and Cochrane Central Register of Controlled Trials. Inclusion criteria were English language studies reporting clinical outcomes after surgical treatment of 3- or 4-part proximal humerus fractures with a minimum of 1-year follow-up.

Study Selection: English language studies reporting clinical outcomes after surgical treatment of 3- or 4-part proximal humerus fractures with a minimum of 1-year follow-up. Levels 1–4 studies were eligible for inclusion.

Data Extraction: Study methodological quality and bias was evaluated using the Modified Coleman Methodology Score.

Data Synthesis: Two-proportion Z test and multivariate linear regression analyses were used for group comparisons.

Conclusions: Significantly better clinical outcomes were observed for ORIF over HA and RSA (American Shoulder and Elbow Score, Disabilities of Arm, Shoulder, and Hand, Constant) ($P < 0.05$). However, ORIF had a significantly higher reoperation rate versus HA and RSA ($P < 0.001$ for both). Comparing HA with RSA, there was no difference in any outcome measure. The rate of tuberosity nonunion was 15.4% in the HA group. There were more complications following closed reduction and percutaneous pinning versus ORIF, HA, and RSA ($P < 0.05$). ORIF for proximal humerus fractures demonstrates better clinical outcome scores but with a significantly higher reoperation rate. HA and RSA are effective as well, but tuberosity nonunion remains a concern with HA.

Key Words: proximal humerus fracture, open reduction and internal fixation, closed reduction and percutaneous pinning, hemiarthroplasty, total shoulder arthroplasty, reverse shoulder arthroplasty, treatment

(*J Orthop Trauma* 2015;29:54–59)

INTRODUCTION

Proximal humerus fractures are the third most common type of fracture, comprising of 4% to 5% of all fractures. They commonly affect the elderly after low energy trauma.[1] In 2008, over 180,000 emergency department visits resulted from proximal humerus fractures. The rate of proximal humerus fractures in the United States has been increasing at over 13% per year over the past 30 years.[1–3] Although the majority of fractures are minimally displaced, surgical treatment is generally considered for unstable displaced 3- and 4-part fractures.[4] Several surgical treatment options are available, including open reduction and internal fixation (ORIF), closed reduction and percutaneous pinning (CRPP), hemiarthroplasty (HA), and reverse total shoulder arthroplasty (RSA).[5–7]

Surgical treatment choice is largely dependent on the surgeon's interpretation of the type of fracture, degree of comminution and displacement, bone quality, and comfort level with a particular technique. In addition, patient functional status and expectations play a large role in decision making. A wide range of outcomes have been reported for each of these treatments.[3,8–12] A consensus does not exist, however, regarding the optimal treatment strategy for such fractures.[5,13] This is largely in part because of multiple factors, such as age, activity level, medical comorbidities, bone quality, degree of comminution, previous surgeries, and associated injuries that influence surgical decision making.

The purpose of this systematic review was to determine and compare outcomes of surgical treatments of 3- and 4-part proximal humerus fractures. The authors' hypothesis is that there will be no significant difference in results between different surgical treatments.

MATERIALS AND METHODS

A systematic review was performed using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines with a PRISMA checklist.[14] Three independent reviewers (2 board-eligible orthopaedic surgeons and 1 orthopaedic surgery resident) completed the search. The search

Accepted for publication August 13, 2014.
From the Division of Sports Medicine, Shoulder and Elbow Surgery, Midwest Orthopaedics at Rush, Chicago, IL.
The authors report no conflict of interest.
Reprints: Anil K. Gupta, MD, MBA, Midwest Orthopaedics at Rush, 1611 W. Harrison St, Suite 300, Chicago, IL 60612 (e-mail: anilgupta07@hotmail.com).

was performed on September 9, 2012 using an explicit search algorithm {(((humerus [Title/Abstract]) OR humeral[Title/Abstract] AND (English [lang]))) AND fracture[Title/Abstract]) AND proximal[Title/Abstract] AND (English[lang]))) NOT intramedullary[Title] AND (English[lang]))) NOT nonunion[Title] AND (English [lang]))) NOT malunion[Title] AND (English[lang]))) NOT biomechanical[Title/Abstract] AND (English[lang]))) NOT cadaveric[Title/Abstract] AND (English[lang]))) NOT cadaver [Title/Abstract] AND (English[lang]))) NOT ((basic[Title/Abstract]) AND science[Title/Abstract] AND (English[lang])) AND (English[lang]))) NOT revision[Title] AND (English [lang]))) NOT ((rotator[Title]) AND cuff[Title] AND (English [lang])) AND (English[lang]))) NOT pediatric[Title] AND (English[lang]))) NOT physeal[Title] AND (English[lang]))) NOT children[Title] AND (English[lang]))) NOT instability [Title] AND (English[lang]))) NOT imaging[Title])) NOT salter[Title])) NOT physis[Title])) NOT shaft[Title])) NOT distal[Title])) NOT clavicle[Title])) NOT scapula[Title])) NOT ((diaphysis[Title]) AND diaphyseal[Title]))) NOT infection [Title])) NOT laboratory[Title/Abstract])) NOT metastatic [Title/Abstract])) NOT (((((((malignancy[Title/Abstract]) OR malignant[Title/Abstract]) OR tumor[Title/Abstract]) OR oncologic[Title/Abstract]) OR cyst[Title/Abstract]) OR aneurysmal [Title/Abstract]) OR unicameral[Title/Abstract])}, in the following databases: Medline, SportDiscus, CINAHL, and Cochrane Central Register of Controlled Trials. Inclusion criteria were English language studies reporting clinical outcomes after surgical treatment of 3- or 4-part proximal humerus fractures with a minimum of 1-year follow-up. Exclusion criteria included studies with less than 1-year clinical follow-up, non-English language, basic science, surgical technique, letters to the editor, biomechanical, systematic reviews/meta-analyses, duplicate subject populations, pediatric patients, revisions, malunion, nonunion, suture-only fixation, external fixation, valgus-impacted fractures, 2-part fractures, arthrodeses, fixation with allograft strut augmentation, and oncologic/pathologic fractures. Levels 1, 2, 3, and 4 evidence were deemed (as per the Oxford Centre for Evidence-Based Medicine used by the American version of the Journal of Bone and Joint Surgery)[15] inclusive. Both e-published and print journal articles were acceptable. However, meeting abstracts and proceedings were disallowed. All references within included studies were cross-referenced for potential inclusion if omitted from the initial search. If 2 or more separate studies reported on a duplicate population of subjects (eg, different lengths of follow-up), only the more/most recent study was retained for final analysis. Figure 1 demonstrates our search algorithm to generate the final studies for inclusion and analysis.

Descriptive statistics were calculated for each study and parameter variable. Continuous variable data were reported as mean ± SD (weighted mean values where applicable). Categorical data was reported as frequencies with percentages. For all statistical analyses, $P < 0.05$ was deemed statistically significant. Study, subject-specific data, and surgical outcomes' data were compared using 2-proportion Z test

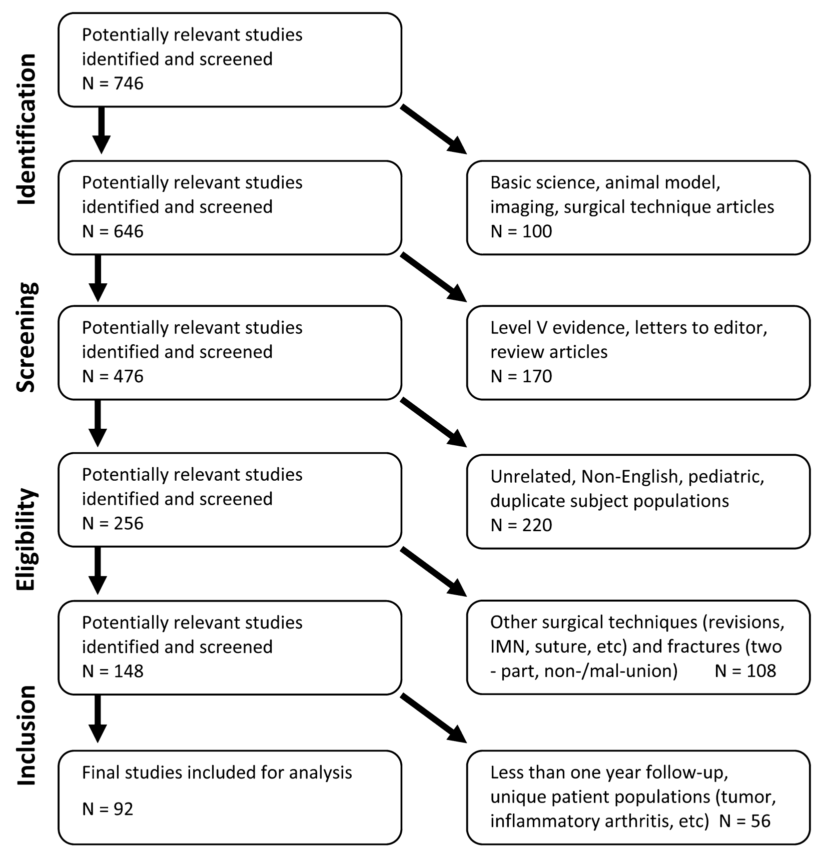

FIGURE 1. Systematic review search algorithm within Medline database according to PRISMA guidelines. After application of all exclusion criteria, 92 studies were identified for inclusion and further analysis. IMN, intramedullary nail.

calculators with alpha 0.05 because of the difference in sample sizes between compared groups. An internet-based statistical calculator was used for Z test calculation. Multivariate regression was also used to control for age differences between groups in comparing functional score, range of motion, reoperations, and mortality between cohorts. Study methodological quality and bias was evaluated using the Modified Coleman Methodology Score (MCMS).[16] This study quality checklist has been used in previous Orthopaedic and Sports Medicine research, applicable to both randomized and nonrandomized controlled trials.[17,18] The MCMS is a 15-item instrument with a scaled potential score ranging from 0 to 100, with scores 85–100 (excellent), 70–84 (good), 55–69 (fair), and <55 (poor).

The age of patients enrolled in each study was evaluated for a planned subgroup analysis with the goal to analyze the outcomes according to patient age greater and less than 70 years. This was performed assuming that RSA is indicated for patients greater than 70 years.

RESULTS

Before screening, 745 studies were identified. After eligibility screening and filtering through inclusion/exclusion criteria, 92 studies remained. There were significantly more single-center versus multicenter studies (92% vs. 8%, $P < 0.001$) (Table 1). There were significantly more level 4 evidence studies (92%) versus all other levels ($P < 0.001$ for each). The mean study level of evidence was 3.5. Forty-nine studies evaluated the outcomes of ORIF only, 5 evaluated CRPP only, 26 HA only, 7 RSA only, 1 ORIF and HA, 1 ORIF and RSA, and 3 HA and RSA. A total of 4536 patients that underwent surgical intervention were available for analysis (88.1% clinical follow-up). The only significant age difference for all patients was between the ORIF group (62.3) and the RSA group (75.1) ($P < 0.001$) (Table 1). Overall mean study quality (through MCMS) was 30.4 (poor quality).

The mean postoperative American Shoulder and Elbow Score (ASES) in patients undergoing ORIF was significantly greater than those undergoing HA ($P < 0.001$; $Z = 4.0$) or RSA ($P < 0.001$; $Z = 3.7$) (Table 2 for all specific score values). The mean postoperative Disabilities of Arm, Shoulder, and Hand (DASH) score was significantly better in patients undergoing ORIF versus HA ($P < 0.026$; $Z = 2.2$). The mean postoperative Constant score was significantly greater in patients undergoing ORIF versus HA ($P < 0.001$; $Z = 6.1$) and RSA versus HA ($P = 0.034$; $Z = 2.1$). Postoperative forward elevation ($P = 0.01$; $Z = 2.5$) and external rotation ($P < 0.001$; $Z = 4.1$) was significantly greater following ORIF versus HA. RSA had significantly less postoperative external rotation versus ORIF ($P < 0.001$; $Z = 5.2$) and HA ($P = 0.002$; $Z = 3.1$).

Controlling for age differences between groups, multivariate regression analysis (Table 3) demonstrated that ORIF had significantly better postoperative DASH ($P = 0.001$) and Constant ($P = 0.002$) scores and forward elevation motion ($P = 0.012$) than HA. Similarly, postoperative DASH ($P = 0.049$) and Constant ($P = 0.014$) scores and forward elevation motion ($P = 0.041$) were significantly better following ORIF versus RSA. In comparing HA with RSA, there was no significant difference in any clinical outcome measure.

Analysis of postoperative complications (Table 4) and reoperations (Table 5) demonstrated several significant

TABLE 1. Study, Subject, and Surgical Demographic Data

Parameter	n (%)
No. studies analyzed	92
Levels of evidence	
1	1 (1.1)
2	1 (1.1)
3	5 (5.3)
4	85 (92)
Single-center studies	84 (91.3)
Multicenter studies	7 (7.6)
Randomized controlled trials	1 (1.1)
Financial conflict of interest	41 (44)
No	3 (3.2)
Yes	48 (53)
Not reported	
Dates of subject enrollment	1976–2010
Mean MCMS	30.4 ± 7.57
No. subjects	5219
Men	1364 (29.6)
Women	3244 (70.4)
No. shoulders	5228
Dominant	809 (53.5)
Nondominant	703 (46.5)
No. subjects available at final follow-up	4536
% subjects with clinical follow-up, %	88.1
No. shoulders available at final follow-up	4605
% shoulders with clinical follow-up, %	88.1
No. shoulders with radiographic final follow-up	4366
% shoulders with radiographic follow-up, %	83.5
Mean age, yrs	
ORIF	62.3
CRPP	61.6
HA	69.3
RSA	75.1
Mean clinical follow-up	31.2 ± 20.5 mo
CRPP	26.6
ORIF	29.5
HA	43.4
RSA	34.3
No. studies with independent observer for follow-up evaluation	10
No. surgical cases analyzed from final follow-up	4536
CRPP	197
ORIF	2939
HA	1182
RSA	218
Concomitant procedures	
Rotator cuff tears (concomitant repair)	35
Biceps tendinopathy (concomitant tenodesis)	83

TABLE 2. Mean Preoperative and Postoperative Outcome Data

Surgical Technique	DASH Pre	DASH Post	ASES Pre	ASES Post	Constant Pre	Constant Post	ROM FE Post	ROM ER Post
ORIF	NR	25.4 (13)	NR	80.7 (4)	15.8 (1)	74.1 (34)	137 (12)	44.3 (9)
CRPP	NR	NR	NR	NR	NR	69.0 (3)	NR	NR
HA	NR	37.8 (4)	NR	67.2 (6)	NR	66.3 (15)	109 (19)	38.9 (17)
RSA	NR	39.3 (1)	NR	61.5 (5)	28 (1)	69.7 (4)	115 (6)	35.0 (6)

ASES, American Shoulder and Elbow Score; ER, external rotation; FE, forward elevation; NR, not recorded; ROM, range of motion.

differences. There was a greater rate of complications following CRPP versus ORIF ($P < 0.001$; $Z = 4.8$), HA ($P < 0.001$; $Z = 6.4$), and RSA ($P = 0.023$; $Z = 2.3$). There was a lower rate of complications following HA versus RSA ($P = 0.0018$; $Z = 3.1$) and ORIF ($P = 0.0019$; $Z = 3.1$). There were significantly more reoperations following ORIF versus HA ($P < 0.001$; $Z = 7.4$) and RSA ($P < 0.001$; $Z = 3.4$).

DISCUSSION

The operative management of displaced unstable 3- and 4-part proximal humerus fractures is controversial. The purpose of this systematic review was to evaluate the outcomes of patients treated surgically with a minimum 1-year follow-up. This is the first systematic review evaluating all of these treatment options in the literature. The results suggest that patients undergoing ORIF had better postoperative clinical outcome scores (ASES, DASH, Constant) and motion versus CRPP, HA, and RSA. Although patients undergoing ORIF were significantly younger than those undergoing RSA, multivariate regression analysis (controlling for patient age) revealed that clinical outcome scores (DASH and Constant scores) and motion were significantly better following ORIF versus HA and RSA. However, the complication rate was significantly higher following ORIF (15%) versus HA (11.3%), and the reoperation rate was significantly higher following ORIF (12.7%) versus HA (4.9%) and RSA (5%). CRPP demonstrated the highest overall complication rate. The authors' hypothesis that RSA would demonstrate the best overall outcome was not confirmed. Nearly all studies were level 4 evidence (92%) with overall poor MCMS study methodological quality scores.

TABLE 3. Multivariate Regression Analysis Comparing Individual Groups With Patient Age as a Covariate

	ORIF Versus HA	ORIF Versus RSA	HA Versus RSA
ASES	0.331	0.274	0.875
DASH	0.001 (ORIF)	0.049 (ORIF)	0.508
Constant	0.002 (ORIF)	0.014 (ORIF)	0.846
Forward elevation	0.012 (ORIF)	0.041 (ORIF)	0.952
External rotation	0.419	0.330	0.458
Reoperation	0.082	0.339	0.423
Mortality	0.630	0.835	0.845

ASES, American Shoulder and Elbow Score.

Three- and 4-part proximal humerus fractures are among the most severe type of proximal humerus fractures and comprise of approximately 5% of all proximal humerus fractures. The type of fracture pattern depends on the bone quality and mechanism of injury. It is more commonly seen in the elderly population with osteopenia as a result of a fall from a standing height.[19] There have been several studies published to date that support the use of ORIF, CRPP, HA, and RSA for the management of these fractures. On the contrary, there are several studies that demonstrate a high complication rate and less desirable outcomes for each of these surgical options, especially ORIF and CRPP.[3–8,11–16] This conflicting data has led to a wide variety of treatment decisions made based on surgeon technical skills and previous experience level as opposed to a purely evidence-based approach.

There is significant interobserver variability between surgeons regarding interpretation of the type of fracture, degree of comminution and displacement, bone quality, and comfort level with a particular technique. In addition, current radiographic classification systems demonstrate significant interobserver variability. As a result, computed tomography–based classification systems have evolved.[20–22] Despite this evolution, no single classification is considered the gold standard at this time. This lack of a highly reliable classification system, combined with the above variables, further convolutes the ability to perform a high-quality, randomized controlled trial.

The findings in this study must be carefully interpreted. Despite the general trend toward improved outcomes with ORIF compared with the other treatment options, there is a higher reoperation and overall complication rate associated with ORIF versus HA and RSA. Unfortunately, of the studies that reported on the outcomes of ORIF, only 5 reported on ORIF using nonlocked plating. Therefore, we were unable to compare the results of locked and nonlocked plating. In the current healthcare environment, where value is playing a more crucial role in impacting surgeon behavior, ORIF may not be the most cost-effective treatment in comparison with HA or RSA. Further studies comparing the cost-effectiveness of these procedures are therefore warranted.

Strengths of this study include the large number of studies and subjects analyzed with several distinct surgical treatments, clear inclusion and exclusion criteria, utilization of a standardized search methodology, and use of validated outcome instruments. In addition, it is the first systematic

TABLE 4. Complications Associated With ORIF, CRPP, HA, RSA

	Hardware Failure	Malunion	Nonunion*	HH Necrosis	Superficial Infection	Deep Infection	Neurologic Injury	Dislocation	Death	DVT	PE	Total, %
ORIF (2939), n (%)	58 (2.0)	8 (0.3)	15 (0.5)	189 (6.4)	25 (0.9)	21 (0.7)	12 (0.4)	6 (0.2)	104 (3.5)	1 (0.04)	1 (0.04)	15.0
CRPP (197), n (%)	8 (4.1)	6 (3.0)	2 (1.0)	23 (11.7)	8 (4.1)	2 (1.0)	3 (1.5)	0 (0)	4 (2.0)	0 (0)	0 (0)	28.4
Hemi (1182), n (%)	6 (0.5)	0 (0)	12 (1.0)	0 (0)	25 (2.1)	11 (0.9)	12 (1.0)	7 (0.6)	60 (5.1)	0 (0)	1 (0.08)	11.3
RSA (218), n (%)	0 (0)	0 (0)	0 (0)	0 (0)	3 (1.4)	5 (2.3)	12 (5.5)	9 (4.1)	10 (4.6)	1 (0.5)	1 (0.5)	18.9

*Nonunion for ORIF indicates failure of any fracture segment from healing. Nonunion for HA indicates failure of tuberosity healing.
DVT, deep venous thrombosis; HH, humeral head; PE, pulmonary embolism.

review comparing ORIF, CRPP, HA, and RSA for the management of complex proximal humerus fractures. Age was recognized as a potential confounder because of the significant age differences between cohorts. With the age of the different groups as covariates, multivariate regression was used to compare the relationship between groups and postoperative outcomes to minimize the effect of age on the outcome variables. This analysis supported the above findings regarding ORIF versus HA and RSA but suggested that there is no significant difference between HA and RSA in all measured clinical outcomes.

Limitations of this systematic review include a lack of randomized controlled trials, lack of long-term follow-up, and the majority of studies being level 4 retrospective case series. Overall, only 324 patients included in this study came from level 1 or 2 evidence, 405 patients from level 3 evidence, and the remainder from level 4 evidence. This lack of comparison and randomization introduces both observer and allocation bias. In addition, many studies were not specific regarding the indications for operative intervention. This introduces selection bias for such studies. Another limitation of this study review is the lack of subdividing patients into different age categories. For example, many would argue that the treatment algorithm for a 75-year-old patient differs from that for a 60-year-old patient, especially if the 60-year-old patient is a healthy active manual laborer. The authors attempted this subgroup analysis to strengthen the results; however, the available studies did not adequately provide enough information regarding the specific ages of the patients enrolled into their studies. Such a subgroup analysis in future studies is important in determining the most effective treatment for varying patient ages in the elderly population. Further, the status of the rotator cuff and bone mineral density play a large role in treatment selection. These issues were seldom addressed within the studies, yet need to be addressed in future investigations. In addition, accounting for patient activity level and comorbidities is also very important and must be the focus of future comparative studies. The patients who underwent ORIF and RSA both demonstrated good functional outcomes, with the outcomes of ORIF slightly superior to RSA, whereas the patients who underwent RSA had a significantly lower complication rate than those who underwent ORIF. Significantly worse outcomes and increased complications could be expected in this age group compared with the much younger ORIF group because of the higher comorbidities present in this age population. This, however, was not the case. The authors therefore postulate that, in patients older than age 70, RSA has the potential to be the most effective operative intervention. The current data to date, however, are yet to fully support this claim because of a lack of consistent accountability of age and associated comorbidities. Lastly, the authors recognize that it is difficult to control for fracture severity and bone quality. Currently, there is no gold standard fracture classification through which there is high intraobserver and interobserver agreement regarding the degree of comminution and bone quality. Not all 3- and 4-part fractures behave the same. Therefore, surgeons must be prepared for alternative treatment options such as HA or RSA in the setting of a high degree of comminution and or poor bone quality, which can lead to early failure with ORIF or CRPP.

TABLE 5. Reoperations Associated With ORIF, CRPP, HA, RSA

	Reoperations	Hardware Removal	Revision to HA	Revision to RSA
ORIF (2939), n (%)	374 (12.7)	91 (3.1)	35 (1.2)	1 (0.04)
CRPP (197), n (%)	197 (100)	197 (100)	0 (0)	2 (1.0)
Hemi (1182), n (%)	53 (4.9)	0 (0)	NA	14 (1.2)
RSA (218), n (%)	11 (5.0)	0 (0)	4 (1.8)	NA

NA, not available.

CONCLUSIONS

Patients undergoing ORIF for proximal humerus fractures using older and newer locking and nonlocking plate technology demonstrate better clinical outcome scores but with a significantly higher reoperation rate. HA and RSA are effective alternatives as well, but tuberosity nonunion remains a concern with HA. Randomized controlled trials and cost

analyses are necessary to determine the optimal treatment method for such fractures.

REFERENCES

1. Kim SH, Szabo RM, Marder RA. Epidemiology of humerus fractures in the United States: nationwide emergency department sample, 2008. *Arthritis Care Res (Hoboken).* 2012;64:407–414.
2. Palvanen M, Kannus P, Niemi S, et al. Update in the epidemiology of proximal humeral fractures. *Clin Orthop Relat Res.* 2006;442:87–92.
3. Launonen AP, Lepola V, Flinkkila T, et al. Conservative treatment, plate fixation, or prosthesis for proximal humeral fracture. A prospective randomized study. *BMC Musculoskelet Disord.* 2012;13:167.
4. Neer CS II. Displaced proximal humeral fractures. II. Treatment of three-part and four-part displacement. *J Bone Joint Surg Am.* 1970;52:1090–1103.
5. Guy P, Slobogean GP, McCormack RG. Treatment preferences for displaced three- and four-part proximal humerus fractures. *J Orthop Trauma.* 2010;24:250–254.
6. Reitman RD, Kerzhner E. Reverse shoulder arthoplasty as treatment for comminuted proximal humeral fractures in elderly patients. *Am J Orthop (Belle Mead NJ).* 2011;40:458–461.
7. Lenarz C, Shishani Y, McCrum C, et al. Is reverse shoulder arthroplasty appropriate for the treatment of fractures in the older patient? Early observations. *Clin Orthop Relat Res.* 2011;469:3324–3331.
8. Schliemann B, Siemoneit J, Theisen C, et al. Complex fractures of the proximal humerus in the elderly—outcome and complications after locking plate fixation. *Musculoskelet Surg.* 2012;96(suppl 1):S3–S11.
9. Cazeneuve JF, Cristofari DJ. The reverse shoulder prosthesis in the treatment of fractures of the proximal humerus in the elderly. *J Bone Joint Surg Br.* 2010;92:535–539.
10. Valenti P, Katz D, Kilinc A, et al. Mid-term outcome of reverse shoulder prostheses in complex proximal humeral fractures. *Acta Orthop Belg.* 2012;78:442–449.
11. Garrigues GE, Johnston PS, Pepe MD, et al. Hemiarthroplasty versus reverse total shoulder arthroplasty for acute proximal humerus fractures in elderly patients. *Orthopedics*. 2012;35:e703–e708.
12. Verbeek PA, van den Akker-Scheek I, Wendt KW, et al. Hemiarthroplasty versus angle-stable locking compression plate osteosynthesis in the treatment of three- and four-part fractures of the proximal humerus in the elderly: design of a randomized controlled trial. *BMC Musculoskelet Disord.* 2012;13:16.
13. Bell JE, Leung BC, Spratt KF, et al. Trends and variation in incidence, surgical treatment, and repeat surgery of proximal humeral fractures in the elderly. *J Bone Joint Surg Am.* 2011;93:121–131.
14. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *J Clin Epidemiol.* 2009;62:1006–1012.
15. Obremskey WT, Bhandari M, Dirschl DR, et al. Internal fixation versus arthroplasty of comminuted fractures of the distal humerus. *J Orthop Trauma.* 2003;17:463–465.
16. Coleman B, Khan K, Maffulli N, et al. Studies of surgical outcome after patellar tendinopathy: clinical significance of methodological deficiencies and guidelines for future studies. *Scand J Med Sci Sports.* 2000;10:2–11.
17. Harris JD, Siston RA, Pan X, et al. Autologous chondrocyte implantation: a systematic review. *J Bone Joint Surg Am.* 2010;92:2220–2233.
18. Harris JD, Siston RA, Brophy RH, et al. Failures, re-operations, and complications after autologous chondrocyte implantation—a systematic review. *Osteoarthritis Cartilage.* 2011;19:779–791.
19. Cadet ER, Ahmad CS. Hemiarthroplasty for three- and four-part proximal humerus fractures. *J Am Acad Orthop Surg.* 2012;20:17–27.
20. Majed A, Macleod I, Bull AM, et al. Proximal humeral fracture classification systems revisited. *J Shoulder Elbow Surg.* 2011;20:1125–1132.
21. Edelson G, Kelly I, Vigder F, et al. A three-dimensional classification for fractures of the proximal humerus. *J Bone Joint Surg Br.* 2004;86:413–425.
22. Bernstein J. Fracture classification systems: do they work and are they useful? *J Bone Joint Surg Am.* 1994;76:792–793.